FLAMELESS PRESSURIZED OXY-COMBUSTION LARGE PILOT DESIGN, CONSTRUCTION, AND OPERATION

Final Technical Report

Award Number: DE - FE0031580
SwRI® Project No. 18.23745

Principal Investigator:

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Co-Authors:
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Scott Hume
George Booras
Michael Stoellinger

Federal Agency to which the report is submitted:

U.S. Department of Energy (DOE)
National Energy Technology Laboratory (NETL), Pittsburgh, PA

Date of the Report:
September 28, 2022

Prime Recipient's DUNS Number: 00-793-6842

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Approved:

Timothy Allison, PhD
Director-R&D
Machinery Department

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1. INTRODUCTION

The team of Southwest Research Institute® (SwRI®), ITEA, Sargent & Lundy (S&L), University of Wyoming (UW), Electric Power Research Institute, Inc. (EPRI), General Electric Global Research (GE), designed a research pilot for Flameless Pressurized Oxy-Combustion (FPO), a novel coal technology.

The current United States (U.S.) electricity market is reliant on increasing renewable penetration, drastically shifting how coal-fired power plants are needed for operation. Rather than typical baseload resources, these plants are needed as load-following resources to support electricity generated from intermittent renewable capacity, as well as to provide critical ancillary services to the grid. Recognizing the DOE vision for the coal plant of the future, FPO technology can show demonstrated impacts on many specified qualities, as follows:

1.1 PLANT EFFICIENCY

Under the flameless conditions created in the combustor, fuel is combusted with no flame front at uniformly (isothermal) high temperatures of 1,400 to 1,700°C. As the combustor is refractory lined, there is minimal heat transfer loss during combustion; instead, the hot flue gases are sent to a separate heat recovery steam generation system, with a greater than 97% efficiency, where the heat exchange takes place. In a full-scale FPO scheme design, which would operate closer to 12 bar pressure, improved heat recovery would result, as the combustion and flue gas energy recovery and recycle schemes operating together are in a closed 'power cycle' with power production at 45.5% of HHV heat input. The minimization of auxiliary power usages, currently estimated to be 12.3% of HHV heat input, will dictate future avenues of technology development in the long term.

1.2 NEAR ZERO EMISSION

Operating under FPO conditions, combustion is stoichiometric, and dioxin, polyaromatic hydrocarbons, and soot are consumed and do not pass into the exhaust gases. Similarly, carbon monoxide levels produced are less than 1 ppm by volume. This means that minimal post-treatment to the flue gas exiting the combustor is required, allowing pressurized flue gas to be recycled to temper combustion. Other than the possible need to neutralize the offtake carbon dioxide (CO_2) and water streams, no further post-treatment is required, and any airborne pollution emissions in the CO_2 output stream conform to the strictest environmental regulations.

1.3 HIGH RAMP RATE AND LOW OPERATING CAPACITY

From 'hot' standby conditions – 5% operating capacity, the FPO combustor can ramp up to a full 100% load within half an hour and exhibits stable efficient power generation across this range. Therefore, there is no direct energy penalty associated with capacity utilization extremes.

1.4 MINIMAL WATER CONSUPTION

Under FPO combustion conditions, the output products are energy, CO_2, and water together with a quantity of a benign vitrified slag. Heat exchangers to recuperate energy are air-cooled. Thus, fired with high water content coals such as lignite and sub-bituminous varieties, the FPO technology produces more water than it consumes.

1.5 REDUCED DESIGN, CONSTRUCTION, AND COMISSIONING SCHEDULES

As FPO is a simple 3-stage process consisting essentially of: coal pretreatment and preparation, the combustor, and the once-through steam generator (OTSG). The firing loop can be prefabricated in modular form and brought to site, ready for site assembly and integration. FPO technology is especially suited to modularization, as it is scalable. Adopting discrete sub-packages which are easily and quickly assembled on-site, means that commissioning of equipment can take place off-site before its arrival. Only commissioning of the integrated aspects of the FPO plant need to take place on-site, thus upgrading and retrofitting existing coal-fired plants incurs minimum disruption and inconvenience to operations compared to alternative addition of pre- and post-combustion solutions.

1.6 REDUCED MAINTENANCE AND OUTAGES

For maintenance purposes, the lances used for providing oxygen into the combustor are easily extractable, and similarly, the heat exchanger tube banks in the heat recovery loop are also easily extractable.

The innovative design of the OTSG and heat exchange assemblies provides a high degree of efficient heat exchange partitioning in a compact arrangement. The neural-network control software permits field learning which in turn assures optimum performance of the integrated scheme across the full operating range.

1.7 CAPABLE OF NATURAL GAS CO-FIRING

From a cold start, FPO uses natural gas to establish equilibrium conditions in the combustor before solid fuels are added. Therefore, co-firing coal and natural gas together is simple and has been proven. Further, the ability of FPO technology to combust multiple fuels alone or together, ranging from gas to residual liquids, waste, and biomass feedstocks, as well as coal has been studied. The ability to co-fire biomass and coal allows FPO technology with CO_2 utilization can generate a negative carbon footprint practically and distinctly.

1.8 INTEGRATED CARBON CAPTURE PROCESS

FPO technology is unique in that it is a technical performance-proven clean-coal technology solution that is neither categorized as a pre- or post-combustion carbon capture solution; rather it represents a versatile integrated carbon capture and combustion solution. There is no parasitic load designated to capture CO_2, and while some energy is consumed to produce oxygen, at the system level, efficiency is comparable or superior to the latest generation supercritical pulverized coal and ultra-supercritical pulverized coal-fired boiler technology, which do not have carbon capture.

2. FEED STUDY

Under this task, a FEED Study Report was developed to provide the necessary detail to achieve an AACE Class 3-cost estimate for the large pilot plant.

2.1 PILOT DESIGN BASIS REFINEMENT

This effort will conclude the finalization of the design basis for the pilot, locking the design for the remainder of the FEED and the detailed engineering effort in Phase III.

2.1.1 BASIC PROCESS DESCRIPTION

FPO can be described as a next-generation pressurized oxy-combustion technology that improves upon existing atmospheric-pressure oxy-combustion technologies. The proposed FPO pilot project will demonstrate the technical feasibility of the FPO technology, validate the performance of FPO, and identify potential risks in the path to commercialization of the technology as a transformative 2nd generation coal technology capable of providing high-efficiency, low-emissions power generation.

The primary difference between the FPO system and conventional coal-fired power generation is the method of coal combustion. In the FPO system, coal and water slurry is fed to a pressurized combustor where it reacts (i.e., combusts) at high pressure with oxygen and recirculated flue gas from the OTSG. Flue gas from the combustion process primarily consists of CO_2 and water, with minimal emissions of other criteria air pollutants such as nitrogen oxides (NOx), sulfur dioxide (SO_2), and particulate matter (PM). ITEA's flue gas desulfurization (FGD) and following condensation column located downstream of the turbo-expander will provide SO_2 control and moisture removal, respectively. Steam generated from the FPO pilot unit will be condensed, and no output (steam or power) will be used. The basic block flow diagram of the process is shown in Figure 1.

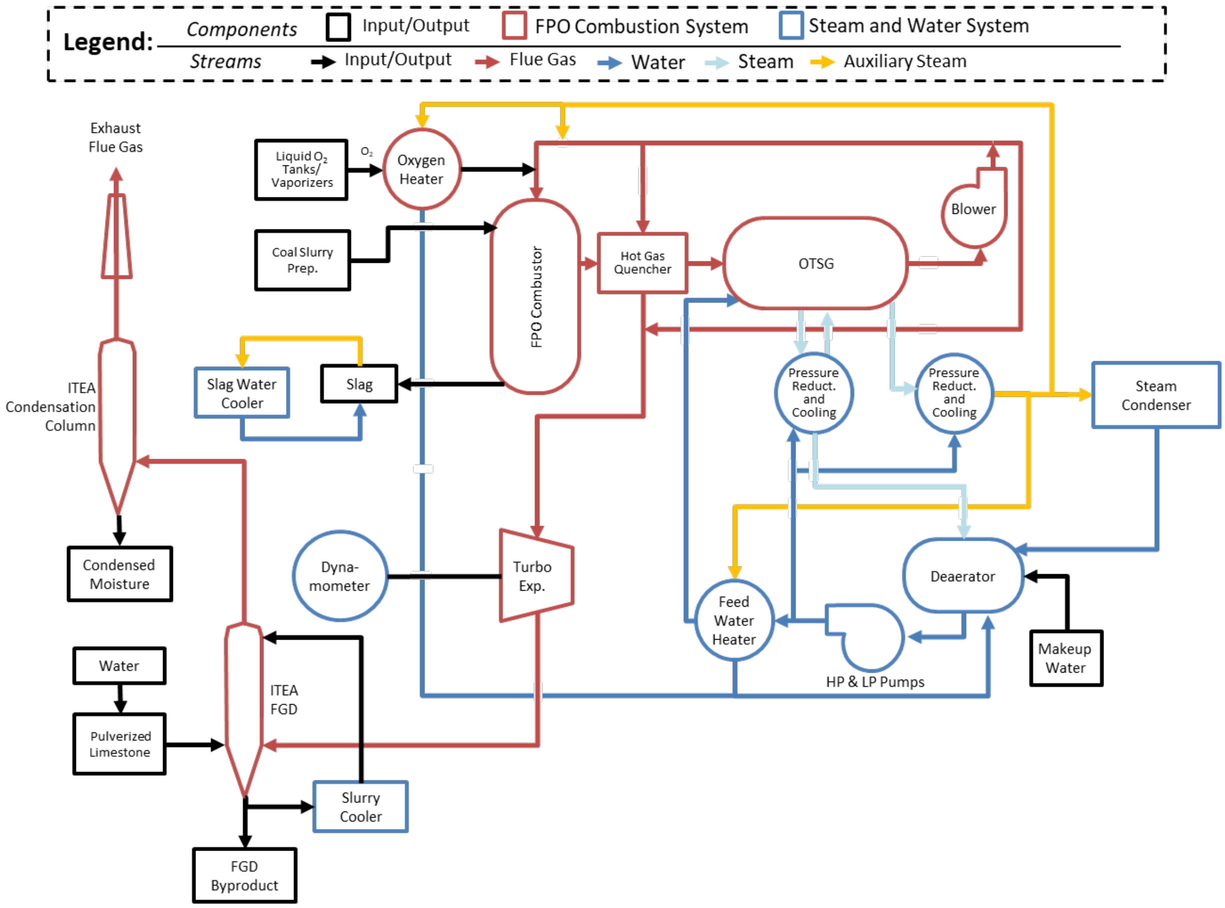

Figure 1. Process Block Flow Diagram

2.1.2 Coal Inputs to the Aspen Model

The goal was to design the plant based on a medium-rank, Wyoming Powder River Basin (PRB) coal. The coal will not be dried but ground and slurried before being pumped into the combustor. Hence, the heating value of the coal that determines the mass flow rate required is the "As Received" value. The PRB coals are sourced from the DOE coal specifications [1].

Figure 2 shows the composition of the design coal, "super-compliance" PRB. Because this is the design coal, this mass flow balance represents the greatest number of hours of operation. The water content of the coal is 27.42%, and the sulfur content is 0.22%.

Proximate Analysis[5]	As-Received	Dry
Moisture	27.42%	0.00%
Volatile Matter	31.65%	43.61%
Ash	4.50%	6.20%
Fixed Carbon	36.43%	50.19%
Total	100.00%	100.00%

Ultimate Analysis[5]	As-Received	Dry
Carbon	50.23%	69.21%
Hydrogen	3.41%	4.70%
Nitrogen	0.65%	0.89%
Sulfur	0.22%	0.30%
Chlorine	0.02%	0.03%
Ash	4.50%	6.20%
Moisture	27.42%	0.00%
Oxygen	13.55%	18.67%
Total	100.00%	100.00%

Heating Value[2,5]	As-Received (Reported)	Dry (Dulong calc.)
HHV (Btu/lb)	8,800	11,546
LHV (Btu/lb)	8,486	11,113
HHV (kJ/kg)	20,469	26,856
LHV (kJ/kg)	19,738	25,850

Hardgrove Grindability Index	52 HGI	

Figure 2. Composition of "Super-Compliance" PRB Subbituminous Coal [1]

2.1.3 Aspen Plus Model Results

Figure 3 provides an example of the Aspen Plus model flow sheet. The combustion loop heats a steam loop that rejects heat to a pressurized condenser. The oxygen is fed from a liquid, cryogenic source, pumped, vaporized, and heated before mixing with the recycle flow. The flow will exit through the turbo-expander before being sent to an FGD system that scrubs the flue gas down to the spec required by permit and commercialization goals.

The various Aspen Plus model results were compiled so that the minimum and maximum mass flow rates and gas compositions defined the pilot design basis. The entirety of the stream results is not replicated here because it represents 86 total streams. Work has begun on representing major streams on the pilot process flow diagram (PFD). All pieces of equipment will be sized based on this approach, using minimums and maximum predicted conditions from the off-design study.

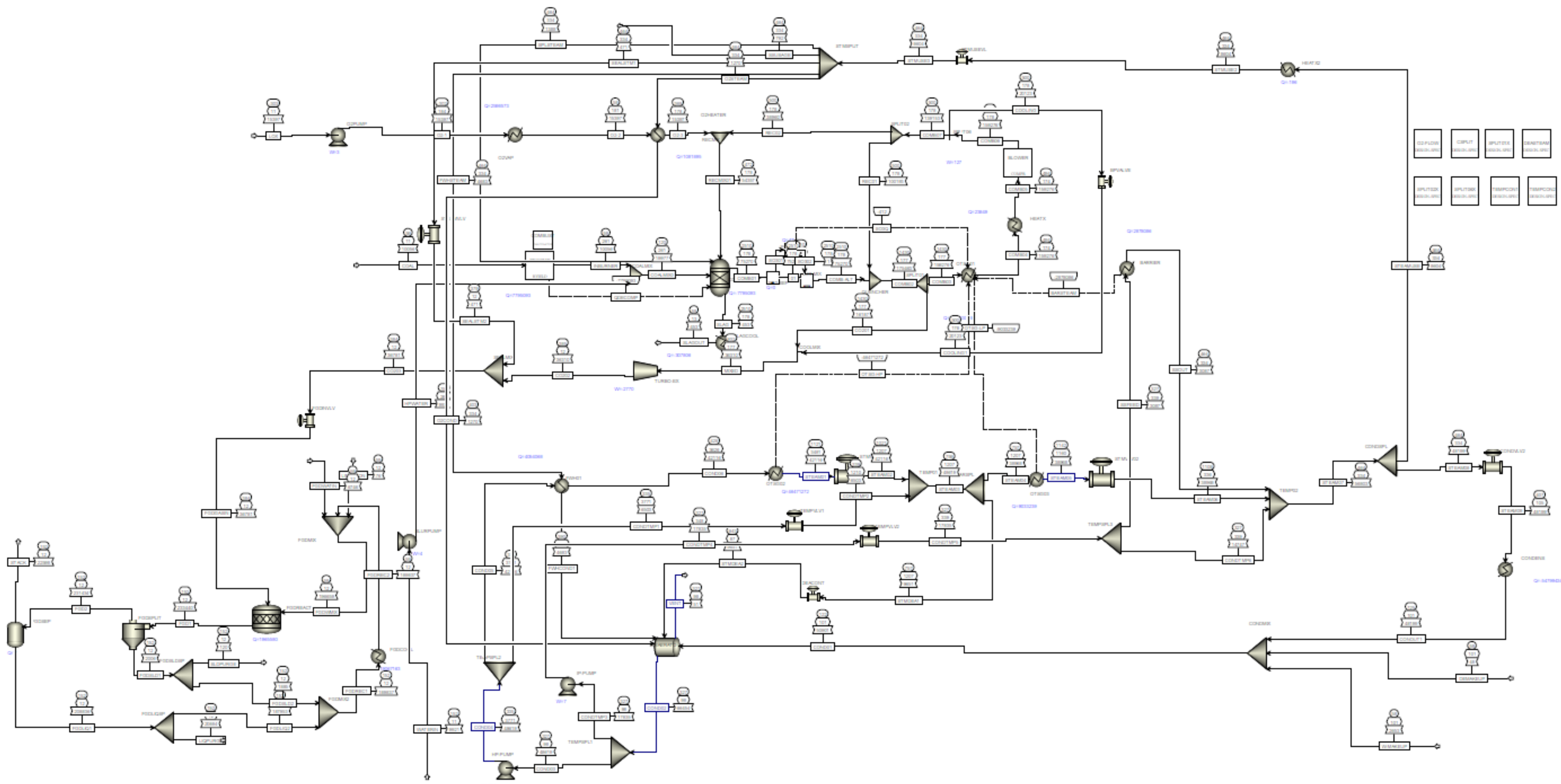

Figure 3. Aspen Plus Flowsheet for the Design PRB Coal

2.1.4 Pilot Major Equipment List

Table 1 represents the Draft Major Equipment List, which was submitted as part of the Phase III proposal.

Table 1. Major Equipment List

FPO Phase II | **FPO Pilot Plant Equipment List** | **December 14, 2020**

Rev. 12

Equip. No.	Equipment Type	Description	Electrical Connections	Foundation Type	Weight	Size	50MWth Motor Sizes (HP)	CONNECTED KW
0CH01S	MATL HANDLNG - Material Handling	Coal Handling System Package Supply & Install	Yes	Foundation	NA	-	NA	NA
0CH01G	MATL HANDLNG - Material Handling	Coal Storage Silo	Yes	Foundation	150 tons	12' dia x 32' H	NA	NA
0CH02G	MATL HANDLNG - Material Handling	Coal Storage Silo Dust Collector	Yes	None	1 ton	3'dia x 4' H	NA	NA
0CH05G	MATL HANDLNG - Material Handling	Coal Silo Outlet Weigh Feeder	Motor	Structure	5 tons	4' W x 20' L x 3.5' H	1	0.75
0CH07G	MATL HANDLNG - Material Handling	Coal Bucket Elevator Conveyor	Motor	Foundation	10 tons	3' W x 4' L x 125' H	50	38.00
0CH09G	MATL HANDLNG - Material Handling	Coal Storage Silo Dust Collector Fan	Motor	Structure	1 ton	3' dia x 5'H	7.5	5.60
0CH10G	MATL HANDLNG - Material Handling	Dust Collector Rotary Airlock Valve	Motor	None	500 lbs	1' W x 1' L x 1' H	1	0.75
0CH11G	MATL HANDLNG - Material Handling	Coal Silo Dust Collector Jib With Hoist	Motor	None	1 ton	-	5	3.70
0CH12G	MATL HANDLNG - Material Handling	Coal Silo Trolley With Hoist	Motor	None	1 ton	-	2	1.50
0CH13GA	MATL HANDLNG - Material Handling	Coal Storage Silo Bin Activator A	Motor	None	1 ton	-	4	3.00
0CH13GB	MATL HANDLNG - Material Handling	Coal Storage Silo Bin Activator B	Motor	None	1 ton	-	4	3.00
0FP01M	FIRE PROTECT - Fire Protection	Coal Storage Silo CO2 Inerting System	Motor	Pad	1 ton	3' W x 3' W x 3' H	1	0.75
0FP02M	FIRE PROTECT - Fire Protection	Turboexpander Lube Oil FP Deluge System	Yes	None	-	-	NA	NA
0CH04G	MATL HANDLNG - Material Handling	Coal Slurry Bar Mill (CH-43EMB02X)	Motor	Foundation	30 tons	6' dia x 12' L	122.4	90.00
0CH01T	MATL HANDLNG - Material Handling	Coal Slurry Paddle Mixer (CH-43EAG01X)	Motor	Pad	20 tons	6' W x 15' L x 4' H	150	110.00
0CH14G	MATL HANDLNG - Material Handling	Coal Elevator Belt (CH-43ENE13X)	Motor	Structure	5 tons	-	5.44	4
0AP10EA	MATL HANDLNG - Material Handling	Coal Elevator Belt VFD	Yes	None	-	-	-	-
0CH15G	MATL HANDLNG - Material Handling	Weigh Feeder Belt (CH-43ENT14X)	Motor	Structure	5 tons	-	5.44	4
0AP10EB	MATL HANDLNG - Material Handling	Weigh Feeder Belt VFD	Yes	None	-	-	-	-
0CH16G	MATL HANDLNG - Material Handling	Vibrating Screen at Bar Mill Outlet	Motor	Structure	2 tons	-	2.72	2
0CH17G	MATL HANDLNG - Material Handling	Recycle Elevator Belt (CH-43ENE01X)	Motor	Structure	2 tons	-	5.44	4
0AP10EC	MATL HANDLNG - Material Handling	Recycle Elevator Belt VFD	Yes	None	-	-	-	-
0CH18G	MATL HANDLNG - Material Handling	Transfer Conveyor Belt (CH-43ENE02X)	Motor	Structure	2 tons	-	2.72	2
0AP10ED	MATL HANDLNG - Material Handling	Transfer Conveyor Belt VFD	Yes	None	-	-	-	-
0CH19G	MATL HANDLNG - Material Handling	Elevator Belt to Mixer (CH-43ENE03X)	Motor	Structure	2 tons	-	4.08	3
0AP10EE	MATL HANDLNG - Material Handling	Elevator Belt to Mixer VFD	Yes	None	-	-	-	-
0CH20G	MATL HANDLNG - Material Handling	Weigh Conveyor Belt to Mixer (CH-43ENE05X)	Motor	Structure	2 tons	-	2.72	2
0AP10EF	MATL HANDLNG - Material Handling	Weigh Conveyor Belt to Mixer VFD	Yes	None	-	-	-	-
0CH01P	PUMPH - Pump - Horizontal	Coal Slurry Feed Pump	Motor	Pad	1 ton	2' W x 12' W x 2' H	9.52	7
0AP10EG	PUMPH - Pump - Horizontal	Coal Slurry Feed Pump VFD	Yes	None	-	-	-	-
0CH02PA	PUMPH - Pump - Horizontal	Coal Slurry Booster Pump A	Motor	Structure	1,300 lbs	2' W x 12' W x 2' H	20.4	15
0AP10EH	PUMPH - Pump - Horizontal	Coal Slurry Booster Pump A VFD	Yes	None	-	-	-	-
0CH02PB	PUMPH - Pump - Horizontal	Coal Slurry Booster Pump B	Motor	Structure	1,300 lbs	2' W x 12' W x 2' H	20.4	15
0AP10EI	PUMPH - Pump - Horizontal	Coal Slurry Booster Pump B VFD	Yes	None	-	-	-	-
0NG01M	VALVE	Fuel Gas Metering & Regulating Station (M&R)	Yes	Pad	1 ton	4' W x 4' L x 4' H	NA	NA
0NG02M	HEATER - Heater	Combustor Slag Port Burner & Gas Skid	Yes	None	1,000 lbs	3' W x 6' L x 6' W	NA	1
0OX01A	HEAT EXCHG - Heat Exchanger	Oxygen O2 Heat Exchanger	No	Pad	2,500 lbs	14" dia x 14' L	NA	NA
0BA01X	FLUE GAS - Flue Gas	Combustor Vessel and Slag Pan	No	Foundation	102 tons	11' dia x 30' H	NA	NA
0BA02X	FLUE GAS - Flue Gas	Combustor Vessel Injection Set	Yes	None	5,500 lbs	11' dia x 15' H	NA	NA
0BA03XA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Flange A	Motor	None	100 lbs	-	2	1.50

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Equip. No.	Equipment Type	Description	Electrical Connections	Foundation Type	Weight	Size	50MWth Motor Sizes (HP)	CONNECTED KW
0BA03EA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Flange A Motor & Converter	Motor	None	-	-	-	-
0BA03XB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Flange B	Motor	None	100 lbs	-	2	1.50
0BA03EB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Flange B Motor & Converter	Motor	None	-	-	-	-
0BA04X	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Fuel Gas Lance	Motor	None	100 lbs	-	2	1.50
0BA04E	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Fuel Gas Lance Motor & Converter	Motor	None	-	-	-	-
0BA05XA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Slurry Lance A	Motor	None	100 lbs	-	2	1.50
0BA05EA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Slurry Lance A Motor & Converter	Motor	None	-	-	-	-
0BA05XB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Slurry Lance B	Motor	None	100 lbs	-	2	1.50
0BA05EB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Slurry Lance B Motor & Converter	Motor	None	-	-	-	-
0BA06XA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 1A	Motor	None	100 lbs	-	2	1.50
0BA06EA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 1A Motor & Converter	Motor	None	-	-	-	-
0BA06XB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 1B	Motor	None	100 lbs	-	2	1.50
0BA06EB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 1B Motor & Converter	Motor	None	-	-	-	-
0BA07XA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 2A	Motor	None	100 lbs	-	2	1.50
0BA07EA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 2A Motor & Converter	Motor	None	-	-	-	-
0BA07XB	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 2B	Motor	None	100 lbs	-	2	1.50
0BA07EA	FLUE GAS - Flue Gas	Combustor Isofeeder Retractable Deflector 2B Motor & Converter	Motor	None	-	-	-	-
0BA01AA	FLUE GAS - Flue Gas	Flue Gas Quencher A	No	Structure	20 tons	5' dia x 21' H	NA	NA
0BA01AB	FLUE GAS - Flue Gas	Flue Gas Quencher B	No	Structure	20 tons	5' dia x 21' H	NA	NA
0BA01MA	FLUE GAS - Flue Gas	Quencher A Inlet Pipe A from Combustor	No	None	4 tons	3.5' dia x 12' L	NA	NA
0BA01MB	FLUE GAS - Flue Gas	Quencher A Inlet Pipe B from Combustor	No	None	4 tons	3.5' dia x 12' L	NA	NA
0BA02MA	FLUE GAS - Flue Gas	Quencher B Inlet Pipe A from Combustor	No	None	4 tons	3.5' dia x 12' L	NA	NA
0BA02MB	FLUE GAS - Flue Gas	Quencher B Inlet Pipe B from Combustor	No	None	4 tons	3.5' dia x 12' L	NA	NA
0BA03MA	FLUE GAS - Flue Gas	Quencher A Lined Outlet Pipe	No	None	4 tons	4' dia x 15' L	NA	NA
0BA03MB	FLUE GAS - Flue Gas	Quencher B Lined Outlet Pipe	No	None	4 tons	4' dia x 15' L	NA	NA
0BA04M	FLUE GAS - Flue Gas	Quencher Common Lined Outlet Piping to OTSG	No	None	5 tons	5.5' dia x 12' L	NA	NA
0BA05M	FLUE GAS - Flue Gas	Combustor Loop Unlined Piping	No	None	20 tons	Various	NA	NA
0BA06M	FLUE GAS - Flue Gas	Refractory for Combustor/Quencher/Outlet Pipes	No	None	107 tons	Various	NA	NA
0BA01C	FLUE GAS - Flue Gas	Recycle Flue Gas Blower	Motor	Pad	5 tons	6' W x 11' L x 6' H	340	250
0AP10EJ	FLUE GAS - Flue Gas	Recycle Flue Gas Blower VFD	Yes	None	-	-	-	-
0BA01F	FILTER/SCRN - Filter/Screen	Flue Gas Recycle Blower Inlet Air Filter	No	None	1 ton	16" dia x 2' H	NA	NA
0BA01B	HEAT EXCHG - Heat Exchanger	Once Through Steam Generator - OTSG	No	Foundation	90 tons	10' dia x 42' L	NA	NA
0BA01K	FLUE GAS - Flue Gas	Turboexpander	Yes	Foundation	33 tons	14' W x 23' L x 12' H	NA	NA
0BA01S	FLUE GAS - Flue Gas	Turboexpander Shaft Coupling	No	None	1 ton	-	NA	NA
0BA02K	DYNAMOMETER	Turboexpander Dynamometer	Motor	Foundation	3 tons	6' Wx 9'L x 4'H	NA	NA
0BA01P	FLUE GAS - Flue Gas	Turboexpander Standby AC Lube Oil Pump	Yes	None	On TE Skid	On Turboexpander Skid	40	30.00
0BA03K	FLUE GAS - Flue Gas	Turboexpander Lube Oil Tank Heater	Yes	None	On TE Skid	On Turboexpander Skid	20	15.00
0BA02P	FLUE GAS - Flue Gas	Turboexpander Emergency DC Lube Oil Pump	Yes	None	On TE Skid	On Turboexpander Skid	7	5.50
0BA10MA	FLUE GAS - Flue Gas	Turboexpander Motor Operated Drain Valve	Yes	None	On TE Skid	On Turboexpander Skid	3.4	2.50
0BA10MB	FLUE GAS - Flue Gas	Turboexpander Motor Operated Drain Valve	Yes	None	On TE Skid	On Turboexpander Skid	3.4	2.50

Equip. No.	Equipment Type	Description	Electrical Connections	Foundation Type	Weight	Size	50MWth Motor Sizes (HP)	CONNECTED KW
0BA10MC	FLUE GAS - Flue Gas	Turboexpander Motor Operated Drain Valve	Yes	None	On TE Skid	On Turboexpander Skid	3.4	2.50
0BA01E	FLUE GAS - Flue Gas	Turboexpander Auxiliary Control Panel	Yes	None	On TE Skid	On Turboexpander Skid	NA	5.00
0BA02E	UNCLASSIFIED - Unclassified	CO2 Analyzer	Yes	None	-	-	NA	NA
0BA01S	FLUE GAS - STACK	Flue Gas Startup and FGD Stack	Yes	Foundation	30 tons	100' H (2 flues)	NA	NA
0BA11MA	VALVE	Dumper Valve - Quencher A Inlet	Yes	None	2 tons	28" Dia	1	0.75
0BA11MB	VALVE	Dumper Valve - Quencher B Inlet	Yes	None	2 tons	28" Dia	1	0.75
0BA12M	VALVE	Dumper Valve - Combustor Inlet	Yes	None	2 tons	28" Dia	1	0.75
0BA13M	VALVE	Dumper Valve - Blower Inlet	Yes	None	4 tons	52" Dia	1	0.75
0BA14M	VALVE	Dumper Valve - Blower Outlet to TurboExp	Yes	None	2 tons	28" Dia	1	0.75
0BA15M	VALVE	Dumper Valve - Cool Gas to OTSG Shell	Yes	None	150 lbs	6" Dia	1	0.75
0BA16M	VALVE	Dumper Valve - Blower Ambient Air Inlet	Yes	None	2 tons	28" Dia	1	0.75
0BA17M	VALVE	Dumper Valve - TurboExp Bypass	Yes	None	2 tons	28" Dia	1	0.75
0BA18M	VALVE	Dumper Valve - Admix Valve	Yes	None	2 tons	28" Dia	1	0.75
0CF01P	WATER TREAT. - Water Treatment	Amine Metering Pump	Motor	Pad	500 lb	2' W x 3' L x 3' H	0.75	0.56
0CF01T	WATER TREAT. - Water Treatment	Amine Storage Tote	No	Pad	1 ton	4' W x 4' L x 4' H	NA	NA
0CD01A	HEAT EXCHG - Heat Exchanger	Condenser and Hotwell	No	Pad	45 tons	7' W x 24' L x 12' H	NA	NA
0CD02A	HEAT EXCHG - Heat Exchanger	Deaerator	Yes	Structure	18 tons	6' W x 13' L x 13' H	NA	NA
0CD01P	PUMP - Pump	Condensate Pump	Yes	Foundation		3' dia x 5'H	50	38
0FW01A	HEAT EXCHG - Heat Exchanger	High-Pressure Feedwater Heater	No	Structure	7 tons	2' dia x 30' L	NA	NA
0FW01P	PUMPHPT - Pump - High Pressure Feedwater	High Pressure Feedwater Pump	Motor	Pad	20 tons	10' W x 18' L x 6' H	850	630
0AP10EK	PUMPHPT - Pump - High Pressure Feedwater	High Pressure Feedwater Pump VFD	Yes	None	-	-	-	-
0FW02P	PUMPHPT - Pump - High Pressure Feedwater	Intermediate Feedwater Pump	Motor	Pad	1.5 tons	4' W x 6' L x 4' H	125	94
0AP10EL	PUMPHPT - Pump - High Pressure Feedwater	Intermediate Feedwater Pump VFD	Yes	None	-	-	-	-
0FW03P	PUMPHPT - Pump - High Pressure Feedwater	Barrier Feedwater Pump	Motor	Pad	1 ton	3' W x 3' L x 3' H	100	75
0AP10EM	PUMPHPT - Pump - High Pressure Feedwater	Barrier Feedwater Pump VFD	Yes	None	-	-	-	-
0HR01M	UNCLASSIFIED - Unclassified	Reheat Steam IP PRV and Attemperator	Yes	None	1 ton	-	NA	NA
0HR02M	UNCLASSIFIED - Unclassified	Reheat Steam LP PRV and Attemperator	Yes	None	2 ton	-	NA	NA
0MS01M	UNCLASSIFIED - Unclassified	Main Steam HP PRV and Attemperator	Yes	None	1000 lbs	-	NA	NA
0AH01GA	ASH HANDLING - Ash Handling	Slag Settler A	No	Pad	20 tons	12' W x 12' L x 20'H	NA	NA
0AH01GB	ASH HANDLING - Ash Handling	Slag Settler B	No	Pad	20 tons	12' W x 12' L x 20'H	NA	NA
0AH01P	PUMPH - Pump - Horizontal	Slag Sluice Pump	Motor	Pad	1 ton	4' W x 4' L x 3' H	4	3
0AH02P	PUMPH - Pump - Horizontal	Slag Quench Water Recycle Pump	Motor	Pad	1 ton	4' W x 4' L x 3' H	3	2
0AH01A	HEAT EXCHG - Heat Exchanger	Slag Sluice Water Heat Exchanger	No	Pad	2 tons	1' dia x 20' L	NA	NA
0AH02A	HEAT EXCHG - Heat Exchanger	Slag Quench Water Heat Exchanger	No	Pad	2 tons	1' dia x 20' L	NA	NA
0CC01A	HEAT EXCHG - Heat Exchanger	CCW Fin Fan Cooler	Yes	Foundation	350 tons	61' W x 139' W x 20' H	NA	NA
0CC02CA	FAN - Fan	Fin Fan Cooler Fan A	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CB	FAN - Fan	Fin Fan Cooler Fan B	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CC	FAN - Fan	Fin Fan Cooler Fan C	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CD	FAN - Fan	Fin Fan Cooler Fan D	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CE	FAN - Fan	Fin Fan Cooler Fan E	Motor	None	-	Included in 0CC01A	40	30.00

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Equip. No.	Equipment Type	Description	Electrical Connections	Foundation Type	Weight	Size	50MWth Motor Sizes (HP)	CONNECTED KW
0CC02CF	FAN - Fan	Fin Fan Cooler Fan F	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CG	FAN - Fan	Fin Fan Cooler Fan G	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CH	FAN - Fan	Fin Fan Cooler Fan H	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CI	FAN - Fan	Fin Fan Cooler Fan I	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CJ	FAN - Fan	Fin Fan Cooler Fan J	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CK	FAN - Fan	Fin Fan Cooler Fan K	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CL	FAN - Fan	Fin Fan Cooler Fan L	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CM	FAN - Fan	Fin Fan Cooler Fan M	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CN	FAN - Fan	Fin Fan Cooler Fan N	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CO	FAN - Fan	Fin Fan Cooler Fan O	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CP	FAN - Fan	Fin Fan Cooler Fan P	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CQ	FAN - Fan	Fin Fan Cooler Fan Q	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CR	FAN - Fan	Fin Fan Cooler Fan R	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CS	FAN - Fan	Fin Fan Cooler Fan S	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CT	FAN - Fan	Fin Fan Cooler Fan T	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CU	FAN - Fan	Fin Fan Cooler Fan U	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CV	FAN - Fan	Fin Fan Cooler Fan V	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CW	FAN - Fan	Fin Fan Cooler Fan W	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CX	FAN - Fan	Fin Fan Cooler Fan X	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CY	FAN - Fan	Fin Fan Cooler Fan Y	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CZ	FAN - Fan	Fin Fan Cooler Fan Z	Motor	None	-	Included in 0CC01A	40	30.00
0CC02CZ1	FAN - Fan	Fin Fan Cooler Fan Z1	Motor	None	-	Included in 0CC01A	40	30.00
0CC01PA	PUMPH - Pump - Horizontal	Closed Cooling Water Pump A	Motor	Pad	2.5 tons	7' W x 8' L x 3.5' H	300	225.00
0CC01PB	PUMPH - Pump - Horizontal	Closed Cooling Water Pump B	Motor	Pad	2.5 tons	7' W x 8' L x 3.5' H	300	225.00
0CC02P	PUMP - Pump	Dynamometer Sump Pump	Motor	None	500 lbs	-	5	3.75
0CC01T	TANK - Tank	Closed Cooling Water Head Tank	No	Structure	6 tons	1,000 gallons	NA	NA
0CC01S	UNCLASSIFIED - Unclassified	Propylene Glycol for CCW System	No	None	18 tons	4,200 gallons	NA	NA
0FG01A	HEAT EXCHG - Heat Exchanger	FGD Flue Gas Cooler	No	Pad	2 tons	8' W x 25' L x12' H	NA	NA
0FG01S	MATL HANDLNG - Material Handling	FGD Limestone Unload / Prep System	Yes	Pad	2 tons	6' W x 6' L x 16' H	2	1.5
0FG01G	MATL HANDLNG - Material Handling	FGD Limestone Bag Hoist	Motor	None	Included	Included in 0FG01S	1	0.75
0FG02G	MATL HANDLNG - Material Handling	FGD Limestone Volumetric Feeder	Motor	None	Included	Included in 0FG01S	1	0.75
0FG01T	TANK - Tank	FGD Limestone Slurry Tank	No	Pad	Included	Included in 0FG01S	NA	NA
0FG02D	MATL HANDLNG - Material Handling	FGD Limestone Slurry Tank Agitator	Motor	None	Included	Included in 0FG01S	0.5	0.40
0FG01D	FGD FGD System	FGD Column	No	Pad	20 tons	5' dia x 44' H	NA	NA
0FG01P	PUMPH - Pump - Horizontal	FGD Limestone Slurry Pump	Motor	Pad	500 lbs	2' W x 3' L x 2' H	2	1.5
0AP10EN	PUMPH - Pump - Horizontal	FGD Limestone Slurry Pump VFD	Yes	None	-	-	-	-
0FG02P	PUMPH - Pump - Horizontal	FGD Column Recycle Pump	Motor	Pad	1 ton	3' W x 4' L x 3' H	4	3
0FG02A	HEAT EXCHG - Heat Exchanger	FGD Slurry Cooler	No	Structure	1.25 ton	LATER	NA	NA
0FG03D	FGD FGD System	FGD Condensation Column	No	Pad	10 tons	6' dia x 26' H	NA	NA
0FG03A	HEAT EXCHG - Heat Exchanger	FGD Condensate Cooler	No	Structure	3 tons	LATER	NA	NA

Equip. No.	Equipment Type	Description	Electrical Connections	Foundation Type	Weight	Size	50MWth Motor Sizes (HP)	CONNECTED KW
0FG03P	PUMPH - Pump - Horizontal	FGD Condensate Column Recycle Pump	Motor	Pad	1 ton	LATER	10	7.5
0FG02T	TANK - Tank	FGD Gypsum Decant Tank	No	Pad	5 tons	5' Dia x 10' H	NA	NA
0FG04P	PUMPH - Pump - Horizontal	FGD Gypsum Decant Liquid Pump	Motor	Pad	1 ton	2' W x 3' L x 2' H	2	1.5
0FG05P	PUMPH - Pump - Horizontal	FGD Decant Gypsum Pump	Motor	Pad	2 tons	2' W x 5' L x 2' H	1.5	1.00
0FG01F	FILTER/SCRN - Filter/Screen	FGD Gypsum Filter Press	Motor	Structure	3 tons	4' W x 10' L x 6' H	4	3.00
0FG01M	MATL HANDLNG - Material Handling	FGD Gypsum Waste Container	No	None	5 tons	6' W x 20' L x 6' H	NA	NA
0IA01C	COMPRESSOR - Compressor	Air Compressor Package	Motor	Pad	4 tons	8'W x 20L' x 9'H	220	165.00
0IA01D	COMPRESSOR - Compressor	Air Dryer Package	Yes	Pad	2 tons	Included in 0IA01C	NA	NA
0IA02D	COMPRESSOR - Compressor	Air Receiver	No	Pad	1 ton	500 Gal	NA	NA
0OX01T	TANK - Tank	Liquid O2 Storage Tank 1 (13,000 gallons)	Yes	Foundation	100 tons	11' dia x 36' H	NA	NA
0OX02A	HEAT EXCHG - Heat Exchanger	O2 Ambient Vaporizer 1	Yes	Foundation	25 tons	8' W x 8' L x 25' H	NA	NA
0OX02T	TANK - Tank	Liquid O2 Storage Tank 2 (13,000 gallons)	Yes	Foundation	100 tons	11' dia x 36' H	NA	NA
0OX03A	HEAT EXCHG - Heat Exchanger	O2 Ambient Vaporizer 2	Yes	Foundation	25 tons	8' W x 8' L x 25' H	NA	NA
0OX03T	TANK - Tank	Liquid O2 Storage Tank 3 (13,000 gallons)	Yes	Foundation	100 tons	11' dia x 36' H	NA	NA
0OX04A	HEAT EXCHG - Heat Exchanger	O2 Ambient Vaporizer 3	Yes	Foundation	25 tons	8' W x 8' L x 25' H	NA	NA
0OX06A	HEAT EXCHG - Heat Exchanger	O2 Pressure Maintenance Vaporizer 1	Yes	Foundation	10 tons	6' W x 6' L x 10' H	NA	NA
0OX07A	HEAT EXCHG - Heat Exchanger	O2 Pressure Maintenance Vaporizer 2	Yes	Foundation	10 tons	6' W x 6' L x 10' H	NA	NA
0WM01P	PUMPH - Pump - Horizontal	Demineralized Water Pump	Motor	Pad	1 ton	3' W x 3' L x 2' H	1	0.75
0WM01T	TANKATM - Tank - Atmospheric	Demineralized Water Tank	No	Pad	70 tons	14' dia x 20' H	NA	NA
0TR01T	TANKATM - Tank - Atmospheric	Reclaimed Water Tank	No	Pad	70 tons	14' dia x 20' H	NA	NA
0TR02T	TANK - Tank	Wastewater Tank	No	Pad	70 tons	14' dia x 20' H	NA	NA
0TR01P	PUMPH - Pump - Horizontal	Reclaimed Water Pump	Motor	Pad	1 ton	4' W x 4' L x 2' H	4	3.00
0TR02P	PUMPH - Pump - Horizontal	Waste Water Pump	Motor	Pad	2 ton	4' W x 4' L x 2' H	7	5.25
0TR03P	PUMP - Pump	Slag Bunker Sump Pump	Motor	Pad	500 lbs	2' W x 2' L x 4' H	2	1.50
0TR04P	PUMP - Pump	Coal Slurry Area Sump Pump	Motor	Pad	501 lbs	2' W x 2' L x 4' H	2	1.50
0TR05P	PUMP - Pump	FGD Area Sump Pump	Motor	Structure	500 lbs	2' W x 2' L x 4' H	2	1.50
0WS01M	UNCLASSIFIED - Unclassified	Water Meter	No	None	NA	-	NA	NA
0AP01E	UNCLASSIFIED - Unclassified	Electrical PDC Building	Yes	Foundation	-	30' W x 70' L x 10' H	NA	20.00
0AP01CA	HVAC - HVAC	PDC Ventilation Fan A	Motor	None	-	-	1	0.75
0AP01CB	HVAC - HVAC	PDC Ventilation Fan B	Motor	None	-	-	1	0.75
0AP02CA	HVAC - HVAC	PDC HVAC Unit A	Motor	None	-	-	1	0.75
0AP02CB	HVAC - HVAC	PDC HVAC Unit B	Motor	None	-	-	1	0.75
0AP01H	HVAC - HVAC	PDC Ventilation Heater	Yes	None	-	-	NA	20.00
0VA01CA	HVAC - HVAC	Combustor Building Ventilation Fan A	Motor	Structure	2 tons	-	10	7.50
0VA01CB	HVAC - HVAC	Combustor Building Ventilation Fan B	Motor	Structure	2 tons	-	10	7.50
0VC01CA	HVAC - HVAC	Coal Handling Room Exhaust Fan A	Motor	Structure	1 tons	-	4	3.00
0VC01CB	HVAC - HVAC	Coal Handling Room Exhaust Fan B	Motor	Structure	1 tons	-	4	3.00
0VA02CA	HVAC - HVAC	Combustor Building Unit Heater A	Motor	Structure	1 ton	-	NA	100.00
0VA02CB	HVAC - HVAC	Combustor Building Unit Heater B	Motor	Structure	1 ton	-	NA	100.00
0VA02CC	HVAC - HVAC	Combustor Building Unit Heater C	Motor	Structure	1 ton	-	NA	100.00

Equip. No.	Equipment Type	Description	Electrical Connections	Foundation Type	Weight	Size	50MWth Motor Sizes (HP)	CONNECTED KW
0VA02CD	HVAC - HVAC	Combustor Building Unit Heater D	Motor	Structure	1 ton	-	NA	100.00
0VA02CE	HVAC - HVAC	Combustor Building Unit Heater E	Motor	Structure	1 ton	-	NA	100.00
0VA02CF	HVAC - HVAC	Combustor Building Unit Heater F	Motor	Structure	1 ton	-	NA	100.00
0VA02CG	HVAC - HVAC	Combustor Building Unit Heater G	Motor	Structure	1 ton	-	NA	100.00
0VA02CH	HVAC - HVAC	Combustor Building Unit Heater H	Motor	Structure	1 ton	-	NA	100.00
0VA02CI	HVAC - HVAC	Combustor Building Unit Heater I	Motor	Structure	1 ton	-	NA	100.00
0VA02CJ	HVAC - HVAC	Combustor Building Unit Heater J	Motor	Structure	1 ton	-	NA	100.00
0VA02CK	HVAC - HVAC	Combustor Building Unit Heater K	Motor	Structure	1 ton	-	NA	100.00
0VA02CL	HVAC - HVAC	Combustor Building Unit Heater L	Motor	Structure	1 ton	-	NA	100.00
0VF01CA	HVAC - HVAC	FGD Building Ventilation Fan A	Motor	Structure	500 lbs	-	2	1.50
0VF01CB	HVAC - HVAC	FGD Building Ventilation Fan B	Motor	Structure	500 lbs	-	2	1.50
0VF02CA	HVAC - HVAC	FGD Building Unit Heater A	Motor	Structure	500 lbs	-	NA	50.00
0VF02CB	HVAC - HVAC	FGD Building Unit Heater B	Motor	Structure	500 lbs	-	NA	50.00
0VF02CC	HVAC - HVAC	FGD Building Unit Heater C	Motor	Structure	500 lbs	-	NA	50.00
0VF02CD	HVAC - HVAC	FGD Building Unit Heater D	Motor	Structure	500 lbs	-	NA	50.00
0VF02CE	HVAC - HVAC	FGD Building Unit Heater E	Motor	Structure	500 lbs	-	NA	50.00
0VF02CF	HVAC - HVAC	FGD Building Unit Heater F	Motor	Structure	500 lbs	-	NA	50.00
0AP02EG	TRANSFORMER	13.8kV/480V Transformer	Yes	Foundation	14 tons	6' W x 8' D x 10' H	NA	NA
0AP03EA	POWER DISTRIBUTION PANEL	480-480/277V Combustor Building Lighting Panel	Yes	None	-	1' W x 2' L x 5' H	100A	-
0AP04EA	TRANSFORMER	480-480/277V Combustor Building Lighting Transformer	Yes	None	-	-	30kVA	-
0AP03EB	POWER DISTRIBUTION PANEL	480-480/277V FGD Building Lighting Panel	Yes	None	-	1' W x 2' L x 5' H	100A	-
0AP04EB	TRANSFORMER	480-480/277V FGD Building Lighting Transformer	Yes	None	-	-	30kVA	-
0AP05EA	POWER DISTRIBUTION PANEL	480-208/120V Combustor Building Process Power Panel	Yes	None	-	1' W x 2' L x 5' H	100A	-
0AP06EA	TRANSFORMER	480-208/120V Combustor Building Process Power Transformer	Yes	None	-	-	30kVA	-
0AP05EB	POWER DISTRIBUTION PANEL	480-208/120V FGD Building Process Power Panel	Yes	None	-	1' W x 2' L x 5' H	100A	-
0AP06EB	TRANSFORMER	480-208/120V FGD Building Process Power Transformer	Yes	None	-	-	30kVA	
0AP07EA	POWER DISTRIBUTION PANEL	Combustor Building 480V Panel A	Yes	None	-	1' W x 2' L x 5' H	250A	-
0AP07EB	POWER DISTRIBUTION PANEL	Combustor Building 480V Panel B	Yes	None	-	1' W x 2' L x 5' H	250A	-
0AP08EA	UNCLASSIFIED - Unclassified	Welding Receptacle A	Yes	None	-	1' W x 1' L x 2' H	60A	-
0AP08EB	UNCLASSIFIED - Unclassified	Welding Receptacle B	Yes	None	-	1' W x 1' L x 2' H	60A	-
0AP09E	UNCLASSIFIED - Unclassified	Welding Receptacle Junction Box	Yes	None	-	1' W x 1' L x 2' H	-	-
0APYYY	UNCLASSIFIED - Unclassified	480V Cable Bus & Steel Supports	Yes	None	-	-	NA	NA
0APZZZ	UNCLASSIFIED - Unclassified	4.16kV Power Supply to Pilot Plant Including FPO Site Mods	Yes	Foundation		-	NA	NA
0CX01E	UNCLASSIFIED - Unclassified	Distributed Control System (DCS)	Yes	None	-	-	NA	100.00
0CX02E	UNCLASSIFIED - Unclassified	Continuous Emission Monitoring System (CEMS)	Yes	None	-	-	NA	50.00
0WD01MA	UNCLASSIFIED - Unclassified	Safety Shower and Eyewash Station A	Yes	None	500 lbs	-	NA	0.20
0WD01MB	UNCLASSIFIED - Unclassified	Safety Shower and Eyewash Station B	Yes	None	500 lbs	-	NA	0.20
0PS01E	INSTRUMENTATION	Combustor Loop Process Sampling / Monitoring	Yes	None	-	-	NA	10
0PS02E	INSTRUMENTATION	Steam Cycle Process Sampling / Monitoring	Yes	Pad	1.000 lbs	-	NA	10
0OD01S	SEPARATOR	Oil Water Separator	Yes	None	2 tons	-	NA	NA

2.1.5 SPECIFICATION AND SOURCING OF COMBUSTOR AND OTSG EQUIPMENT

The novel equipment that makes up the FPO loop was specified. A general description of the process and purpose of the equipment was written. Data sheets that define the normal operating conditions and other specifications were filled out for the combustor, quencher, OTSG, and refractory piping. Detailed drawings that define the dimensions of features of the equipment were produced. Assembly drawings and cross-sections were used to show the equipment assembly. This detail was needed for the FEED study to get a more detailed estimate of the fabrication costs of the novel equipment.

2.1.5.1 Fabricator Capability Questionnaire

As part of the request for a quote from qualified fabricators, a questionnaire was developed to help assess capabilities and experience. The questions are shown below in Table 2. Fabricators are expected to answer these questions with any quote that is supplied for the FEED study.

Table 2. Questionnaire for Qualified Fabricators of FPO Equipment

Question
Project Interest and Experience
Is your company interested in performing the work scope summarized in the attached summary of work, and will your company submit a response if issued a proposal request?
Has your company previously manufactured similar pressure vessels for combustion and associated components? If so, provide a list of projects and client contact information, where your company has performed work.
Please list previous relevant work experience fabricating pressure vessels.
Commercial
Has your company been engaged in contract litigation in the past five (5) years? If yes, please explain.
Has your company defaulted on a contract in the past five (5) years? If yes, please explain.
Has your company, or any of your principals' former companies where they held a management role, ever filed for bankruptcy or reorganizational proceeding? If yes, please explain.
Does your company have any pending judgments, claims, or lawsuits? If yes, please explain.
Has your company filed any liens, lawsuits, or requested arbitration or mediation within the past five (5) years? If yes, please explain.
Have claims been made against your company surety in the past five (5) years? If yes, please explain.
Please provide a W-9 form for your company.
Financial
What is the annual value of pressure vessel fabrication work your company has executed in the last four (4) years?
What are the sizes of your company's typical equipment fabrication contracts, in terms of labor man-hours worked (largest / smallest / typical)?
What are your company's current 2020 and 2021 pressure vessel fabrication work backlogs per year? ($)
Personnel
The number of presently employed direct staff (non-craft) dedicated to:
Project Management
Construction Supervision
Safety
Cost and Scheduling

Procurement
Quality Assurance / Quality Control
Administration
Engineering
Please provide an organization chart of the company's management.
Quality Control
Does your company operate under any agency/certification guidelines such as ISO 9001, ISO 14001 or ISO 18001? If yes, provide information.
Has your company performed code work (e.g., ASME, ANSI, AWS, etc.)? List all codes under which your company is certified to perform.
Does your company have a formal written quality control manual?
Does your company have a separate QA/QC organization or department?
Does your company have a quality training program for supervision and craft?
Does your company conduct routine job site quality and safety audits?
General Information
Workshop total area (ft2)
Workshop covered area (ft2)
Access/Connections to railways (Y/N)
ASME - Please specify the Stamps.
Provide an experience list of your work performed directly related to the fabrication of pressure vessels.
Manufacturing Activity
Does the company have dedicated procedures/instructions availability? (If yes, please enclose a copy of the detailed list.)
Does the company implement special processes? (i.e., welding, heat treatment, NDT, etc.) If yes, please enclose copy of the detailed list.
Are Welding Processes (WPS/PQR) and Welders qualified? If yes, please enclose a copy of the detailed list.
Manufacturing machines and devices. Please enclose a detailed list.
Utilization of external manufacturing companies? (yes/no)
Identify the work in Appendix II that your company would self-perform on this project.
Identify the work in Appendix II that your company would subcontract on this project.
Will your company accept industry-standard liquidated damages for scheduled performance?
Head forming capability - (maximum diameter/maximum thickness)
Rolling machines capability - (maximum diameter/maximum thickness)
Post heat treatment oven - (dimensions: length/width/height/max temperature)
Does your company have room for special assembly? (skid assembly, refractory assembly, etc.) - Dimensions: length/width/height
Does your company have NDE test and inspection devices? If yes, please enclose a copy of a detailed list.
Does your company have NDT procedures? If yes, please enclose a copy of the detailed list.
Are the NDT Inspectors qualified? If yes, please enclose a copy of the detailed list with codes, levels, and NDT methods.
Does your company hold an ASME U stamp certification to manufacture pressure vessels under ASME BPVC Section VIII?
Insurance Coverage
Please provide a copy of your company's Certificate of Liability Insurance.
Health, Safety, and Environmental (HS&E)
Worker's Compensation Interstate Experience Modification Rate (EMR)
Recordable Injury Incidence Rate
Lost Workday Injury Incidence Rate

2.1.5.2 Contacting Pressure Vessel Vendors

Refractory lined pressure vessels include the combustor, OTSG, quenchers, and connective high-temperature piping in the FPO loop. International and domestic vendors were approached with a request for a quote to fabricate the pressure vessels. The vendors were presented with the specifications, drawings, and questionnaires to ensure proper fabrication capability. Here is a list of the vendors that were pursued for a quote on these items:

- Chattanooga Boiler & Tank
- Addison Fabricators, Inc.
- Arrow Tank & Engineering Co.
- AC Boiler
- TEI
- KHOCH

Final costs were incorporated into the cost estimate for Phase III.

2.1.6 SOURCING OF QUALIFIED MAJOR EQUIPMENT VENDORS

Qualified vendors for other major equipment were sought. In particular, the emissions control equipment was an area of focus for vendor quotes. Vendors of emission control equipment can provide the proper models and evidence needed to complete the environmental assessment/permitting tasks. ITEA provided the specification for the pressurized FGD, and it was considered part of the novel equipment. The remainder of the equipment was commercially available and sourced as part of the qualification and quoting exercise.

2.1.7 SPECIFICATION OF TURBO-EXPANDER EQUIPMENT

The turbo-expander was a key piece of equipment to the research program. Figure 4 shows the development of the turbo-expander layout and equipment. The green space is the primary machinery with gas inlet. The blue section is the bearing lube oil equipment. The orange block is the reserved space for the dynamometer.

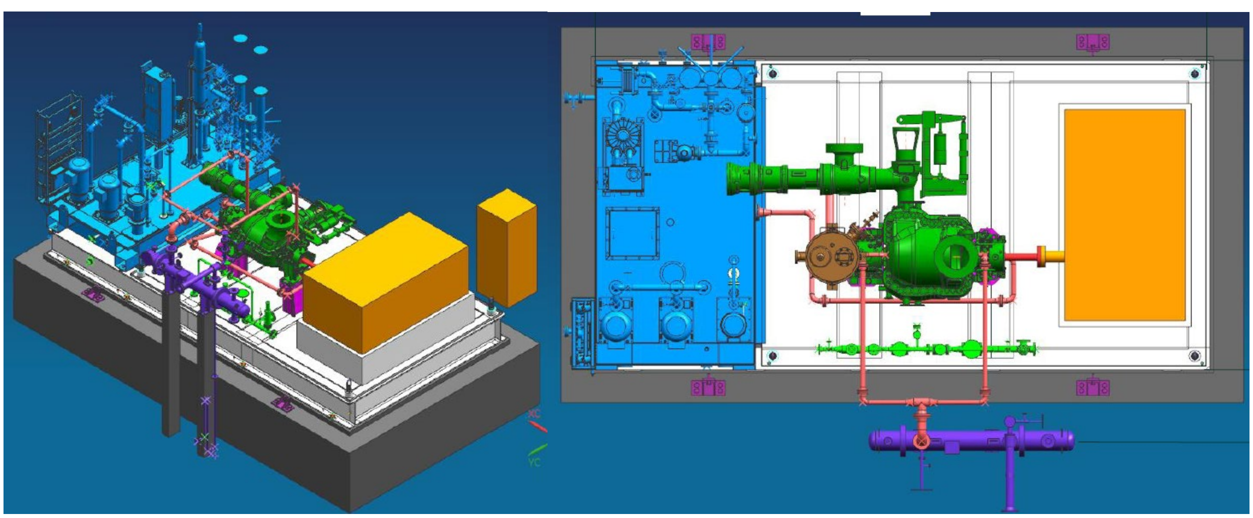


Figure 4. Isometric (left) and Overhead (right) Layout of the Turbo-expander Equipment

Figure 5 shows the 3D layout of the preferred dynamometer that connects to the turbo-expander. Two companies were considered for dissipating the shaft energy of the turbo-expander. The Froude equipment represented the most comprehensive package that pairs with large, land-based installations of rotating machinery.

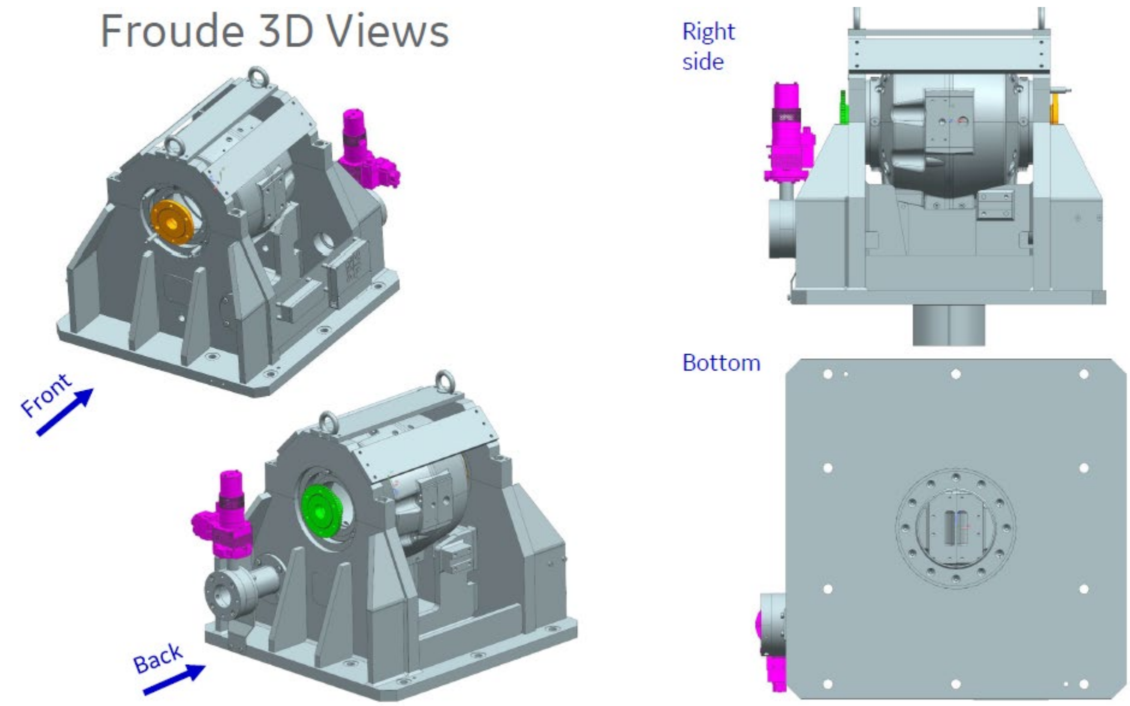


Figure 5. 3D Representation of the Froude Dynamometer

2.2 FACILITY DEVELOPMENT

Substantial work in the development of facility design concluded for the proposal of Phase III. A summary description of activities is included in the following sections.

2.2.1 FACILITY DESIGN

The performance of the FPO unit's novel pieces of equipment, including the coal preparation and pressurized slurrying equipment, the FPO combustor or the hot fumes quencher located immediately after the combustor, the OTSG, the turbo-expander, and the ITEA FGD and condensation columns will be evaluated in detail as part of the research program.

The proposed pilot will consist of the following major pieces of equipment/systems:

- Coal preparation and pressurized slurrying equipment
- Liquid oxygen equipment
- Oxy-combustor
- Hot fumes quencher
- OTSG
- Turbo-expander – sized for 25 MWth
- Dynamometer – sized for 25 MWth
- ITEA's FGD System, including an FGD and moisture condensation columns, as well as supporting reagent preparation, and dewatering equipment systems.

- Main flue gas stack and startup stack
- Cooling systems

It should be noted that all of the above equipment will be sized for 50 MWth operation, except for the turbo-expander and dynamometer, as these components were only sized for 25 MWth equivalent of flue gas volume. Therefore, when performing limited tests of peaking and load-following operation at 50 MWth, these components sized for 25 MWth will be bypassed as part of those test campaigns.

2.2.2 Process Flow Diagrams and Major Equipment List

The PFDs are shown in Figure 6 through Figure 10, corresponding to the list of major plant equipment as shown in Table 1.

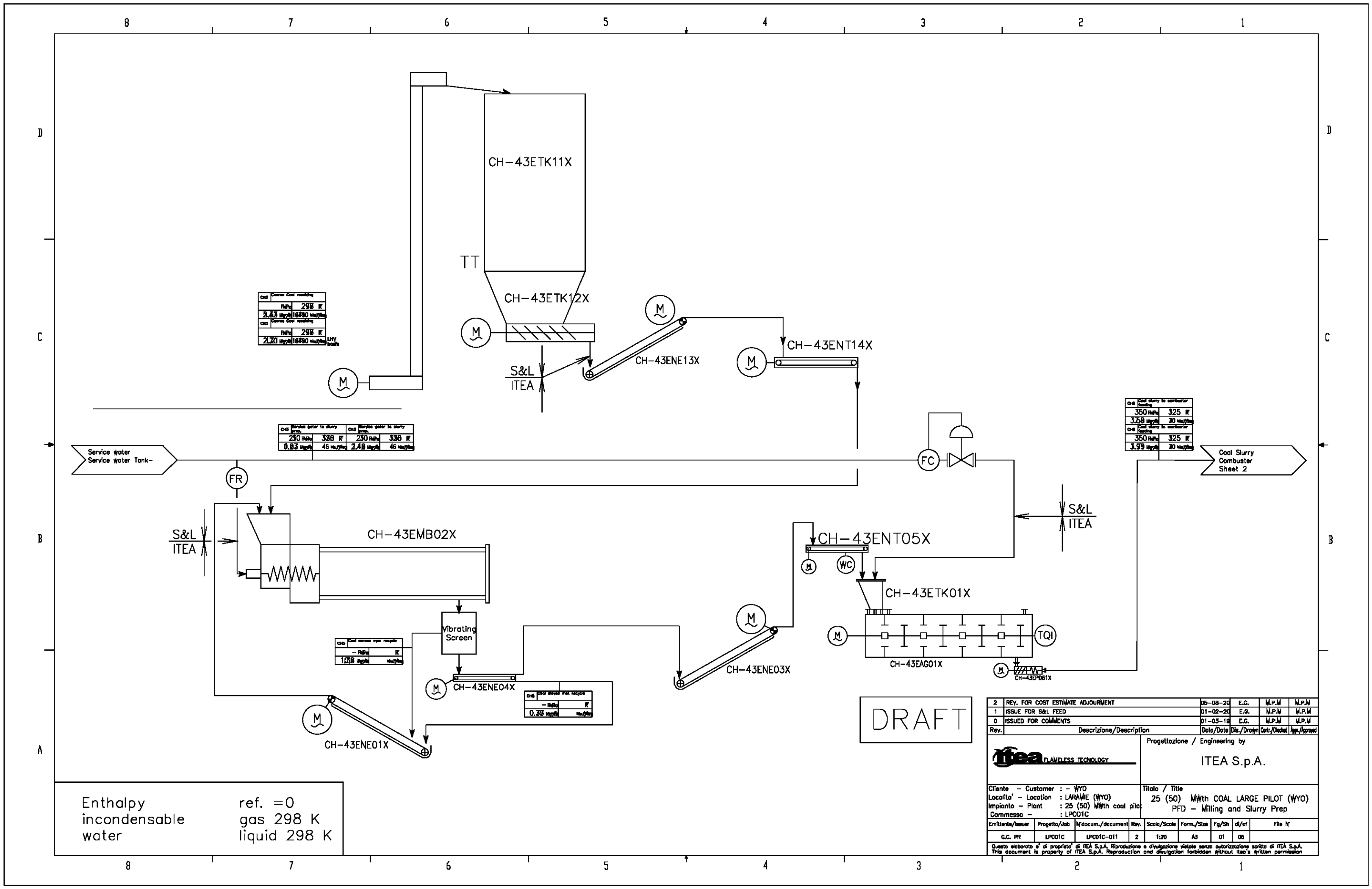


Figure 6. Sheet 1 of the Plant PFD

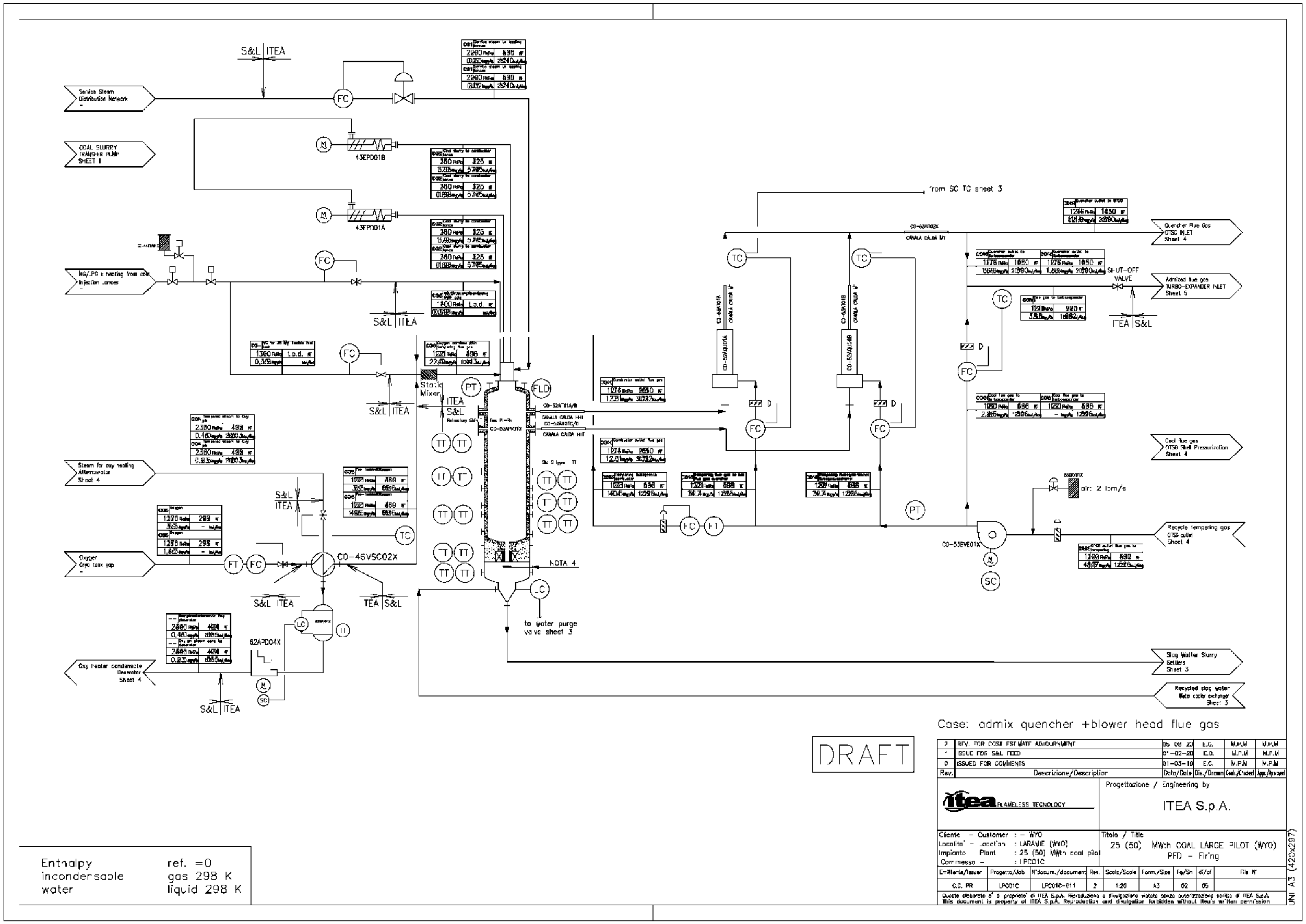


Figure 7. Sheet 2 of the Plant PFD

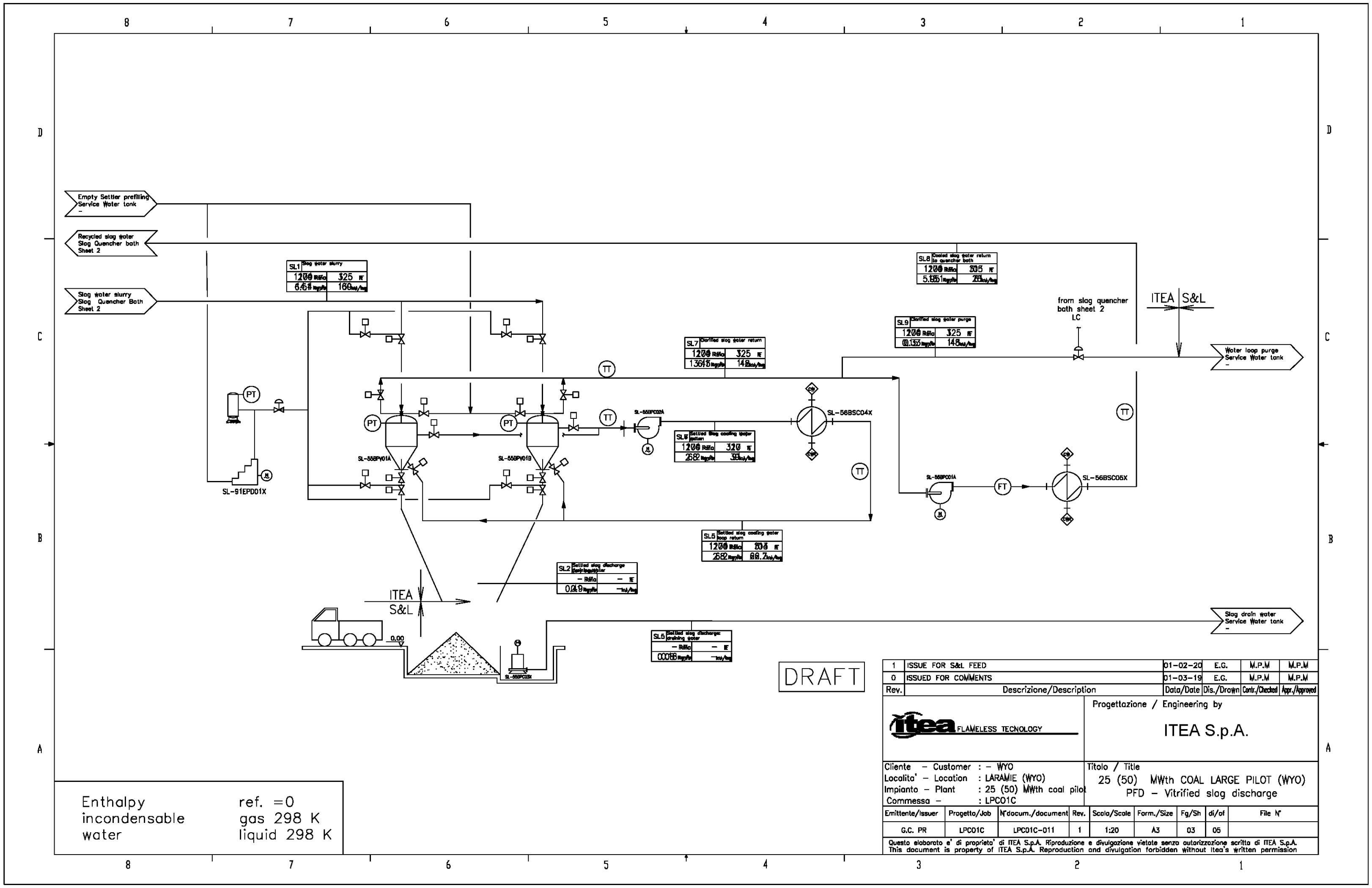


Figure 8. Sheet 3 of the Plant PFD

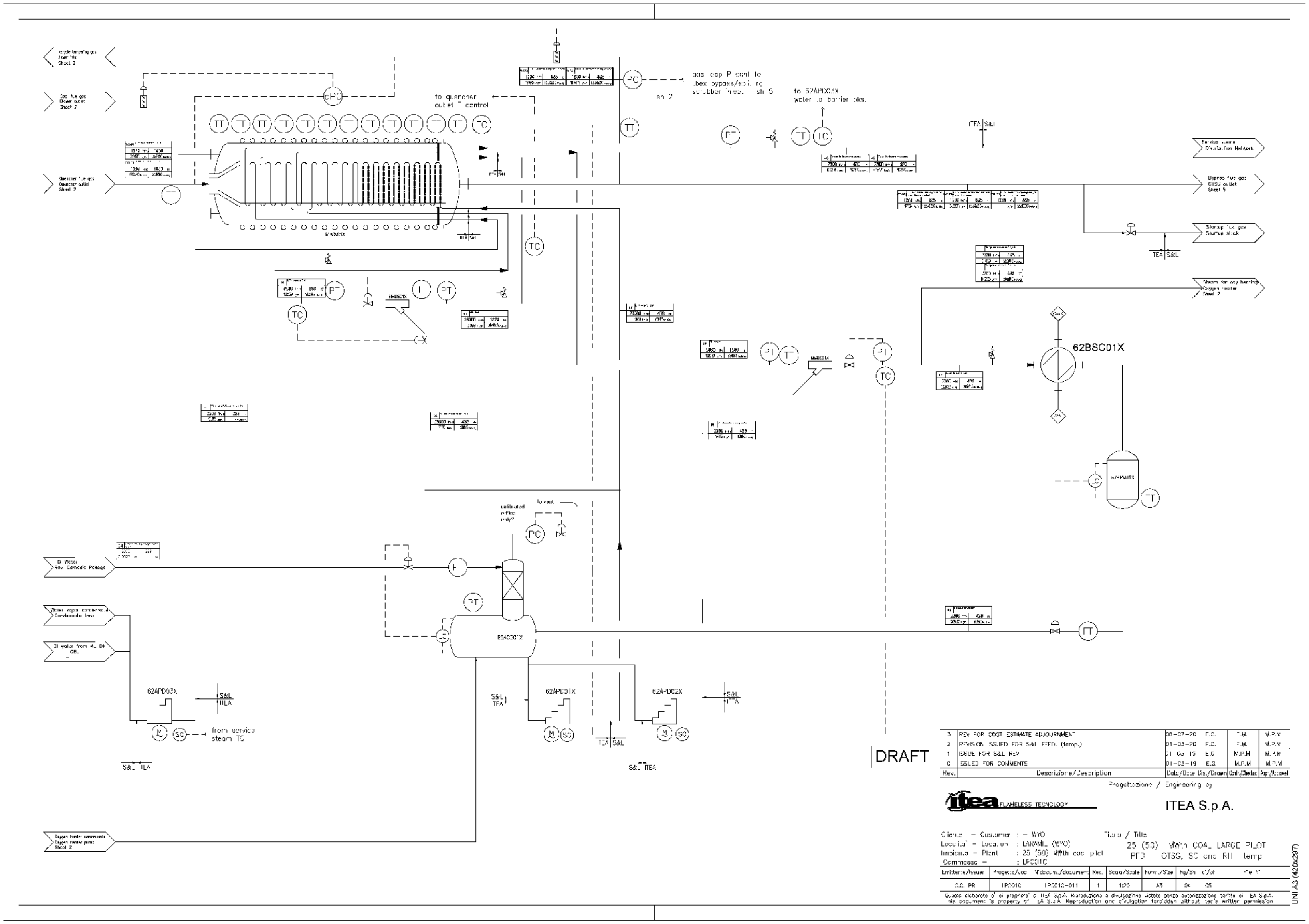


Figure 9. Sheet 4 of the Plant PFD

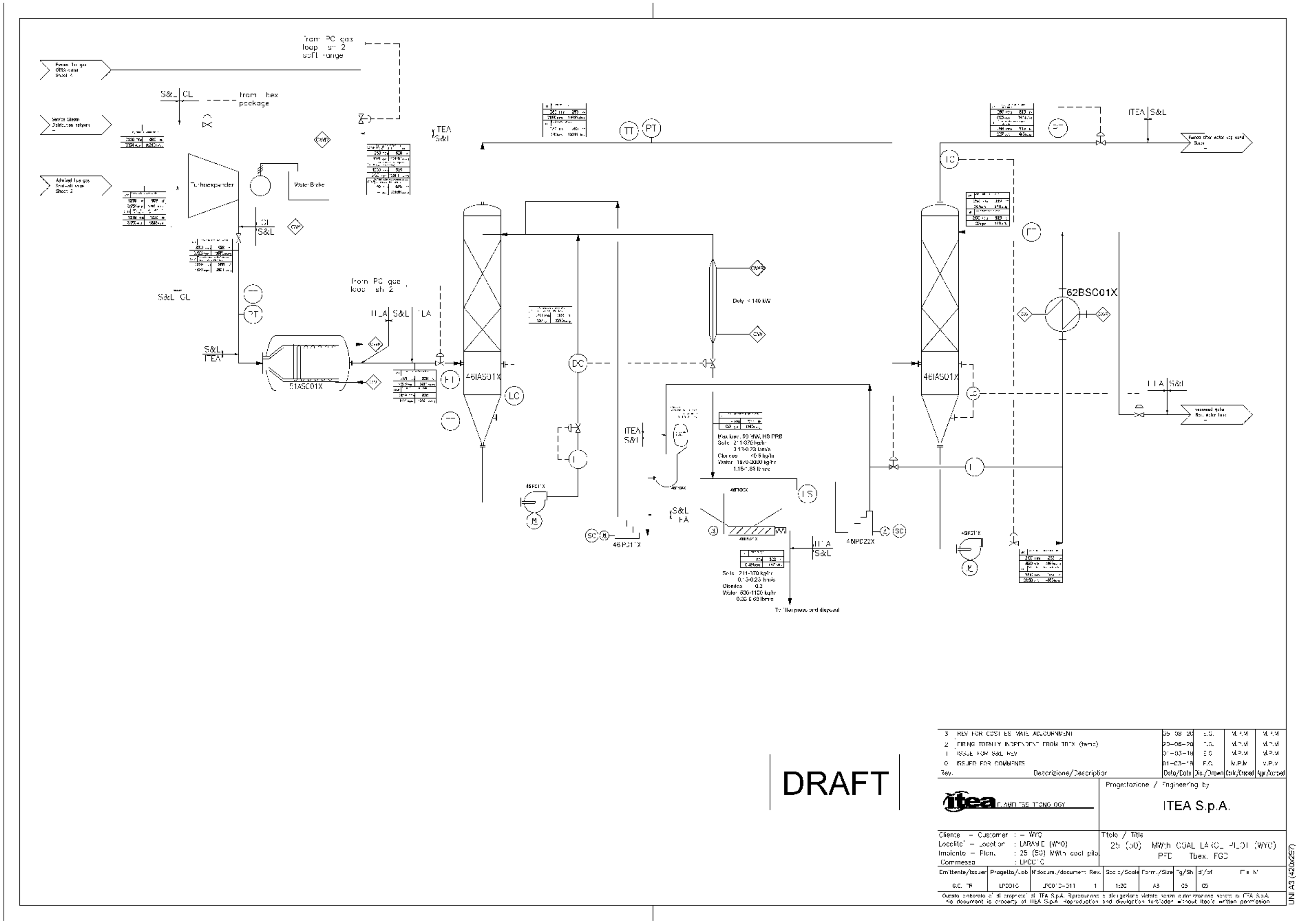


Figure 10. Sheet 5 of the Plant PFD

2.2.3 SITE LOCATION AND GENERAL ARRANGEMENT

The FPO pilot unit will be installed on Black Hills Energy property that was previously part of the Wyodak Coal Mine and has since been reclaimed. The proposed project site is located five miles east of Gillette, Campbell County, WY. Campbell County has been designated as attainment or unclassifiable for all National Ambient Air Quality Standards (NAAQS). The site proposed for the FPO plant is an approximately 2-acre portion of a 5,750-acre site. The site is previously graded and currently vacant. The site is bordered by an existing office building to the north and reclaimed mining land to the south, east, and west.

The Wyodak mine is a surface coal mine, primarily supplying coal to power plants at the adjacent Neil Simpson Complex. The following power plants are located within a mile of the proposed project site and are subject to the Wyoming Department of Environmental Quality (WYDEQ) air quality permitting requirements:

- Neil Simpson II, owned by Black Hills Power, Inc.
- Wyodak Plant, owned by PacifiCorp
- Wygen Station I, owned by Black Hills Wyoming, LLC
- Wygen Station II, owned by Cheyenne Light, Fuel & Power Company
- Wygen Station III, owned by Black Hills Power, Inc.

Land use in the vicinity of the site is a mix of industrial and vacant, reclaimed mining land. There are no residences within a mile of the site. Two industrial ponds are located in the vicinity of the site: South Pit Pond is approximately 600 feet west of the project site, while the Peerless Pit and its associated process water ponds are located approximately 2,000 feet north of the project site. In addition, Donkey Creek is located approximately 1,400 feet east of the project site. Aerial views of the project site location are shown in Figure 11. The proposed GA for the facility is shown in Figure 12, and the GA for the power distribution center is shown in Figure 13. The placement of the pilot is shown in Figure 14.

Figure 11. Aerial View of the Proposed Site Location

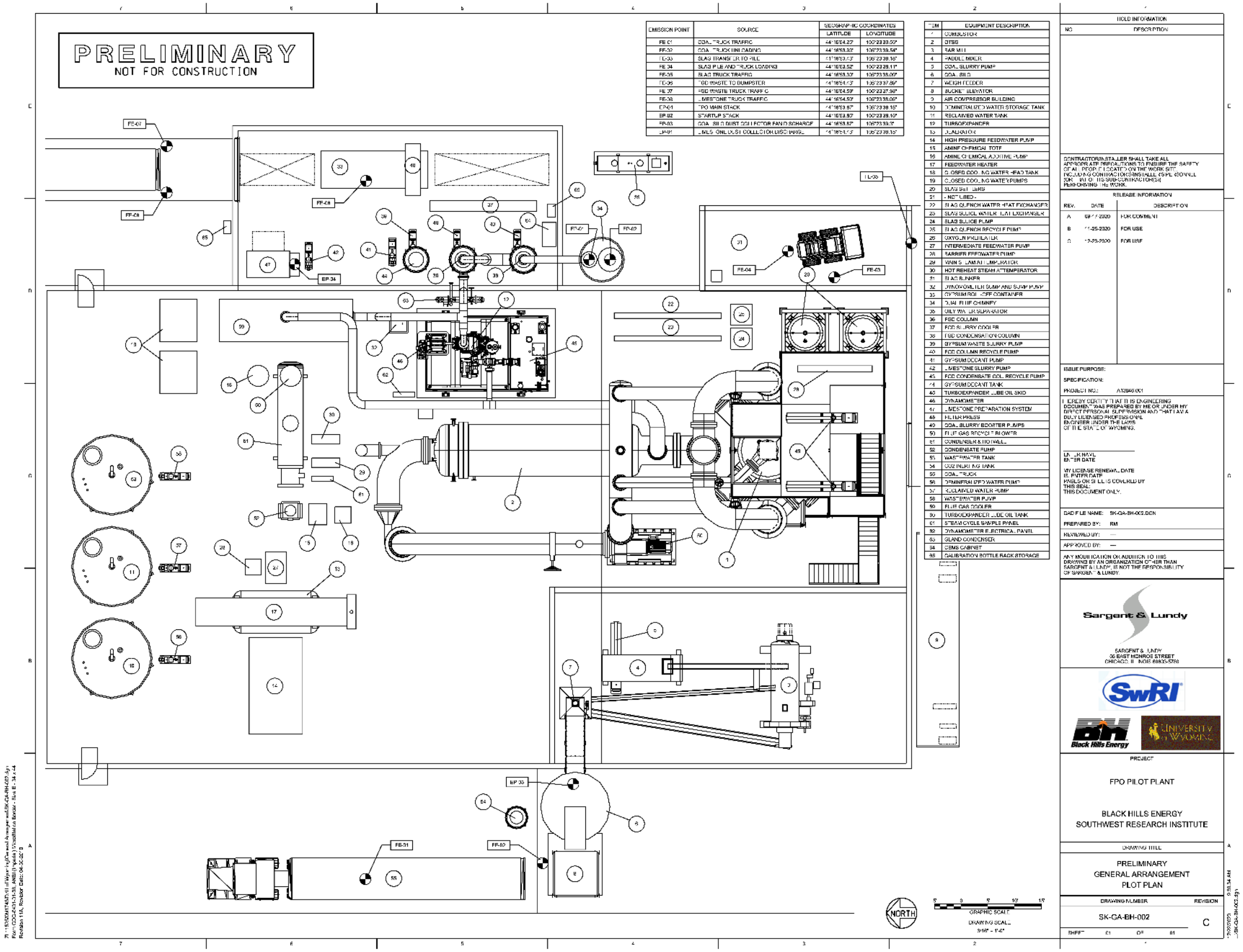


Figure 12. Overhead GA of the Planned Pilot

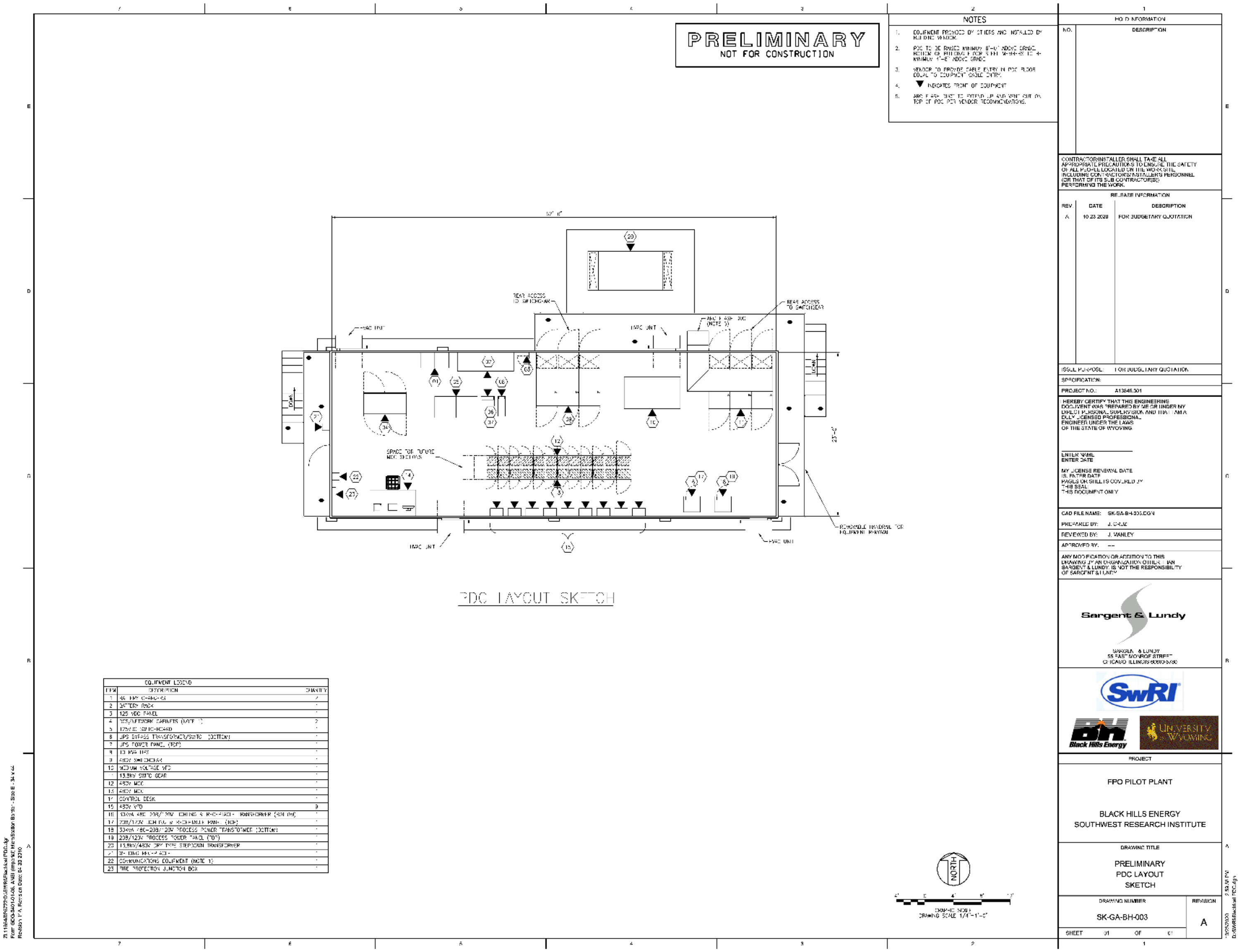


Figure 13. GA of the Power Distribution Center

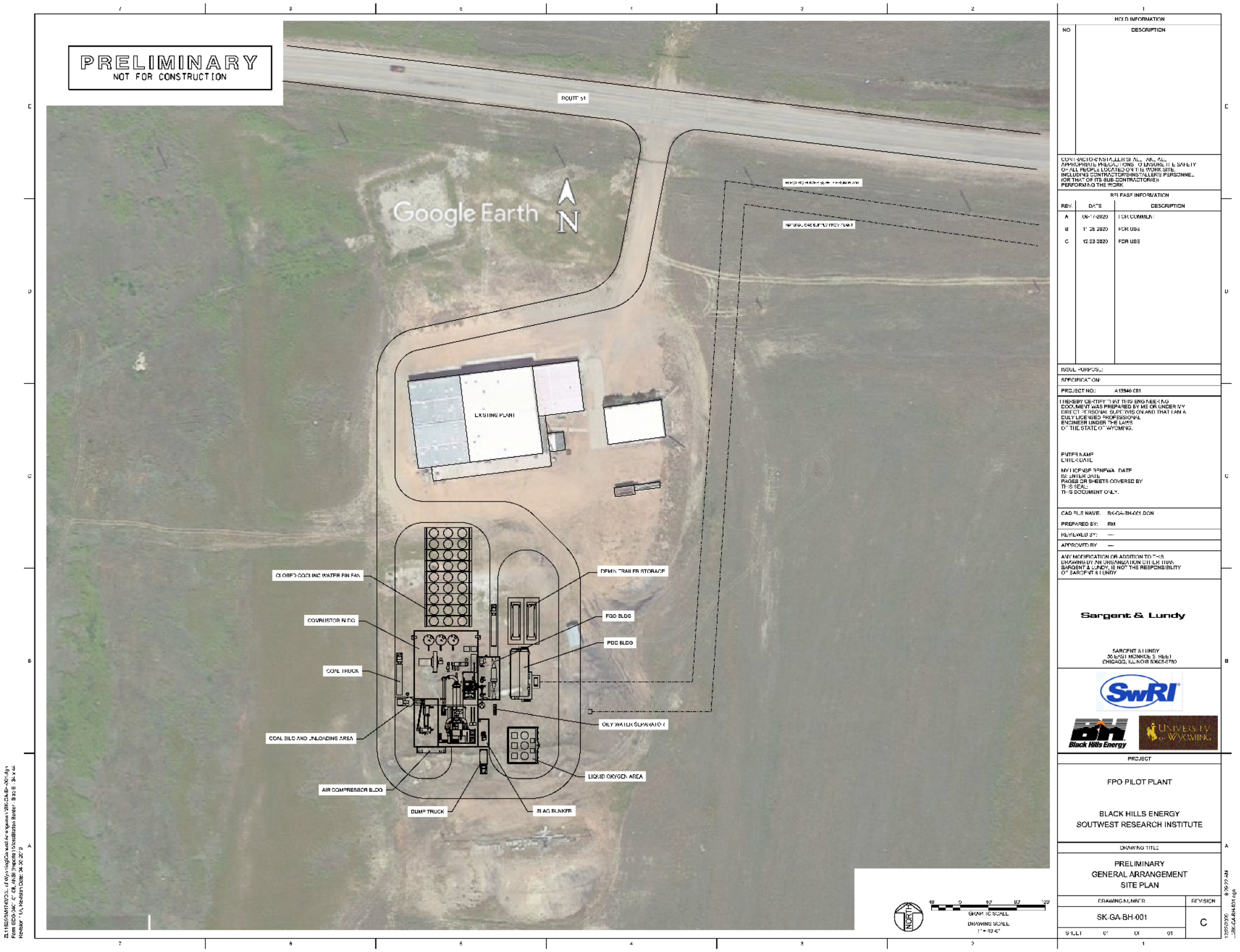


Figure 14. Positioning of the Pilot Facility at the Proposed Site

2.3 REFINEMENT OF THE PHASE III COST ESTIMATE

This effort reviewed and ensured the validity of the costs associated with the Phase III effort. A review of the estimated costs in connection with the goals and scope of the program will be checked against the FEED Study cost estimate. This will allow for several stages of cost development and refinement during the project. At the end of the project, the complete costs of Phase III were AACE Class 3.

2.3.1 BASIS OF THE CAPITAL COST ESTIMATE

General Information

The scope of this work is to provide a cost estimate for the addition of an FPO pilot design:

- Type of Estimate – Conceptual
- Project Location – Gillette, Wyoming
- New or Existing Facility – New
- Facility Type – Pilot Design for Coal Burning
- MW Rating of Units – 25 MW
- Contracting Strategy – Multiple Lump Sum
- Unit of Measurement – United States Customary Units
- Currency – U.S. Dollar

Estimate Development

The cost estimate was developed utilizing engineering scope information. It is based largely on S&L's experience with power generation projects. Detailed engineering has not been performed to firm up the project details, and specific site characteristics have not been fully analyzed. The team has attempted to assign allowances where necessary to cover issues that are likely to arise but are not quantified at this time. Listed below is a summary level scope (not all-inclusive) of facilities included in the estimate:

- Civil Work
- Structural Work
- Concrete Work
- Mechanical Work
- Electrical Work
- Instrumentation and Controls

Pricing and Quantities

All quantities and scope of facilities were based on input from engineering. Equipment and material costs were estimated based on S&L in house data, ITEA supplied data, vendor catalogs, industry publications, and other related projects. Instead of historical data, vendor budgetary quotes were solicited and received for the following items:

- Steel Flue Gas Stack
- Coal Reclaim Conveyor (Truck Unloader)
- Coal Bucket Elevator Conveyor
- Coal Storage Silo Inlet Screw Conveyor
- Coal Storage Silo (Feed Bin)

- Coal Storage Silo Bin Activator
- Coal Silo Outlet Weigh Feeder
- Coal Slurry Bar Mill
- Coal Slurry Agitated Mixing Tank
- Coal Slurry Feed Pumps
- Recycle Flue Gas Blower
- Turbo-expander
- Liquid O_2 Storage Tanks
- O_2 Ambient Vaporizers
- O_2 Pressure Maintenance Vaporizers
- Boiler Feed Water Pumps
- Slag Settlers
- Turbo-expander Dynamometer
- Supercritical Steam Deaerator

Labor Wage Rates

Labor profile: Prevailing wages for Cheyenne, WY.

Craft labor rates were developed from the publication “RS Means Labor Rates for the Construction Industry”, 2019 edition. These rates are representative of union or non-union rates, whichever are prevailing in the area. Costs have been added to cover social security, workmen’s compensation, and federal and state unemployment insurance. The resulting burdened craft rates were then used to develop typical crew rates applicable to the task being performed.

A regional labor productivity multiplier of 1.15 is included based on Compass International Global Construction Yearbook. The use of this productivity factor is an approach to compare construction productivity in various locations in the U.S. to a known basis or benchmark of 1.00 for Gulf Coast productivity in Texas. The productivity multiplier does not include weather-related delays.

Labor Work Schedule and Incentives - Assumed a 5-day workweek with 10 hours per day.

Construction Equipment

Construction equipment cost is included on each estimate line, as needed, based on the type of activity and construction equipment requirements to perform the work. Heavy lifting cranes are included as a separate line item in the cost estimate.

Construction Direct/Indirect Costs and General Conditions

The estimate is constructed in such a manner where most of the direct construction costs are determined directly, and several direct construction cost accounts are determined indirectly by taking a percentage of the directly determined costs. These percentages are based on our experience with similar size projects. Listed below are the additional costs included, unless noted as not included.

- Additional Labor Costs:
    - Labor Supervision
    - Show-up Time
    - Cost of Overtime
    - Per Diem

- Site Overheads:
    - Construction Management
    - Field Office Expenses
    - Material & Quality Control
    - Site Services
    - Safety
    - Temporary Facilities
    - Temporary Utilities
    - Mobilization/Demobilization
    - Legal Expenses/Claims
- Other Construction Indirect Costs:
    - Small Tools and Consumables
    - Scaffolding
    - General Liability Insurance
    - Construction Equipment Mobilization/Demobilization
    - Freight on Material
    - Freight on Process Equipment
    - Sales Tax – Not Included
    - Contractors General &Administration (G&A) Expense
    - Contractors Profit

Project Indirect Costs

- A/E Engineering Services
- A/E Construction Management
- A/E Start-up and Commissioning Support
- Start-Up Spare Parts
- Owner's Cost
- EPC Fee – Not Included
- AFUDC – Not Included

Escalation

Escalation cost is included and calculated based on the following rates. Preliminary project schedule and cash flow expenditures are reflected in the cash flow curves for each cost category.

- 2% / Yr for Process Equipment
- 1.5% / Yr for Materials
- 2% / Yr for Subcontract Costs
- 3% / Yr for Labor
- 1% / Yr for Construction Equipment
- 3% / Yr for Project Indirect Costs

Items Excluded

All known or conceptual scope of required physical facilities, as provided by the project team to encompass a complete project, has been included in the estimate. Any known intentional omissions are documented in the assumptions and clarifications.

The cost estimate represents only the costs listed in the estimate. The estimate does not include allowances for any other costs not listed and incurred by the owner. Excluded costs are any that are not listed in the estimate. There may be additional costs that the owner should consider such as (the list below is not all-inclusive):

- Owner's staff - project management, engineering support, procurement services, IT support, clerical staff
- Site facilities for owner's personnel, construction management, and start-up & commissioning (offices/trailers, guardhouses, furniture, signage, staff parking, vehicles, access control, computer network/servers, safety equipment, etc.)
- Site services for owner's personnel, construction management, and start-up & commissioning (telephone, electricity, natural gas, potable water, sewage, sanitary, garbage collection, recycled materials/metals collection (may also be collected from contractors, depending on owner's policy), snow removal, dust control, janitorial services, internet, cable services, reprographics, etc.)
- Construction Power
- Safety Incentives (any Owner's safety incentive, over and above contractor's programs)
- Lock-out/Tag-Out Program (personnel, procedures, and hardware)
- First Fills
- Spare Parts
- Plant Staff Training (time for personnel being trained is at the Owner's cost. Also includes Owner's time for preparation and/or modification of plant operating procedures.)
- Legal and Accounting Fees
- Per diem/Travel expenses for the Owner's Personnel assigned to the site
- Applicable Taxes
- Independent inspection company to perform code-required testing and inspection
- Permitting
- Insurance
- Owner’s Bond Fees
- Owner’s Contingency
- Project Financing
- Community Relations (if applicable, costs associated with any special provisions or facilities required by the local community, such as support for schools, fire department, police due to increased temporary population, etc.)

Notes/Assumptions/Clarifications

- The utility has sufficient capacity to supply 13.8 kv power from the existing switchgear at 19th & Willet. A spare 4” conduit is available in the existing duct bank from 19th & Willet to 19th & Gibbon to route the 13.8 kv utility feed. The 13.8 kv utility feed will be routed in direct buried conduit with concrete cover from 19th & Gibbon to the new site transformer. Roadway lighting will be provided around the liquid O_2 delivery area. No other roadway lighting is provided.

- The combustor building will be required to conform to the University of Wyoming Design Guidelines for building architectural and landscaping.
- Foundation estimates are based on the 1979 Geotechnical Investigation for the Proposed Coal Fired, Central Heating and Chilled Water Plant and Support Facilities at the University of Wyoming located in Laramie, Wyoming. An additional geotechnical investigation will be required to refine the foundation design. Driller piers of 24 inches, 30 inches, and 36 inches in diameter have been assumed for the estimate.

2.3.2 Actions to Refine the Cost Estimate

The project schedule for a cost estimate basis assumes two years of construction with an estimated completion at the end of 2023. Phase II will need to document the number of hours for the demonstration period in more detail. S&L should include the estimated peak construction workload in the cost estimate basis. The refinement of the process equipment costs included these items:

- Bar Mill
- Slurry Mixing Tank
- Coal Slurry Pump
- Coal Slurry Circulating Pump
- Service/Flush Water Tank
- Demineralization Water Tank
- Oxygen Storage
- Oxygen Vaporizer
- Oxygen Pressure Maintenance Vaporizer
- Oxygen Heat Exchanger
- Pressurized Air-cooled Condenser
- Cooling Water Air Cooling Fin Fan
- Slag Quench Heat-exchanger
- Slag Water Cooling Pump
- Slag Quench Recycle Pump
- Slag Settlers Flush Water Pump
- Slag Sump Pump
- Injection Set
- High-temperature Piping Loop
- Refractory (combustor, quenchers, high-temperature piping)
- Quenchers
- Settlers
- Combustor Vessel and Slag Pan
- OTSG
- Blower
- Feedwater Pump, High-pressure
- Feedwater Pump, Intermediate-pressure
- Air Compressor Package

- Air Compressor Air Cooling
- Power Distribution Center (includes a transformer, and switchgear)
- Distributed Control Center

2.4 DETAILED COSTS FOR PHASE III

Based upon an AACE Class 3 cost estimate, the current estimate of Phase III Project construction cost is $121.1 million, as shown in Table 3. Because this effort is a full combustion test, these costs were benchmarked against other recent, transformational research pilots, ensuring that costs are reasonable and appropriate for this type of pilot and scale.

Table 3. Estimated Phase III Capital and Labor Costs for the 25-MWth Pilot Plant

Phase III Engineering, Purchases, Construction, and Labor	
Direct Construction Labor	$8,977,374
Direct Materials	$8,773,565
Construction Equipment	$2,190,697
Process Equipment	$26,871,428
Facility Construction and Other Facility Costs	$25,374,132
Engineering, Operation Labor, and Other Costs	$48,866,273
Total Capital and Labor Costs	$121,053,469

The operating costs, shown in Table 4, are predicted to be $2.02 million, with a total Phase III Project cost of $123,076,950 million.

Table 4. Phase III Operating Costs for the 25-MWth Pilot Plant

Operating Costs	
Natural Gas Fuel Cost	$164,328
PRB Coal Fuel Cost	$68,400
High BTU Kemmerer Coal Fuel Cost	$9,200
Biomass Wood Pellet Fuel Cost	$75,000
Oxygen Supply Cost	$515,240
Water Supply Cost	$90,000
Auxiliary Power Cost	$479,864
Limestone Reagent Cost	$2,080
Pilot Waste Disposal Cost (including Trucks)	$619,369
Total O&M Costs for the Test Plan	$2,023,481

2.5 RESOURCE-LOADED SCHEDULE

The project completed a resource-loaded schedule for the pilot test campaign. The first page and the last page of the schedule are shown in Figure 15 and Figure 16, respectively. The schedule was re-worked to have project months as the primary time metric, so that the schedule is not tied to a particular stretch of time and can be applied to future projects. The labor hours distribution for engineering and construction are shown by month and cumulatively in Figure 17.

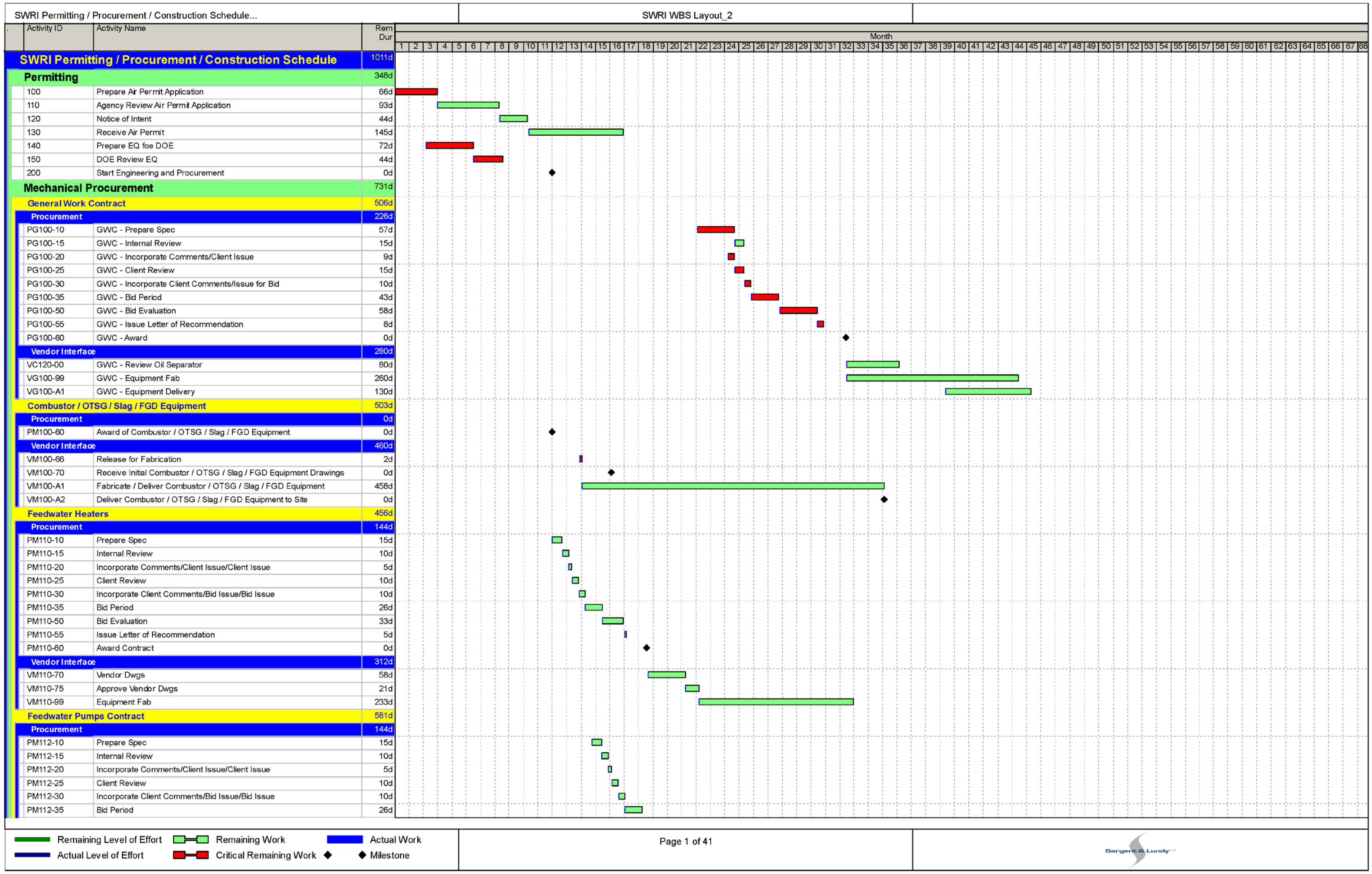


Figure 15. First Page of the Resource-Loaded Schedule

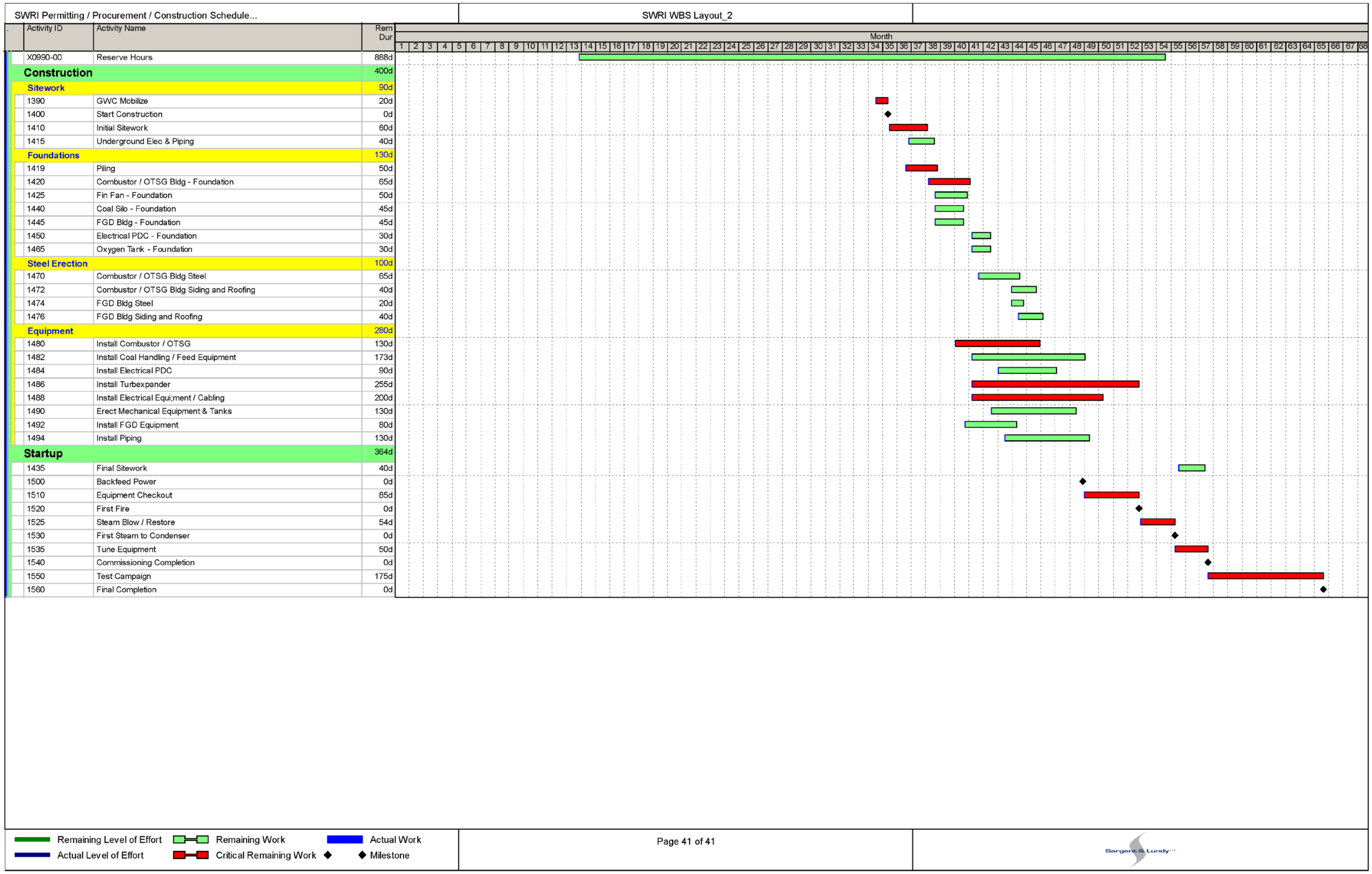


Figure 16. Last Page of the Resource-Loaded Schedule

Southwest Research Institute
Oxy-Combustion FPO Demo Project

Figure 17. Labor Hours by Project Month and Cumulatively

3. NEPA AND PERMITTING AT HOST SITE

Before this task, an Environmental Information Volume (EIV) was developed for the primary candidate site, following the recommendation of the site selection team. The EIV followed DOE guidelines and describes characteristics of the site that will assist in completing the National Environmental Protection Act (NEPA) process. During Q2FY19, the EIV was completed and delivered to the DOE as part of the Phase I Topical Report.

The process moved on to the NEPA contractor selection in Q2FY20.

3.1 NEPA DETERMINATION FOR HOST SITE

DOE determined that an Environmental Assessment (EA) was required during Phase II. The process of selecting a NEPA contractor began in Q1FY20.

Several potential independent contractors were assessed for performing the NEPA evaluation. The prospective organizations and their relevant experience to the project are listed below:

- Potomac-Hudson Engineering
    - NEPA experience in Wyoming
- AECOM
    - NEPA experience in Wyoming
- CH2M Hill
    - Environmental experience in Wyoming
- BSA Environmental Services
- Solv, LLC
    - Nationwide NEPA experience, but no office in Wyoming
- Dade Moeller (NV5)
    - Nationwide NEPA experience, but no office in Wyoming
- Apex Companies
    - Environmental experience in Wyoming
- Trihydro Corporation
    - Environmental experience in Wyoming
    - Performed work for UW (not Central Energy site)
- Western Water Consultants
    - Environmental experience in Wyoming
    - Civil work at the UW site

3.2 AUTHORING OF THE NEPA CONTRACTOR SCOPE OF WORK

3.2.1 ENVIRONMENTAL ASSESSMENT SPECIFICATION

The scope of work for this project is to prepare an EA for the FPO Pilot project under the direction of the DOE to satisfy NEPA environmental review requirements, which the team completed. The expected tasks for the EA were written in a scope that should conform to the following tasks:

3.2.1.1 EA Kickoff/Site Visits

The purpose of the kick-off meeting includes reviewing project details, project schedule, roles, required support, deliverables, and ongoing communication needs. In addition, this task will include a biological and cultural resources site visit. Each team member will conduct a site walk and review of the site surroundings specific to their resource.

This task also includes a search of WyoTrack, the Wyoming online cultural records database, which is available for review by professional archeologists. Information on previous investigations and known cultural resources obtained from this search will augment the publicly available information presented in the EIV that was obtained from the National Register of Historic Places listing for Wyoming.

3.2.1.2 Draft EA

Activities that will be conducted under this task include preparation of the Draft EA and supporting documentation. The EA will incorporate work already completed for the EIV that has been prepared for the project to the extent practicable. The EA will include the following sections:

Chapter 1.0 Introduction: This chapter will provide a summary of the proposed action; introduce the project and its objectives, clearly present the purpose of the action and how the action meets the general objective; provide the legal framework for the action, and document agency coordination and public involvement activities associated with the project.

Chapter 2.0 Proposed Action and Alternatives: This chapter will introduce the Proposed Action, No-Action Alternative, and alternatives considered but eliminated from detailed analysis, based on the text presented in the EIV. This chapter will include the project description, based on the text prepared for the EIV updated to reflect any changes in the project design. In addition, this chapter will include a list of issues considered and dismissed based on the initial EIV, preliminary research, coordination with DOE and regulatory agencies.

Chapter 3.0 Environmental Settings and Consequences: This chapter will present a general description of the existing conditions at the project site and in the project vicinity. The regulatory setting and existing conditions for applicable resource topics—based in part on DOE's EIV guidance, and as confirmed at the kick-off meeting with DOE—will be discussed. In addition, the environmental consequences of the alternatives (direct, indirect, and cumulative) will be documented for each issue or environmental resource carried forward for analysis. Based on the EIV, the following resources are anticipated to be discussed in detail:

- Air Quality (including greenhouse gases)
- Cultural Resources
- Geology and Soils
- Health & Safety/Noise
- Land Use
- Socioeconomic Resources

- Vegetation and Wildlife
- Visual Resources
- Waste Management
- Water Resources

Chapter 4.0 References: This chapter will document the references used in preparation of the EA.

Chapter 5.0 List of Preparers: This chapter will document the list of preparers for the EA.

Chapter 6.0 Distribution List: This chapter will document the distribution list for the EA, including federal, state, and local agencies, organizations, and Native American tribes.

For any impacts identified during the EA of the project, the team will work with DOE to identify potential mitigation measures and indicate proposed mitigation measures in the EA, as needed.

3.2.1.3 Final EA

After public review of the Draft EA, the team will revise, review, and produce the Final EA. In coordination with the DOE, the team will prepare a spreadsheet of individual comments extracted from comment letters/submittals with remarks indicating how each comment will be addressed in the Final EA. Upon final approval from DOE, the team will provide the Final EA for public release.

3.2.2 SUBMISSION OF PERMIT APPLICATION

A permit application was submitted for the research pilot. Wyoming Air Quality Standards and Regulations (WAQSR) Chapter 6, Section 2(a)(i) state that "any person who plans to construct any new facility or source, modify any existing facility or source, or to engage in the use of which may cause the issuance of or an increase in the issuance of air contaminants into the air of this state shall obtain a construction permit from the State of Wyoming, Department of Environmental Quality before any actual work is begun on the facility."

S&L prepared a New Source Review (NSR) application to support the permitting effort for the planned FPO pilot unit. The permit application forms are included in the NSR report, which serves as the project summary required by WYDEQ, and contains the following sections:

- **Section 2 - Project Description** of the NSR contained information describing the FPO pilot unit, the site location, and the project proponent (including contact person for this permit application).
- **Section 3 - Project Emissions** of the NSR provided a description and potential emissions for the FPO pilot unit. Detailed emission calculations are included in Section 3.2.3. Material handling diagrams are included in Section 3.2.4.
- **Section 4 - Regulatory Review** of the NSR provided an assessment of the applicable state and federal air quality regulations.
- **Section 5 - Air Quality Impact Analysis** of the NSR provided a summary of the qualitative impact evaluation conducted to evaluate potential impacts to ambient air quality.
- **Section 6 - Proposed Permit Limits** of the NSR provided a summary of the proposed emission limits for the FPO pilot unit.

The proposed permit emission limits are shown in Table 5.

Table 5. Proposed Emission Limits

Pollutant	Coal Emissions (tons/year)	Natural Gas Emissions (tons/year)	Total Annual Emissions (tons/year)
NOx	18.0	12.3	30.3
CO	2.3	7.4	9.6
VOC	0.65	0.48	1.1
SO_2	15.8	0.13	15.9
H_2SO_4	0.29	0.0077	0.30
PM	6.1	0.67	6.9
PM_{10}	6.1	0.67	6.9
$PM_{2.5}$	6.1	0.67	6.8
CO_2	39,807	10,757	50,564
HAPs	0.60	0.17	0.77

3.2.3 EMISSIONS CALCULATIONS

SWRI - FPO Pilot Unit
Emissions Summary

Table 1. Annual Emissions Summary

Pollutant	FPO Combustor Emissions		Material Handling Emissions (tons/yr)	Total Project Emissions (tons/yr)
	Normal Operation [Coal-firing] (tons/yr)	Startup/Standby [Nat gas-firing] (tons/yr)		
NO_X	18.0	12.3		**30.3**
CO	2.3	7.4		**9.6**
VOC	0.65	0.48		**1.1**
SO_2	15.8	0.13		**15.9**
H_2SO_4	0.39	0.0077		**0.39**
PM (total)	6.1	0.67	0.17	**6.9**
PM_{10} (total)	6.1	0.67	0.088	**6.9**
$PM_{2.5}$ (total)	6.1	0.67	0.070	**6.8**
CO_2	39,807	10,757		50,564
HAPs	0.60	0.17		**0.77**

Table 2. Maximum Annual Fuel Consumption Rates and Material Throughputs

Emissions Source	Parameter	Units	Annual Consumption / Throughput
FPO Combustor	Heat Input (Coal-Firing)	MMBtu/yr	358,555
	Heat Input (Gas-Firing)	MMBtu/yr	179,277
Coal Handling System	Coal Throughput	tons/yr	21,700
Slag Handling System	Slag Throughput	tons/yr	1,894
FGD Waste Handling System	FGD Waste Throughput	tons/yr	1,000
Limestone Handling System	Limestone Throughput	tons/yr	460

SWRI - FPO Pilot Unit
Material Handling System

Table 4. Material Handling Emissions Summary

Emission Point ID	Description	PM Emissions (tons/yr)	PM_{10} Emissions (tons/yr)	$PM_{2.5}$ Emissions (tons/yr)
Coal Handling System				
FE-01	Coal truck traffic	8.51E-02	1.70E-02	4.18E-03
FE-02	Coal truck unloading	7.96E-03	3.76E-03	5.70E-04
EP-03	Bin vent at top of coal silo	6.43E-02	6.43E-02	6.43E-02
	Subtotal - Coal Handling System	***1.57E-01***	***8.51E-02***	***6.90E-02***
Slag handling System				
FE-03	Slag transfer to pile	1.57E-04	7.40E-05	1.12E-05
FE-04	Slag pile & truck loading	6.15E-03	1.69E-03	1.73E-04
FE-05	Slag truck traffic	3.31E-03	6.63E-04	1.63E-04
	Subtotal - Slag Handling System	***9.62E-03***	***2.43E-03***	***3.47E-04***
FGD Waste Handling System				
FE-06	FGD waste transfer to dumpster	1.13E-04	5.35E-05	8.10E-06
FE-07	FGD waste truck traffic	1.75E-03	1.75E-04	4.29E-05
	Subtotal - FGD Waste Handling System	***1.86E-03***	***2.28E-04***	***5.10E-05***
Limestone Handling System				
FE-08	Limestone truck traffic	1.62E-03	3.24E-04	7.96E-05
EP-04	Dust Collector for Supersack Unloading	6.43E-02	6.43E-02	6.43E-02
	Subtotal - Limestone Handling System	***1.62E-03***	***3.24E-04***	***7.96E-05***
Total Material Handling Emissions		**0.17**	**0.09**	**0.07**

SWRI - FPO Pilot Unit
Coal Handling System

Table 5. Coal Handling System Emissions Estimates

ID	Description	Emission Controls	Emission Factors	PM Emissions	PM_{10} Emissions	$PM_{2.5}$ Emissions
				tons/yr	tons/yr	tons/yr
FE-01	Coal truck traffic	Paved Roads	0.15 lb/VMT (PM)	8.51E-02	1.70E-02	4.18E-03
FE-02	Coal truck unloading	Foggers	0.00073 lb/ton PM	7.96E-03	3.76E-03	5.70E-04
EP-03	Bin vent at top of coal silo	Bin Vent Filter	0.005 gr/scf ($PM/PM_{10}/PM_{2.5}$)	6.43E-02	6.43E-02	6.43E-02
Total Coal Handling Emissions				**1.57E-01**	**8.51E-02**	**6.90E-02**

Coal Throughput

Maximum Hourly Coal Consumption:	21,700	lb/hr
Maximum Annual Coal Consumption:	21,700	tons/year

Emission Factors

Paved Roads

$E_{ext} = [k\ (sL)^{0.91}\ (W)^{1.02}]\ (1 - P/4N)$ (AP42 Section 13.2.1, Eqn 2)

where:			
k (PM) =	0.011		AP42 Table 13.2.1-1
k (PM_{10}) =	0.0022		AP42 Table 13.2.1-1
k ($PM_{2.5}$) =	0.00054		AP42 Table 13.2.1-1
sL =	0.6	g/m^2	AP42 Table 13.2.1-2, Ubiquitous baseline
W =	22	tons	Assume: Truck Tare Weight = 12 tons, Truck Capacity = 20 tons
P =	80	days/yr	AP42 Figure 13.2.1-2
N =	365	days/yr	
Control Efficiency =	0%		
E_{ext} (PM) =	0.15	lb/VMT	
E_{ext} (PM_{10}) =	0.031	lb/VMT	
E_{ext} ($PM_{2.5}$) =	0.0075	lb/VMT	
Maximum Annual Coal Requirement:	21,700	ton/yr	
Number of Coal Deliveries:	1085	(assumes 20 ton truck capacity)	
Coal Unloading Hours:	1085	hr/yr (assumes 1 hour to unload truck)	
Length of Road:	0.5	miles (total)	
Annual VMT:	1113.8	miles per year	

Coal Transfer Points

$E\ (lb/ton) = k\ (0.0032)\ (U/5)^{1.3} / (M/2)^{1.4}$ (AP42 Section 13.2.4, Eqn 1)

where:		Source
k =	0.74	AP42 Section 13.2.4, page 4
k =	0.35	AP42 Section 13.2.4, page 5
k =	0.053	AP42 Section 13.2.4, page 6
U =	7.7	mean wind speed, Sheridan County Airport, 1990
M =	6.9%	AP42 Table 13.2.4-1
Control Efficiency =	50%	with foggers
E (PM) =	0.00073	lb/ton (includes controls)
E (PM_{10}) =	0.00035	lb/ton (includes controls)
E ($PM_{2.5}$) =	0.000053	lb/ton (includes controls)

SWRI - FPO Pilot Unit
Slag Handling System

Table 6. Slag Handling System Emissions Estimates

ID	Description	Emission Controls	Emission Factors		PM Emissions tons/yr	PM10 Emissions tons/yr	PM2.5 Emissions tons/yr
FE-03	Slag transfer to pile	Moisture Content	0.00017	lb/ton (PM)	1.57E-04	7.40E-05	1.12E-05
FE-04a	*Front end loader activity*	*Moisture Conent*	*0.879*	*lb/VMT (PM)*	*5.99E-03*	*1.62E-03*	*1.62E-04*
FE-04b	*Slag transfer to truck*	*Moisture Content*	*0.00017*	*lb/ton (PM)*	*1.57E-04*	*7.40E-05*	*1.12E-05*
FE-04	Slag pile & truck loading	Moisture Content			6.15E-03	1.69E-03	1.73E-04
FE-05	Slag truck traffic	Paved Roads	0.05	lb/VMT (PM)	3.31E-03	6.63E-04	1.63E-04
Total Slag Handling Emissions					**9.62E-03**	**2.43E-03**	**3.47E-04**

Slag Throughput

Max Hourly Slag Generated	1,894 lb slag/hr
Max Annual Slag Generated	1,894 tons/year

Emission Factors

Slag Pile - Front End Loader Activity

E_{ext} (lb/VMT) = k $(s/12)^a$ / $(W/3)^b$ ((365-P)/365) (AP42 Section 13.2.2, Eqns 1a and 2)

where:

k =	4.9	PM-30	per AP-42 Table 13.2.2-2
k =	1.5	PM-10	per AP-42 Table 13.2.2-2
k =	0.15	PM-2.5	per AP-42 Table 13.2.2-2
a =	0.7	constant a (PM)	per AP-42 Table 13.2.2-2
a =	0.9	constant a (PM10/PM2.5)	per AP-42 Table 13.2.2-2
b =	0.45	contant b (PM)	per AP-42 Table 13.2.2-2
b =	0.45	constant b (PM10/PM2.5)	per AP-42 Table 13.2.2-2
s =	6.4	surface silt content (%)	per AP-42 Table 13.2.2-1
W =	50.6	mean vehicle weight (tons)	estimated average front-end loader weight
P =	80	days/yr AP42 Figure 13.2.1-2	
Control Efficiency =	90%	for moisture content of slag material	
E (PM) =	0.88	lb/VMT (controlled)	
E (PM_{10}) =	0.24	lb/VMT (controlled)	
E ($PM_{2.5}$) =	0.024	lb/VMT (controlled)	
VMT =	14	vehicle miles traveled per year	based on front-end loader activity

SWRI - FPO Pilot Unit
Slag Handling System

Slag Transfer Points

$E (lb/ton) = k (0.0032) (U/5)^{1.3} / (M/2)^{1.4}$ (AP42 Section 13.2.4, Eqn 1)

			Source
where:			
k =	0.74	PM < 30um	AP42 Section 13.2.4, page 4
k =	0.35	PM < 10um	AP42 Section 13.2.4, page 5
k =	0.053	PM < 2.5um	AP42 Section 13.2.4, page 6
$U_{exposed}$ =	7.7	mean wind speed, Sheridan County Airport, 1990	
M_{slag} =	20%	Assumed moisture content of slag	
E (PM) =	0.00017	lb/ton	
E (PM_{10}) =	0.00008	lb/ton	
E ($PM_{2.5}$) =	0.000012	lb/ton	

Paved Roads

$E_{ext} = [k (sL)^{0.91} (W)^{1.02}] (1 – P/4N)$ (AP42 Section 13.2.1, Eqn 2)

where:			
k (PM) =	0.011		AP42 Table 13.2.1-1
k (PM_{10}) =	0.0022		AP42 Table 13.2.1-1
k ($PM_{2.5}$) =	0.00054		AP42 Table 13.2.1-1
sL =	0.6	g/m^2	AP42 Table 13.2.1-2, Ubiquitous baseline
W =	8	tons	Assume: Truck Tare Weight = 4 tons, Truck Capacity = 8 tons
P =	80	days/yr	AP42 Figure 13.2.1-2
N =	365	days/yr	
Control Efficiency =	0%		
E_{ext} (PM) =	0.05	lb/VMT	
E_{ext} (PM_{10}) =	0.011	lb/VMT	
E_{ext} ($PM_{2.5}$) =	0.0027	lb/VMT	
Maximum Annual Slag Generated:	1,894	ton/yr	
Number of Slag Trucks per Year:	237	(assumes 8 ton truck capacity)	
Length of Road:	0.5	miles (total)	
Annual VMT:	121.6	miles per year	

SWRI - FPO Pilot Unit
FGD Waste Handling System

Table 7. FGD Waste Handling System Emissions Estimates

ID	Description	Emission Controls	Emission Factors		PM Emissions tons/yr	PM_{10} Emissions tons/yr	$PM_{2.5}$ Emissions tons/yr
FE-06	FGD waste transfer to dumpster	Moisture Content	0.00023	lb/ton (PM)	1.13E-04	5.35E-05	8.10E-06
FE-07	FGD waste truck traffic	Paved Roads	0.05	lb/VMT (PM)	1.75E-03	1.75E-04	4.29E-05
Total FGD Waste Handling Emissions					**1.86E-03**	**2.28E-04**	**5.10E-05**

FGD Waste Throughput

Max Hourly FGD Waste Generated	1,000	lb/hr
Max Annual FGD Waste Generated	1,000	tons/year

Emission Factors

FGD Waste Transfer Points

$E\ (lb/ton) = k\ (0.0032)\ (U/5)^{1.3} / (M/2)^{1.4}$ (AP42 Section 13.2.4, Eqn 1)

where:			Source
k =	0.74	PM < 30um	AP42 Section 13.2.4, page 4
k =	0.35	PM < 10um	AP42 Section 13.2.4, page 5
k =	0.053	PM < 2.5um	AP42 Section 13.2.4, page 6
$U_{exposed}$ =	9.8	mph	mean wind speed, Indianapolis International Airport, 2005]
$M_{fix\ Matl}$ =	20%		Assumed moisture content of fixated material
E (PM) =	0.00023	lb/ton	
E (PM_{10}) =	0.00011	lb/ton	
E ($PM_{2.5}$) =	0.000016	lb/ton	

Paved Roads

$E_{ext} = [k\ (sL)^{0.91}\ (W)^{1.02}]\ (1 - P/4N)$ (AP42 Section 13.2.1, Eqn 2)

where:			
k (PM) =	0.011		AP42 Table 13.2.1-1
k (PM_{10}) =	0.0022		AP42 Table 13.2.1-1
k ($PM_{2.5}$) =	0.00054		AP42 Table 13.2.1-1
sL =	0.6	g/m^2	AP42 Table 13.2.1-2, Ubiquitous baseline
W =	8	tons	Assume: Truck Tare Weight = 4 tons, Truck Capacity = 8 tons
P =	80	days/yr	AP42 Figure 13.2.1-2
N =	365	days/yr	
Control Efficiency =	0%		
E_{ext} (PM) =	0.05	lb/VMT	
E_{ext} (PM_{10}) =	0.011	lb/VMT	
E_{ext} ($PM_{2.5}$) =	0.0027	lb/VMT	
Maximum Annual FGD Waste Generated:	1,000	ton/yr	
Number of Annual FGD Waste Trucks	125	(assumes 8 ton truck capacity)	
Length of Road:	0.5	miles (total)	
Annual VMT:	64.2	miles per year	

SWRI - FPO Pilot Unit
Limestone Handling System

Table 8. Limestone Handling System Emissions Estimates

ID	Description	Emission Controls	Emission Factors	PM Emissions	PM_{10} Emissions	$PM_{2.5}$ Emissions
				tons/yr	tons/yr	tons/yr
FE-08	Limestone truck traffic	Paved Roads	0.05 lb/VMT (PM)	1.62E-03	3.24E-04	7.96E-05
EP-04	Dust Collector for Supersack Unloading	Dust Collector	0.005 gr/scf ($PM/PM_{10}/PM_{2.5}$)	6.43E-02	6.43E-02	6.43E-02
Total Limestone Handling Emissions				**6.59E-02**	**6.46E-02**	**6.44E-02**

Limestone Requirement

Max Hourly Limestone Requirement	460 lb /hr
Max Annual Limestone Requirement	460 tons/year

Emission Factors

Emission Factor Calculation -- Paved Roads

$E_{ext} = [k\ (sL)^{0.91}\ (W)^{1.02}]\ (1 - P/4N)$ (AP42 Section 13.2.1, Eqn 2)

where:

k (PM) =	0.011		AP42 Table 13.2.1-1
k (PM_{10}) =	0.0022		AP42 Table 13.2.1-1
k ($PM_{2.5}$) =	0.00054		AP42 Table 13.2.1-1
sL =	0.6	g/m^2	AP42 Table 13.2.1-2, Ubiquitous baseline
W =	8	tons	Assume: Truck Tare Weight = 4 tons, Truck Capacity = 8 tons
P =	80	days/yr	AP42 Figure 13.2.1-2
N =	365	days/yr	
Control Efficiency =	0%		
E_{ext} (PM) =	0.05	lb/VMT	
E_{ext} (PM_{10}) =	0.011	lb/VMT	
E_{ext} ($PM_{2.5}$) =	0.0027	lb/VMT	
Maximum Annual Limestone Requirement:	460	ton/yr	
Number of Limestone Deliveries:	58	(assumes 8 ton truck capacity)	
Length of Road:	0.5	miles (total)	
Annual VMT:	59.5	miles per year	

SWRI - FPO Pilot Unit
HAP Emissions

Table 9. HAP Emissions Estimates - Inputs

Parameter	Normal Operation (Coal)	Startup / Standby (Nat. Gas)
Maximum Fuel Flow (coal), tons/hr	10.9	---
Maximum Fuel Flow (Nat. Gas), mmSCF/hr	---	0.176
Annual Hours of Operation	2,000	1,000

Table 10. HAP Emissions

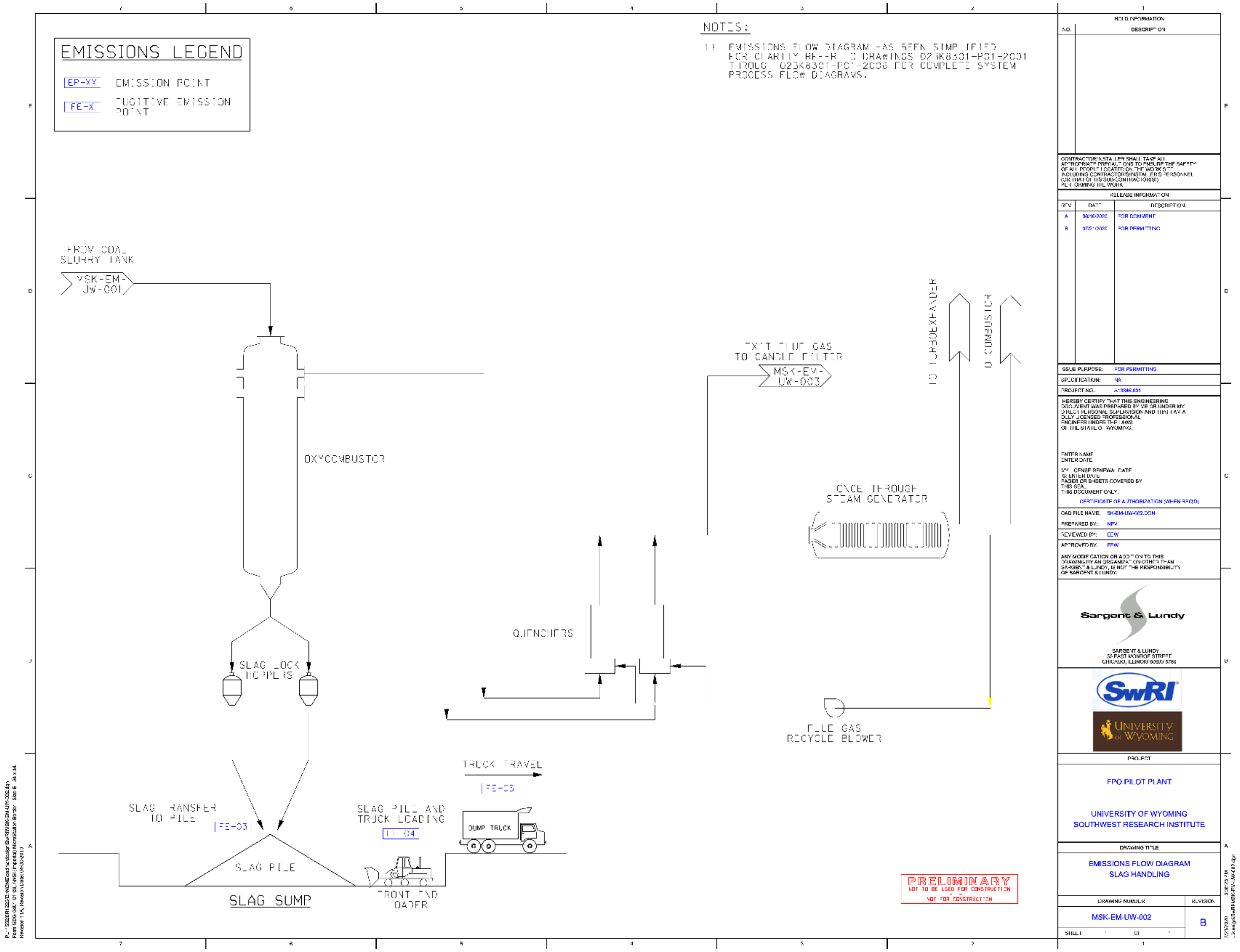
Pollutant	Normal Operation - Coal				Startup/Standby - Natural Gas				Total Annual HAP Emissions (ton/yr)
	Emission Factor (lb/ton)	Emission Factor Source	Hourly HAP Emissions (lb/hr)	Annual HAP Emissions (tons/yr)	Emission Factor (lb/mmscf)	Emission Factor Source	Hourly HAP Emissions (lb/hr)	Annual HAP Emissions (tons/yr)	
2-Methylnaphthalene	---	---	---	---	2.40E-05	(4)	4.22E-06	2.11E-06	2.11E-06
3-Methylchloroanthrene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
7,12-Dimethylbenz(a)anthracene	---	---	---	---	1.60E-05	(4)	2.81E-06	1.41E-06	1.41E-06
Acenaphthene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
Acenaphthylene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
Acetaldehyde	5.70E-04	(1)	6.18E-03	6.18E-03	---	---	---	---	6.18E-03
Acetophenone	1.50E-05	(1)	1.63E-04	1.63E-04	---	---	---	---	1.63E-04
Acrolein	2.90E-04	(1)	3.15E-03	3.15E-03	---	---	---	---	3.15E-03
Anthracene	---	---	---	---	2.40E-06	(4)	4.22E-07	2.11E-07	2.11E-07
Benzene	1.30E-03	(1)	1.41E-02	1.41E-02	2.10E-03	(4)	3.69E-04	1.85E-04	1.43E-02
Benzo(a)anthracene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
Benzo(a)pyrene	---	---	---	---	1.20E-06	(4)	2.11E-07	1.05E-07	1.05E-07
Benzo(b)fluoranthene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
Benzo(g,h,i)perylene	---	---	---	---	1.20E-06	(4)	2.11E-07	1.05E-07	1.05E-07
Benzo(k)fluoranthene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
Benzyl Chloride	7.00E-04	(1)	7.60E-03	7.60E-03	---	---	---	---	7.60E-03
Bis(2-ethylhexyl)phthalate	7.30E-05	(1)	7.92E-04	7.92E-04	---	---	---	---	7.92E-04
Bromoform	3.90E-05	(1)	4.23E-04	4.23E-04	---	---	---	---	4.23E-04
Carbon Disulfide	1.30E-04	(1)	1.41E-03	1.41E-03	---	---	---	---	1.41E-03
Chrysene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
2-Chloroacetophenone	7.00E-06	(1)	7.60E-05	7.60E-05	---	---	---	---	7.60E-05
Chlorobenzene	2.20E-05	(1)	2.39E-04	2.39E-04	---	---	---	---	2.39E-04
Chloroform	5.90E-05	(1)	6.40E-04	6.40E-04	---	---	---	---	6.40E-04
Cumene	5.30E-06	(1)	5.75E-05	5.75E-05	---	---	---	---	5.75E-05
Cyanide	2.50E-03	(1)	2.71E-02	2.71E-02	---	---	---	---	2.71E-02
Dibenz(a,h)anthracene	---	---	---	---	1.20E-06	(4)	2.11E-07	1.05E-07	1.05E-07
Dichlorobenzene	---	---	---	---	1.20E-03	(4)	2.11E-04	1.05E-04	1.05E-04
2,4-Dinitrotoluene	2.80E-07	(1)	3.04E-06	3.04E-06	---	---	---	---	3.04E-06
Dimethyl sulfate	4.80E-05	(1)	5.21E-04	5.21E-04	---	---	---	---	5.21E-04
Ethylbenzene	9.40E-05	(1)	1.02E-03	1.02E-03	---	---	---	---	1.02E-03
Ethyl chloride	4.20E-05	(1)	4.56E-04	4.56E-04	---	---	---	---	4.56E-04
Ethylene dichloride	4.00E-05	(1)	4.34E-04	4.34E-04	---	---	---	---	4.34E-04
Ethylene dibromide	1.20E-06	(1)	1.30E-05	1.30E-05	---	---	---	---	1.30E-05
Fluoranthene	---	---	---	---	3.00E-06	(4)	5.27E-07	2.64E-07	2.64E-07
Fluorene	---	---	---	---	2.80E-06	(4)	4.92E-07	2.46E-07	2.46E-07

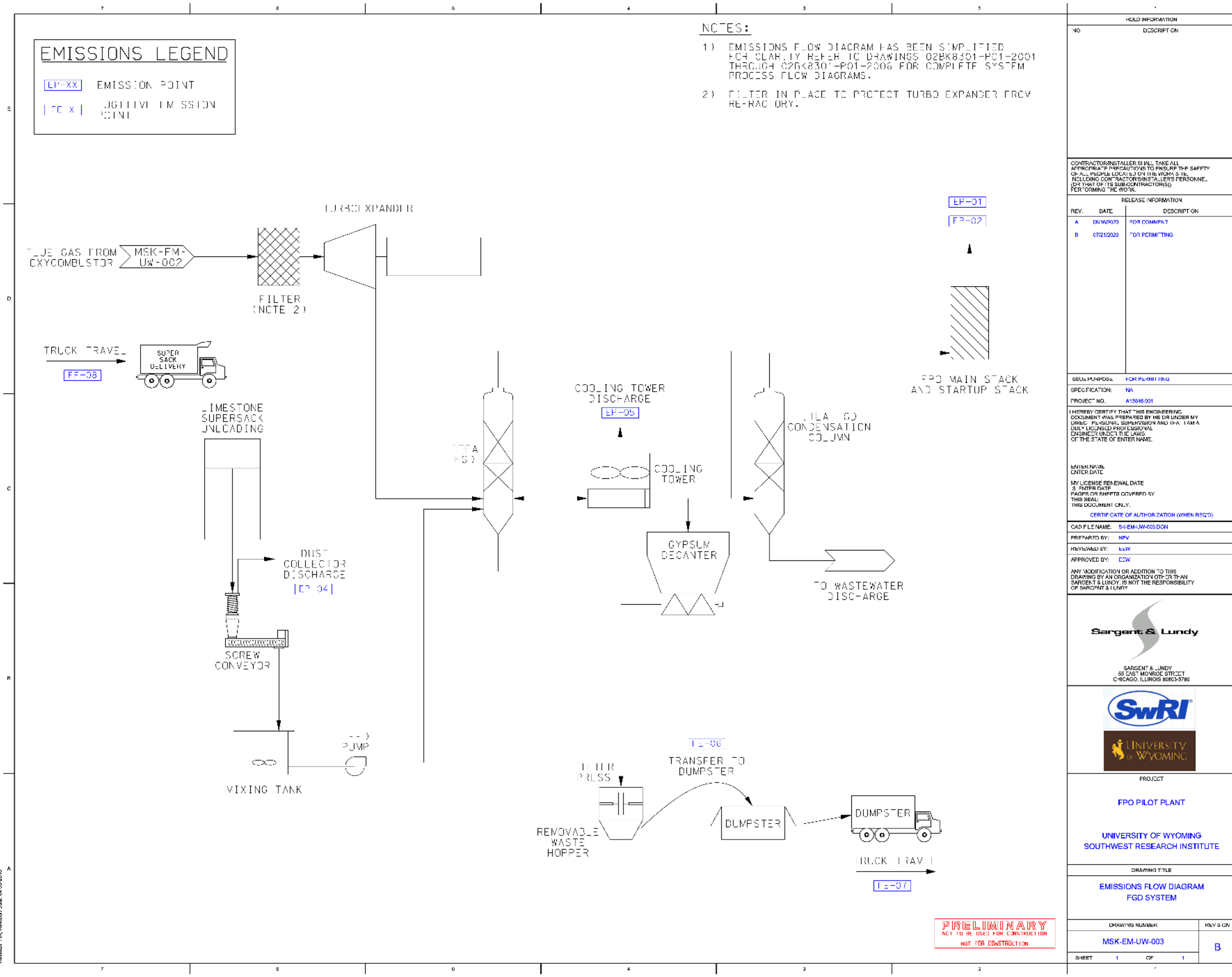
SWRI - FPO Pilot Unit
HAP Emissions
Table 10. HAP Emissions (cont.)

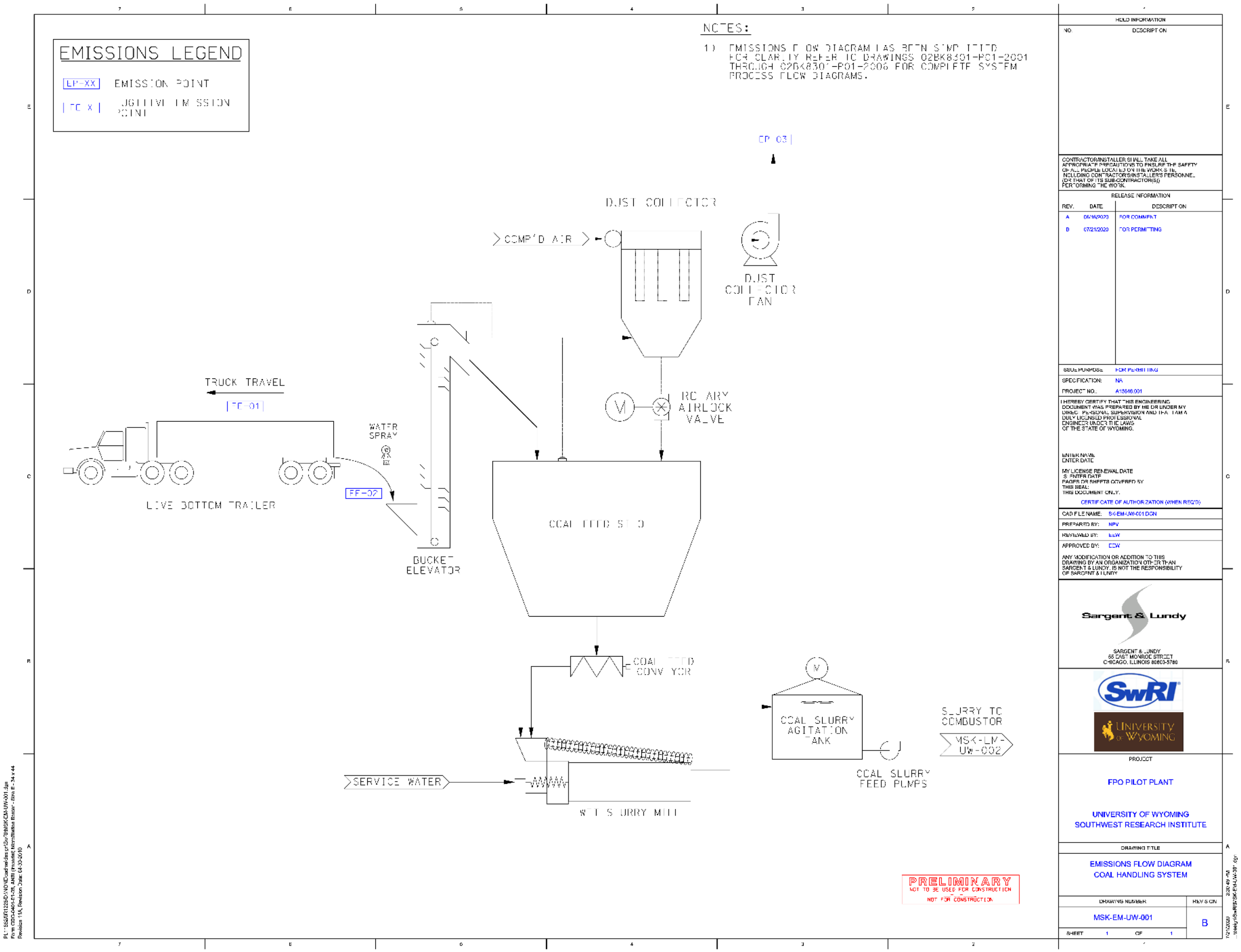
Pollutant	Normal Operation - Coal				Startup/Standby - Natural Gas				Total Annual HAP Emissions (ton/yr)
	Emission Factor (lb/ton)	Emission Factor Source	Hourly HAP Emissions (lb/hr)	Annual HAP Emissions (tons/yr)	Emission Factor (lb/mmscf)	Emission Factor Source	Hourly HAP Emissions (lb/hr)	Annual HAP Emissions (tons/yr)	
Formaldehyde	2.40E-04	(1)	2.60E-03	2.60E-03	7.50E-02	(4)	1.32E-02	6.59E-03	9.20E-03
Hexane	6.70E-05	(1)	7.27E-04	7.27E-04	1.80	(4)	0.32	1.58E-01	1.59E-01
Hydrochloric Acid	3.45E-02	(2)	3.74E-01	3.74E-01	---	---	---	---	3.74E-01
Hydrofluoric Acid	8.49E-03	(2)	9.22E-02	9.22E-02	---	---	---	---	9.22E-02
Indeno(1,2,3-cd)pyrene	---	---	---	---	1.80E-06	(4)	3.16E-07	1.58E-07	1.58E-07
Isophorone	5.80E-04	(1)	6.29E-03	6.29E-03	---	---	---	---	6.29E-03
Methyl bromide	1.60E-04	(1)	1.74E-03	1.74E-03	---	---	---	---	1.74E-03
Methyl chloride	5.30E-04	(1)	5.75E-03	5.75E-03	---	---	---	---	5.75E-03
Methyl ethyl ketone	3.90E-04	(1)	4.23E-03	4.23E-03	---	---	---	---	4.23E-03
Methyl hydrazine	1.70E-04	(1)	1.84E-03	1.84E-03	---	---	---	---	1.84E-03
Methyl methacrylate	2.00E-05	(1)	2.17E-04	2.17E-04	---	---	---	---	2.17E-04
Methyl tert butyl ether	3.50E-05	(1)	3.80E-04	3.80E-04	---	---	---	---	3.80E-04
Methylene chloride	2.90E-04	(1)	3.15E-03	3.15E-03	---	---	---	---	3.15E-03
Naphthalene	---	---	---	---	6.10E-04	(4)	1.07E-04	5.36E-05	5.36E-05
Phenanthrene	---	---	---	---	1.70E-05	(4)	2.99E-06	1.49E-06	1.49E-06
Phenol	1.60E-05	(1)	1.74E-04	1.74E-04	---	---	---	---	1.74E-04
Propionaldehyde	3.80E-04	(1)	4.12E-03	4.12E-03	---	---	---	---	4.12E-03
Pyrene	---	---	---	---	5.00E-06	(4)	8.79E-07	4.39E-07	4.39E-07
Tetrachloroethylene	4.30E-05	(1)	4.67E-04	4.67E-04	---	---	---	---	4.67E-04
Toluene	2.40E-04	(1)	2.60E-03	2.60E-03	---	---	---	---	2.60E-03
1,1,1-Trichloroethane	2.00E-05	(1)	2.17E-04	2.17E-04	---	---	---	---	2.17E-04
Styrene	2.50E-05	(1)	2.71E-04	2.71E-04	---	---	---	---	2.71E-04
Xylenes	3.70E-05	(1)	4.01E-04	4.01E-04	---	---	---	---	4.01E-04
Vinyl acetate	7.60E-06	(1)	8.25E-05	8.25E-05	---	---	---	---	8.25E-05
Toluene	---	---	---	---	3.40E-03	(4)	5.98E-04	2.99E-04	2.99E-04
Antimony	1.85E-05	(3)	2.01E-04	2.01E-04	---	---	---	---	2.01E-04
Arsenic	4.10E-04	(3)	4.45E-03	4.45E-03	2.00E-04	(5)	3.52E-05	1.76E-05	4.47E-03
Beryllium	2.10E-05	(3)	2.28E-04	2.28E-04	1.20E-05	(5)	2.11E-06	1.05E-06	2.29E-04
Cadmium	5.10E-05	(3)	5.53E-04	5.53E-04	1.10E-03	(5)	1.93E-04	9.67E-05	6.50E-04
Chromium	2.60E-04	(3)	2.82E-03	2.82E-03	1.40E-03	(5)	2.46E-04	1.23E-04	2.94E-03
Cobalt	1.00E-04	(3)	1.09E-03	1.09E-03	8.40E-05	(5)	1.48E-05	7.38E-06	1.09E-03
Lead	4.20E-04	(3)	4.56E-03	4.56E-03	5.00E-04	(6)	8.79E-05	4.39E-05	4.60E-03
Manganese	4.90E-04	(3)	5.32E-03	5.32E-03	3.80E-04	(5)	6.68E-05	3.34E-05	5.35E-03
Mercury	8.30E-05	(3)	9.01E-04	9.01E-04	2.60E-04	(5)	4.57E-05	2.28E-05	9.23E-04
Nickel	2.80E-04	(3)	3.04E-03	3.04E-03	2.10E-03	(5)	3.69E-04	1.85E-04	3.22E-03
Selenium	1.30E-03	(3)	1.41E-02	1.41E-02	2.40E-05	(5)	4.22E-06	2.11E-06	1.41E-02
Total HAPs, tpy				**0.60**				**0.17**	**0.77**

Emission Factor Source:
(1) AP42 Table 1.1-14
(2) emissions estimate for FPO Pilot Unit
(3) AP42 Table 1.1-18
(4) AP42 Table 1.4-3
(5) AP42 Table 1.4-4
(6) AP42 Table 1.4-2

3.2.4 Emissions Material Handling Diagrams




EMISSIONS LEGEND
EMISSION POINT
NOTES:
1) EMISSIONS FLOW DIAGRAM HAS BEEN SIMPLIFIED FOR CLARITY. REFER TO DRAWINGS 02BK8301-P01-2001 THROUGH 02BK8301-P01-2006 FOR COMPLETE SYSTEM PROCESS FLOW DIAGRAMS.
2) FILTER IN PLACE TO PROTECT TURBO EXPANDER FROM REFRACTORY.
FILTER (NOTE 2)
EP-01
COOLING TOWER DISCHARGE
EP-05
COOLING TOWER
GYPSUM DECANTER
TO WASTEWATER DISCHARGE
SCREW CONVEYOR
MIXING TANK
TRANSFER TO DUMPSTER
DUMPSTER
REMOVABLE WASTE HOPPER
PRELIMINARY
NOT FOR CONSTRUCTION
Sargent & Lundy
SwRI
FPO PILOT PLANT
UNIVERSITY OF WYOMING
SOUTHWEST RESEARCH INSTITUTE
EMISSIONS FLOW DIAGRAM
FGD SYSTEM
MSK-EM-UW-003
B


EMISSIONS LEGEND
EMISSION POINT
NOTES:
TRUCK TRAVEL
LIVE BOTTOM TRAILER
WATER SPRAY
BUCKET ELEVATOR
DUST COLLECTOR
DUST COLLECTOR FAN
COMP'D AIR
VALVE
SERVICE WATER
COAL SLURRY AGITATION TANK
COAL SLURRY FEED PUMPS
SLURRY TO COMBUSTOR
PRELIMINARY
FPO PILOT PLANT
UNIVERSITY OF WYOMING
SOUTHWEST RESEARCH INSTITUTE
EMISSIONS FLOW DIAGRAM
COAL HANDLING SYSTEM
MSK-EM-UW-001
B

3.3 FINAL NEPA ENVIRONMENTAL ASSESSMENT

The NEPA EA was produced for public review. The final report is reproduced in part below. DOE made an announcement of the assessment during the beginning of 2022 and made the document available for public comment.

DOE/EA-2127D

Draft Environmental Assessment

Flameless Pressurized Oxy-Combustion

Large-Scale Pilot Test

December 2021

U.S. Department of Energy

NATIONAL ENERGY TECHNOLOGY LABORATORY

National Energy Technology Laboratory

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Responsible Agency: United States Department of Energy

Title: Flameless Pressurized Oxy-Combustion Large-Scale Pilot Test, Environmental Assessment (DOE/EA-2127D)

Location: Gillette Energy Complex, 13151 Highway 51, Gillette WY, 82718

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Abstract: The United States Department of Energy (DOE) National Energy Technology Laboratory prepared this Environmental Assessment (EA) to analyze the potential environmental, cultural, and social impacts of partially funding a large-scale pilot test facility for flameless pressurized oxy-combustion (FPO) to improve the performance, efficiency, and cost of using a coal-fueled system to generate electricity. The FPO large-scale pilot project (FPO Pilot Project) would be designed, constructed, and operated by the Southwest Research Institute (SwRI) in conjunction with the Electric Power Research Institute, Black Hills Energy, and the University of Wyoming. The FPO Pilot Project would be located at the existing Gillette Energy Complex on lands owned by a Black Hills Energy subsidiary, the Wyodak Resources Development Corporation. This site is approximately 5 miles east of the city of Gillette, Wyoming.

DOE's proposed action is to provide financial assistance to SwRI. DOE proposes to provide approximately $60 million of the project's $123 million total cost. SwRI and the project partners are required to obtain funding for the remaining project cost. The funding will be used to develop and operate the FPO Pilot Project.

Availability: This EA is being released for public review and comment. Hard copies of the EA are being distributed to Tribal agencies and the Campbell County Public Library in Gillette, with electronic copies sent to the project mailing list and others who requested an electronic copy. The public is invited to provide written or e-mail comments to DOE on the Draft EA during the comment period, from December 20, 2021 to January 26, 2022. Comments should be provided to the National Energy Technology Laboratory M/S:922-273C, P.O. Box 10940, Pittsburgh, PA 15236-0940, Attention: Pierina Fayish or Pierina.Fayish@NELT.DOE.GOV. Comments received after January 26, 2022 will be considered to the extent possible.

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1.0 INTRODUCTION/PURPOSE AND NEED

1.1 Introduction

The United States Department of Energy (DOE) National Energy Technology Laboratory prepared this Environmental Assessment (EA) under the National Environmental Policy Act (NEPA). This EA analyzes the potential environmental, cultural, and social impacts of partially funding a large-scale pilot test facility for flameless pressurized oxy-combustion (FPO) to improve the performance, efficiency, and cost of using a coal-fueled system to generate electricity. The FPO large-scale pilot project (FPO Pilot Project) would be designed, constructed, and operated by the Southwest Research Institute (SwRI) in conjunction with the Electric Power Research Institute, Inc., Black Hills Energy, and the University of Wyoming. The FPO Pilot Project would be located at the existing Gillette Energy Complex on lands owned by a Black Hills Energy subsidiary, the Wyodak Resources Development Corporation (WRDC). This site is approximately 5 miles east of the city of Gillette, Wyoming (Figure 1).

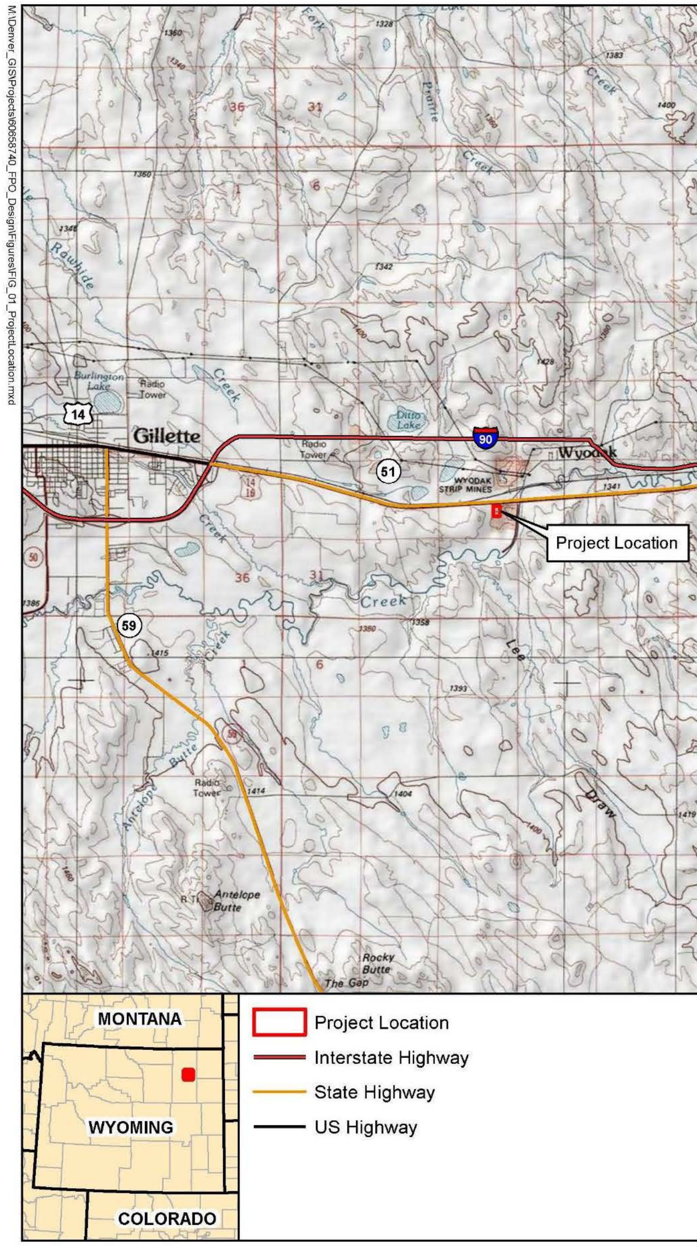
1.2 Background

In 2017, Congress directed the DOE's Office of Fossil Energy to develop large-scale pilot projects for potentially transformational coal technologies aimed at enabling improvements in coal-powered system performance, efficiency, and cost of electricity. These technologies include post-combustion carbon dioxide (CO_2) capture systems. The technologies are at various stages of development, but some are ready to proceed to large-scale pilot testing. Large-scale pilots are necessary to reduce the technical and financial risk associated with the adoption of a new technology in the marketplace.

To implement the Fossil Fuel Large-Scale Pilot program, DOE issued Funding Opportunity Announcement DE-FOA-0001788 on September 28, 2017, requesting proposals for large-scale pilot projects. DOE conducted a competitive merit review of the proposals and selected projects for the planning phase of project development in January 2018.

The Fossil Fuel Large-Scale Pilot program consists of three phases: feasibility, design, and construction/ operation. To select the optimal projects for implementation, the proposed projects undergo competitive down-selections at critical points in the project. In Phase I (feasibility), the objective was to demonstrate that the team is fully committed and able to implement Phases II and III, update the budget and schedule, and complete an environmental information volume. Phase I was completed for all selected projects in April 2019, and DOE competitively assessed each project location for technical merits and potential environmental impacts prior to selecting six projects to proceed to Phase II (design). During Phase II, the selected project participants will complete a Front-End Engineering Design study, secure funding for Phase III, and complete the NEPA process. These six projects, including the FPO Pilot Project, have proceeded through the multi-step selection process and are the only projects available to be selected for construction and operation. The other five projects will be analyzed for potential impacts separately and will not be discussed further in this EA.

The proposed FPO Pilot Project is in the final stage of research and development prior to commercial demonstration. The technical success of its integrated components has already been demonstrated in the small-scale pilot; the FPO Pilot Project was selected by DOE to proceed to Phase II, requiring completion of an assessment under NEPA.



FPO Pilot Project

Figure 1
Project Location

DOE assessed previous phases of the FPO large-scale pilot project, as required by NEPA implementing procedures and regulations. DOE issued a Categorical Exclusion (CX) to the project prior to work being conducted for Phase I and again prior to work being conducted for Phase II. Copies of CXs for the previous phases of the proposed project are included in Appendix A.

1.3 Purpose and Need

The purpose and need for DOE action is to advance the commercial readiness development of potentially transformative coal technologies that can improve system performance, efficiency, and the cost of electricity.

Congress directed DOE to complete pilots of this size to enable step-change improvements in coal-powered system performance, efficiency, and cost of electricity. A large-scale pilot is the final step in the research and development process and would demonstrate the scalability and commercial potential of FPO technology using domestically produced coal. This would mitigate the risks associated with adopting this technology at full scale, creating a pathway for commercial deployment in the United States. SwRI proposed the Gillette Energy Complex as the site for this project because it is a preexisting facility with the space and coal type needed to complete the project.

This EA will analyze the potential environmental impacts of the FPO Pilot Project, focusing on those that are most significant and probable.

1.4 Regulatory Requirements and Permits Needed

1.4.1 National Environmental Policy Act and Related Procedures

DOE prepared this EA in accordance with NEPA, as amended (42 United States Code [U.S.C.] 4321), the President's Council on Environmental Quality (CEQ) regulations for implementing NEPA (40 Code of Federal Regulations [CFR] 1500-1508), and DOE's implementing procedures for compliance with NEPA (10 CFR 1021). This statute and the implementing regulations require that DOE, as a federal agency:

- Assess the environmental impacts of its proposed action;
- Identify any adverse environmental effects that cannot be avoided, should the proposed action be implemented;
- Propose mitigation measure for adverse environmental effects, if appropriate;
- Evaluate alternatives to the proposed action, including a no action alternative; and
- Describe the cumulative impacts of the proposed action together with other past, present, and reasonably foreseeable future actions.

These provisions must be addressed before a final decision is made to proceed with any proposed federal action that has the potential to cause impacts to the natural or human environment, including providing federal funding to a project. This EA is intended to meet DOE's regulatory requirements under NEPA and provide DOE with the information needed to make an informed decision about providing financial assistance. In accordance with the above-listed regulations, this EA allows for public input into the federal decision-making process; provides federal decision-makers with an understanding of potential environmental effects of their decisions; and documents the NEPA process.

1.4.2 Federal Laws, Regulations, and Executive Orders

The following federal laws, regulations, and Executive Orders (EOs) were also considered in the evaluation of the FPO Pilot Project.

- Clean Air Act (CAA)
- Clean Water Act
- Protection of Wetlands (EO 11990)
- Floodplain Management (EO 11988)
- Endangered Species Act (ESA)
- Migratory Bird Treaty Act (MBTA)
- Bald and Golden Eagle Protection Act (BGEPA)
- The Noise Control Act of 1972, as amended
- Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (EO 12898)
- Pollution Prevention Act of 1990
- Resource Conservation and Recovery Act
- Comprehensive Environmental Response, Compensation, and Liability Act
- Toxic Substances Control Act
- Occupational Safety and Health Act

1.4.3 State and Local Regulations and Requirements

To implement the proposed FPO Pilot Project, the following permits or licenses would likely be required from state and local agencies.

- New Source Review Construction Permit from the Wyoming Department of Environmental Quality (Wyoming DEQ) Air Quality Division for construction activities

- Minor Source Operation Permit from the Wyoming DEQ Air Quality Division for operations

- Wyoming Pollutant Discharge Elimination System (WYPDES) authorization of coverage under the Small Construction General Permit from the Wyoming DEQ Water Quality Division for construction activities

- Amendment of the WYPDES permit for the Gillette Energy Complex to allow use of the existing wastewater ponds for containment of the new wastewater streams

Project emissions are not expected to exceed prevention of significant deterioration (PSD) levels and would not require a PSD Permit.

1.5 Organization of EA

The DOE has prepared this EA in compliance with NEPA and other relevant federal and state laws and regulations. This EA discloses the direct, indirect, and cumulative environmental effects that would result from the proposed action and alternatives. The document is organized into four parts:

- Chapter 1: Introduction – This chapter includes information on the purpose of and need for the project, the agency's proposal for achieving that purpose and need, applicable laws and regulations, and other permits that may be required.

- Chapter 2: Proposed Action and Alternatives – This chapter provides a more detailed description of the agency's proposed action and evaluates the no action alternative. Alternatives considered by the applicant are also discussed in this chapter.

- Chapter 3: Affected Environment and Environment Consequences – This chapter contains a description of current resource conditions in the project area and the environmental effects of the proposed action and no action alternatives.

- Chapter 4: Consultation and Coordination – This chapter provides a detailed discussion of the consultation and coordination that has occurred for the EA. The chapter also includes a list of preparers for the EA.

- Chapter 5: Acronyms and Abbreviations – This chapter includes a listing of all acronyms and abbreviations used in the EA.

- Chapter 6: References – This chapter provides references for literature and data cited throughout the document.

- Appendices – The appendices provide information on previous NEPA actions, consultation efforts, and other information to support the analyses presented in the EA.

4. ANALYTICAL TECHNICAL RISK ASSESSMENT

The team completed a Technical Risk Assessment, authoring a Risk Analysis and Mitigation Plan. Table 6 details the preliminary assessment of the technical and programmatic risks and their mitigation.

Table 6. Risk Analysis and Mitigation Plan

FPO Phase II

FPO Pilot Plant Risk Register

December 11, 2020
Revision: 0

Item No.	Risk	Category	Potential Impact(s)	Probability (High-3, Medium-2, or Low-1)	Consequence (High-3, Medium-2, or Low-1)	Overall Risk (Column E x F)	Mitigating Measure(s)	Responsible Organization / Individual	Expected Completion Date
1	**Design**	Design							
1.1	New Technology	Design	Equipment does not function or perform as intended.	3	3	9	Engaged Subject Matter Expert(s) (SMEs). Allotted additional schedule time for troubleshooting and addressing issues that emerge. The level 3 engineering, procurement and construction schedule includes 6 months of float to allow for unanticipated delays.	ITEA	Complete
1.2	Scale up to 50MWth	Design	Equipment does not function or perform as intended.	2	2	4	Both ITEA and UW have completed CFD scale up modeling to confirm no adverse effects. UW results were comparable to the results from a ITEA funded study at the Polytecnico di Bari.	UW	Complete
1.3	Design interface issues between technology supplier (ITEA) and BOP engineering (S&L)	Design	Missing scope or incompatibility of interfacing equipment / connections.	3	2	6	A detailed Division of Responsibility (DOR) has been prepared for the project and distributed to responsible organizations.	S&L	Complete
1.4	Improperly sized or specified equipment, piping, valves, etc.	Design	Potential for incompatible equipment that cannot accommodate process conditions.	1	2	2	The FPO process mass and energy flow diagram has been completed, as well as the project design criteria / system description document.	ITEA/SWRI/S&L	Complete
2	**Equipment**	Equipment							
2.1	Impact of equipment failure	Equipment	Equipment failures that may require long lead time parts to repair.	2	2	4	Request commissioning spare parts in equipment specifications as base scope.Request 2 year spare parts options from equipment suppliers and purchase the critical spares.	ITEA / S&L	Ongoing during procurement phase
2.2	Availability of coal milling and slurry preparation equipment that meets ITEA's particle size criteria.	Equipment	Potential plugging of coal slurry piping and injection lances, as well as poor FPO performance.	2	3	6	Collaborate with coal mill suppliers to obtain confidence that the bar mill, particle recycle system and paddle mixer can produce the required particles sizes.	ITEA	
2.3	Item No. 2.2 above may also affect slag particle sizes.	Equipment	Potential sluice system pipe plugging if there are oversized slag particles.	2	1	2	Slag sluice and quench pumps and piping have been sized to maintain sufficient fluid velocities to prevent settling out of solids in pipelines, and pipe lines have been sized with margin compared to the maximum anticipated slag particle sizes.	ITEA/S&L	Complete
2.4	Availability of fabricator for combustor and hot loop piping with shop installed refractory lining.	Equipment	Inability to have properly shop installed refractory.	1	3	3	ITEA has collaborated with the Combustor/loop fabricator and the refractory supplier such that the refractory will be installed in the Combustor fabricator's shop under controlled conditions, and under supervision of the refractory supplier to ensure quality. S&L has obtained quotes from domestic suppliers to fabricate combustor and loop piping as a back up plan. ITEA to collaborate with refractory vendor for field installed refractory.	ITEA	Complete
2.5	Flue gas ash particle quantities and size.	Equipment	Potential turboexpander pre-mature blade wear resulting in pre-mature equipment failure. Potential need for particulate filter for permitting.	1	2	2	SWRI provided GE the flue gas particle size and quantity distribution from ITEA past pilot testing and GE reviewed the data with the Turboexpander OEM, Baker Huges (BH). BH concluded that the particle sizes and quantities were not of concern for the pilot plant and that no special upstream particulate collection would be required. Similarly the quantities of particles from the previous pilot fall below the quantity that would require particulate control. In addition, the wet scrubber and condensation column will collet a substantial portion of particulate.	SWRI / GE	Complete
2.6	Use of a pressurized, high temperature Air Cooled Condenser and high pressure / temperature condensate pump.	Equipment	Domestic ACC suppliers do not supply high pressure / temperature ACC's.	1	1	1	The project has elected to use a more conventional atmospheric steam condenser and condensate pump with sub-cooling that are domestically available and will maintain sufficient NPSH for pumping.	S&L	Complete
2.7	Liquid oxygen equipment availability	Equipment	Insufficient source of oxygen.	2	3	6	Praxair has agreed to provide and install temporary rental liquid oxygen storage tanks and vaporizers, and provide the liquid oxygen. Praxair has provided a proposal for this service. S&L to continue to collaborate with Praxair for an acceptable rental agreement.	S&L	

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3	**Site Related**	Site							
3.1	Site access issues and constraints for shipping equipment to site.	Site	Potential for oversized equipment delivery issues.	1	1	1	The FPO Pilot Plant host site was changed from the University of Wyoming to the Wyodak coal mine and power plant area. This eliminates potential concerns with oversized loads. The project team has developed a 3D model of the project for purposes of finalizing the general arrangement with consideration of equipment installation/removal space and truck turning radii.	UW / SWRI / S&L	Complete
3.2	Ambient conditions	Site	Potential freezing of water lines and overheating of temperature sensitive equipment.	1	2	2	The site design ambient conditionshave been included in the project design criteria as well as the equipment procurement specifications. The closed cooling water system will use 50/50 water/glycol mixture to preclude freezing above ground water pipes. Outdoor fire protection and demin water pipelines will be routed underground below the frost line. Sensitive DCS controls equipment will be located in the air conditioned PDC.	S&L	Complete
3.3	Unavailability of water	Site	Potential added expense to truck in water if water is not readily available	1	1	1	S&L confirmed with Black Hills that there is an existing 16-inch underground public water main located along the south side of route 51 on the north side of the FPO site. There is a 6-inch underground fire water main and a 2-inch potable water line routed on site to the existing admin building immediately north of the planned FPO location. The costs of tie-ins and extensions of these systems to the FPO have been accounted for the FPO design and cost estimate.	S&L	Complete
3.4	Wastewater disposal	Site	Costly remote wastewater disposal	1	1	1	S&L confirmed with Black Hills that there is an existing disposal pit nearby that is owned / operated by Black Hills that can be used for wastewater disposal. The FPO design also includes a reclaimed water system that collects and reuses nearly all reusable process water.	S&L	Complete
3.5	Fuel gas availability	Site	Costly / long underground fuel gas supply line ROW, engineering, procurement and installation.	2	2	4	S&L confirmed with Black Hills Energy that the existing natural gas M&R station at Neil Simpson station operates at 600 psig. A 3-inch fuel gas pipeline can be routed from the existing M&R station to the new FPO location and has been included in the design and cost estimate along with a new M&R station at the FPO plant to control the pressure and flow for the FPO conditions.	S&L	Complete
3.6	Availability of electricity	Site	Costly power supply	2	1	2	The existing Black Hills Neil Simpson Station (NSS) medium voltage power system is 4.16kV and does not have sufficient spare circuit breakers or electrical buses to support the FPO pilot plant. In addition losses in a 4.16kV overhead line from NSS to the FPO site would be prohibitive. The design and cost estimate is based on obtaining power from the existing 69kV overhead line located along the south side of route 51 on the north side of the FPO site. This requires the addition of a small electrical substation. The associated high voltage circuit breaker, disconnect switches, step down transformer, conductors, FPO project cost estimate	S&L	Complete
3.7	Availability of coal supply	Site	The ITEA FPO process requires a coal size of 2-inch x 0-inch. This could potentially require additional milling equipment.	1	2	2	Local coal suppliers were contacted to confirm size can be made available. Bergener trucking can provide self unloading conveyor trucks to unload directly to the bucket elevator hopper.	SWRI / S&L	Complete

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3.8	Unknown undergrounds	Site	Discovery of unknown U/G utilities on site during FPO pilot plant construction that may add cost and delay construction.	2	2	4	Contract a surveying company to perform Ground Penetrating Radar (GPR) survey at the beginning of Phase 3 design.	S&L	At beginning of phase 3.
3.9	Site soil / geotechnical conditions	Site	Foundation pile lengths and types assumed in the project cost estimate may not be adequate/long enough and additional foundation costs may be incurred during project execution.	2	2	4	S&L used existing available geotechnical information for nearby locations that should be representative of the FPO site. At the beginning of Phase 3, the project will contract a geotechnical company to preform soil borings on the FPO pilot site to obtain necessary formal input for foundation design and to validate the cost estimate basis.	S&L	At beginning of phase 3.
4	**Personnel**	Personnel							
4.1	Availability of ITEA resources	Personnel	Insufficient ITEA staff to perform ITEA FPO technology detailed design and procurement scope of work per the DOR would result in schedule delays and threaten project completion.	3	3	9	ITEA to prepare advanced resource planning and verify qualified personnel are available and budgeted.	ITEA	Prior to phase 3
4.2	Availability of SWRI resources	Personnel	Insufficient SWRI staff to perform SWRI FPO overall management and commercial procurement scope for multiple equipment and service contracts would result in schedule delays and threaten project completion.	3	3	9	SWRI to hire commercial procurement staff for Phase 3 or request S&L to peform commercial procurement on behalf of SWRI and update the DOR to show S&L as responsible for commercial procrement.	SWRI	Prior to phase 4
4.3	Availability of S&L resources	Personnel	Insufficient S&L staff to perform S&L FPO BOP detailed design and techncial procurement, would restult in schedule delays and threaten project completion.	1	3	3	S&L has prepared a resource loaded detailed engineering and procurement schedule and has verified that qualified S&L staffing starting in mid 2021 is available. The team should use the remaining Phase 2 budget to continue development of the detailed design and to keep the project teamengaged in the project leading into initiation of Phase 3.	S&L	Complete
4.4	Project team members have not worked together or have limited experience working together	Personnel	Potential miscommunication / interpretations that may result in coordination errors.	2	3	6	Conduct regular project team coordination meetings during Phase 3 with all disciplines. Conduct regular technical discipline coordination meetings. Conduct regular procurement meetings. Conduct regular equipment supplier meetings after award of each equipment specification.	All	Conduct meetings throughout phase 3
5	**Suppliers / Contractors**	Suppliers / Contractors							
5.1	Availability of equipment and material suppliers to meet scope and schedule (market conditions)	Suppliers / Contractors	Potential schedule and cost impacts.	1	2	2	Equipment and material demands are currently low and are expected to continue to be low over the next two years. This is a low risk aspect and there are minimal actions that can be taken to lessen this risk other than sourcing equipment and materials to qualified suppliers as S&Land ITEA normally do.	NA	Complete

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5.2	Labor pool availability / ability of installation contractor to attract qualified labor	Suppliers / Contractors	Potential schedule and cost impacts.	1	2	2	Labor demands are currently low and are expected to continue to be low over the next two years. Upon authorization of Phase 3, SWRI and S&L will conduct a pre-qualification survey by sending pre-qual questions to general work contractors and reviewing the GWC responses. Topics will include GWC interest in the project, safety records, GWC recent commercial history such as pending/recent litigation, default on contracts, lawsuits, liens, and claims, financial status, current and booked workload, sizes of past projects, similarity of past experience to the experience required for the FPO project, etc. Also what aspects of the work the contractors would self perform vs. subcontract, number of permanent employees, and familiarity with the local labor pool.	SWRI / S&L	At beginning of phase 3.
6	**Schedule**	Schedule							
6.1	Availability of equipment, materials with long lead items.	Schedule	Potential schedule and cost impacts.	1	2	2	S&L has prepared a level 3 detailed engineering and procurement schedule that includes delivery lead times for equipment and materials. The schedule is developed with 6 months of float to provide contingency for delays.	S&L	Complete
7	**Budget**	Budget							
7.1	Budget confidence level is low or unknown	Budget	Potential Cost Overrun	2	2	4	The FPO pilot project cost estimate has been prepared as an AACE Class 3 estimate with -20%/+30% accuracy. S&L solicted competitive bids with detaied specifications for the more expensive BOP equipment, and obtained quotes and used the S&L cost database for medium to lower cost equipment. ITEA obtained quotes from European suppliers for the ITEA supplied equipment and S&L validated the higher cost equipment such as the combustor, quenchers, loop and OTSG estimate by soliciting similar quotes from domestic suppliers. S&L also estimated commidity quantities based on a reasonably mature project specific 3D model, general arrangement drawings, process flow diagrams, P&IDs and electrical single line diagrams.	ITEA / S&L	Complete
7.2	Volatility in equipment and material costs	Budget	Potential Cost Overrun	1	2	2	Include contingency in project budget. Based on the recent economic contraction due to COVID19, forecast for inflation over the next two years, when much of the equipment and material would be purchased, if foreast to be between 1-2%. S&L has accounted for inflation/escalation in the cost estimate.	S&L	Complete
8	**Regulatory Issues / Interfaces**	Regulatory Issues / Interfaces							
8.1	Authorities having jurisdiction may not approve project or may require changes to facilitate approval	Regulatory Issues / Interfaces	Potential schedule and cost impacts.	2	2	4	Meeting was held with WYDEG prior to submittal of air the permit application. WYDEQ review air permit application completeness by 12/25/20 WYDEQ approve/disapprove air permit application by 2/23/20 WYDEQ air permit 30 day public comment period end 3/26/20	S&L	12/25/2020
8.2	State and local regulations and ordinances may not be clearly defined	Regulatory Issues / Interfaces	Potential schedule and cost impacts.	2	2	4	The project team developed a permit matrix for the project based on the UW site location and is in process of revising for the Wyodak site location.	S&L	12/31/2020
8.3	Regulatory agency approval may not be obtained or may be delayed	Regulatory Issues / Interfaces	Potential schedule and cost impacts.	2	2	4	Meet with regulatory agencies / authorities having jurisdiction to discuss applicable project aspects prior to initiation and procurement of those aspects.	SWRI / S&L	

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8.4	Mercury emissions	Regulatory Issues / Interfaces	Potential schedule and cost impacts if WYDEQ requires emission control equipment for mercury.	2	2	4	Air permit application was submitted to WYDEQ on 11/25/20 and WYDEQ scheduled to complete review by 2/23/20. If controls are requird, an activated carbon injection system could be installed.	SWRI / S&L	2/23/2020
9	**Social / Political**	Social / Political							
9.1	Potential interveners	Social / Political	Potential schedule and cost impacts.	2	2	4	SWRI / UW can conduct public relation campaign and local town hall meetings with the public to inform that the project is a pilot demonstration with the goal of reducing carbon emissions.	SWRI / UW	
10	**Safety**	Safety							
10.1	Slips, trips, and falls	Safety	Potential personnel injury.	1	2	2	The FPO pilot plant will be designed in accordance with the applicable OSHA regulations, including walkways, stairways, ladders, platforms and galleries.	S&L	Ongoing thru detailed design phase
10.2	Falls into trenches	Safety	Potential personnel injury.	1	2	2	The FPO pilot plant will be designed in accordance with the applicable OSHA regulations. Concrete sumps and trenches will have covers. Outdoor trench excavation during construction will be roped off and follow OSHA excavation side slope guidelines.	S&L	Ongoing thru detailed design phase
10.3	Dust in eyes	Safety	Potential personnel injury.	1	2	2	The FPO pilot plant will specify construction dust control measures in the general work contract specification. Plant personnel will be required to wear safety glasses for eye protection.	S&L	Complete
10.4	Potential head impact	Safety	Potential personnel injury.	1	2	2	The FPO pilot plant will be designed in accordance with the applicable OSHA regulations for head clearance in walkways. S&L will use the 3D model to review / eliminate potential head clearance issues.	S&L	Ongoing thru detailed design phase
10.5	Exposure to noise	Safety	Potential personnel injury.	1	2	2	The project design criteria specifies allowable noise levels that will be included in equipment procurement specifications. The project design critiera also requires that in cases where specified limits cannot be met, signage will be posted requiring personnel to wear hearing protection in those designated areas.	S&L	Complete
10.6	Chemical exposure	Safety	Potential personnel injury.	1	2	2	Amine in 5% solution is the only chemical planned for use at the FPO pilot plant. It will be stored in small chemical totes and will be pumped into the condensate with a small metering pump. The FPO pilot plant design criteria requires that a safety eyewash / shower be provided nearby the tote and pump.	S&L	Complete
10.7	Burns	Safety	Potential personnel injury.	1	2	2	The FPO project design criteria requires insulation to protect from hot surfaces and insulation/jacketing will meet OSHA surface temperature requirements in accessible areas. Insulation will be specified in project equipment and installation specifications	S&L	Complete
10.8	Exposure to electrical hazards	Safety	Potential personnel injury.	1	2	2	Electrical equipment, raceway and protective relaying will be designed in accordance with applicable NEMA/IEEE standards. Electrical swithgear will be posted with arc flash energy levels which will dictate the level of PPE required.	S&L	Complete
10.9	Suffocation from lack of oxygen	Safety	Potential personnel injury.	1	3	3	FPO project construction and O&M will follow confined space rules. In addition CO instrumentation will be located in the combustor building to monitor conditions.	S&L	Complete

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10.1	Explosions from flammable gas	Safety	Potential personnel injury.	1	3	3	FPO Pilot Plant design criteria requires areas and electrical equipment to be classified in accordance with NFPA / NEC 70 Article 500 and NFPA 497 to reduce or eliminate the risk of electrical equipment igniting a potentially explosive atmosphere.	S&L	Complete
11	**Other**	Other							
11.1	COVID-19 pandemic	Other	Potential for delays in equipment fabrication and project construction schedules.	2	2	4	Incorporate commercial terms in all contracts such that contractors are responsible for economic loss due to COVID and not Owner. Establish COVID testing guidelines and rules for site workers to reduce the potential for infecting construction personnel.	S&L	Ongoing thru procurement phase
11.2	Labor strikes	Other	Potential delays and schedule impact.	1	2	2	Collaborate with successful general work contractor to offer incentives to labor that are commensurate with those being offered in the area.	S&L	Ongoing thru procurement phase
11.3	Euro vs. US dollar conversion rate	Other	Potential cost impact if US dollar looses value with respect to Euro	2	2	4	The cost estimate includes an 18% conversion factor for equipment will be supplied from Italy. An additional percentage can be inluded ot provide margin to account for potential higher conversion percentage.	SWRI	
11.4	FPO pilot plant decommissioning costs	Other	The cost of demolition / decommissioning may become an issue.	3	3	9	DOE February 2020 guidance stated that decommissioning costs are not part of allowable project costs. After further review, DOE determined that decommissioning costs will be an allowable cost for Phase III of the project.	UW	

5. DATA COLLECTION, PROCESSING AND ANALYSIS PLAN

A report detailing the preliminary data collection and analysis approach was provided. It is partially reproduced in this section.

5.1 FIGURES OF MERIT

The goal of the pilot testing is to collect field performance data to better judge the adequacy of the design and performance objectives of the FPO process through the information obtained on emissions, energy (via composition, flows, pressure, and temperature measurements), effectiveness, efficiencies, and operations during the specified testing periods.

A process-monitoring program will be designed to characterize the pilot plant operation using field measurements and develop data for the calculation of the figures of merit (FOM) for the FPO process. These measured data and the resulting FOM will support follow-on engineering and economic assessment for potential implementation of the process at commercial demonstration scale and provide documented evidence for end-users assessing the progress and validity of the technology. Typically, FOM are evaluated from data taken during the steady-state operation of the pilot after it has undergone full commissioning and has been optimized. The duration of time required to measure FOM can be relatively short, although multiple sets of measurements are preferred.

The high-level streams from which measurements would be taken to calculate FOM for a complete FPO pilot are shown in Figure 18. A preliminary look at where actual measurements would be made and what would be measured in a complete FPO pilot is shown in Figure 19.

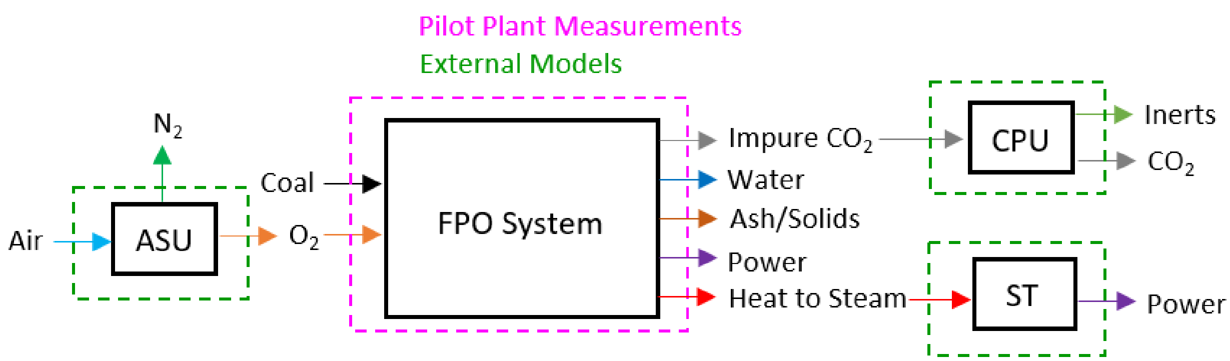

Figure 18. Streams Where Pilot Plant Measurements Would be Taken

The FOM were developed based on engineering judgment from the team and balancing the desires of the vendor with perceived needs from the industry. The FOM presented are at a high level and will be further specified once the pilot specifics have been set. In particular, the full equational form and exact measurements used to calculate the FOM are not presented now but can be readily developed later when the pilot design is being finalized.

Note that the FOM presented here pertain to a pilot that would have the full process installed, especially including the steam power island and CO_2 purification unit (CPU).

The FOM are given in Table 1. The 21 total FOM are grouped into categories with the FOM name and a high-level description of how it is calculated is provided.

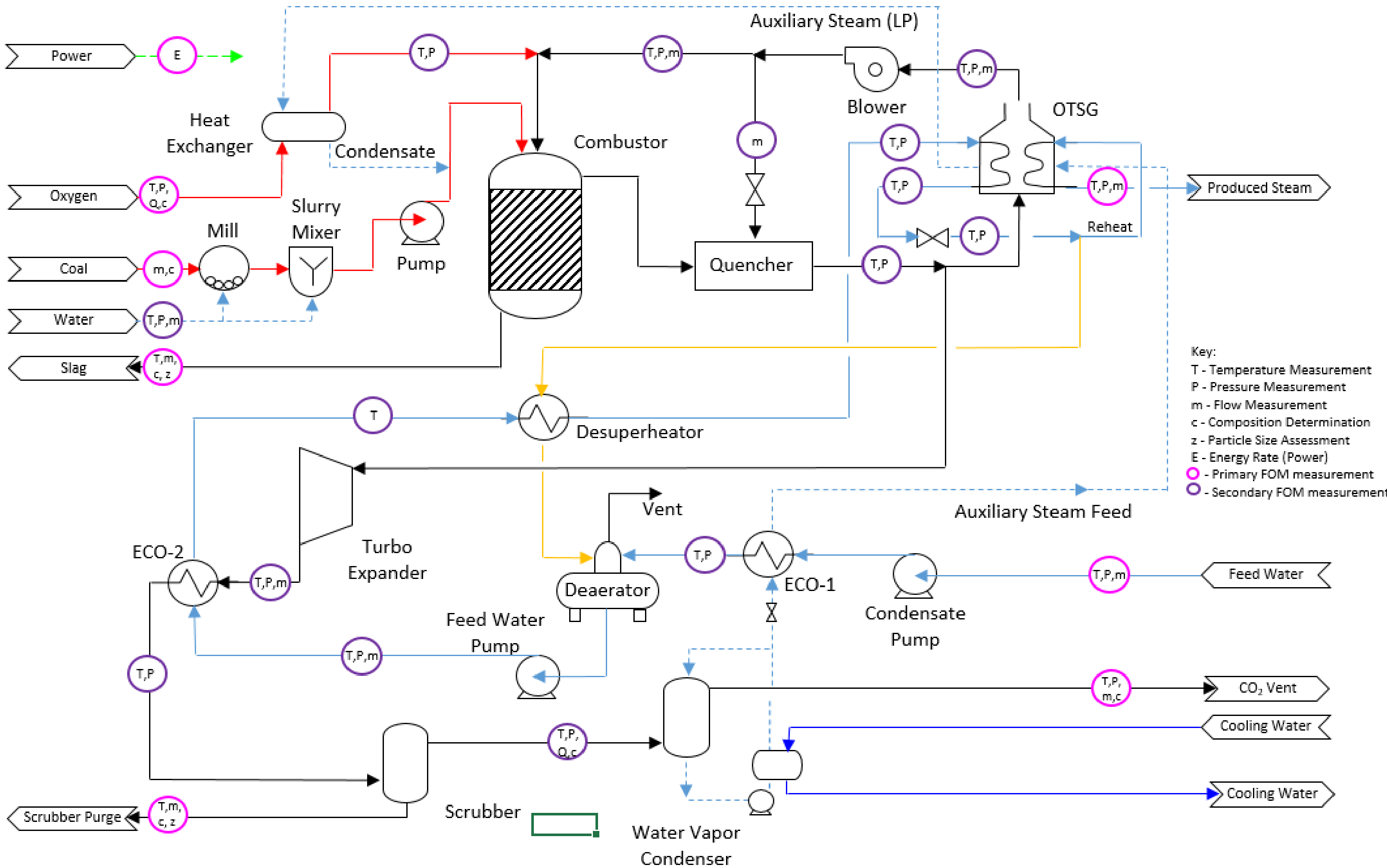

Figure 19. Preliminary Measurement Locations and Types for the FPO Pilot

Table 1. Figures of Merit

Environmental Performance	
CO_2 Capture, %	% of Carbon in CO_2 Stream vs. Carbon-in-Fuel (based on measurements) **Note:** Dry CO_2 stream composition (O_2 concentration + inerts)
Emissions	CO, mercury, NOx, particulate matter, and SOx outlet concentrations
Slag Properties	Carbon content, composition, density, and reachability
Solids Production	Slag, fly ash, and scrubber solids weight measurement
Water Production	Quantity Produced - Recycle for Auxiliary Steam Generation and Slurry Use
Heat Exchange	
Combustor Efficiency, %	Feed stream energy [oxygen (m, H) + coal (m, H, GCV)] - Heat to Steam **Note:** Enthalpy flow of product gas stream is excluded
Cooler Effectiveness, %	Circulation ratio, total dissolved solids, and cooling effectiveness (cooling water temperature vs. gas outlet temperature)
Feedwater Heat Recovery	OTSG Feedwater m x h (T, P) - Condensate Feedwater m x h (T, P) **Note:** Heat to Steam and Feedwater Recovery converted to electrical output and added to expander output for the total gross generation
Heat to Steam	Main Steam m x h (T, P) - OTSG Feedwater m x h (T, P)
OTSG Effectiveness, %	
Oxygen Heater Effectiveness, %	Oxygen outlet temperature vs. steam supply temperature
Quencher Controllability	Mixing efficiency (maximum temperature / average temperature) and turndown performance
Mills	
Mill Effectiveness	Inspection for prevention of significant deterioration during an outage
System Performance	
Auxiliary Power, MWe	MW use of blowers, mills, pumps, cooling systems, etc.
Maximum Net Power, MWe	
Minimum Stable Load, MWth	
Net Efficiency, % Lower Heating Value	
Plant Operations	Measured total operating hours and availability, startup time, ramp rates, stable load range, and longest continuous operation
Turbo Expander	
Efficiency, %	(Inlet Gas Enthalpy - Outlet Gas Enthalpy) / (Inlet Gas Enthalpy - Isentropic Expansion Enthalpy) **Note:** Turbo expander output to be monitored for total output evaluation.
Operability	Measured startup time, load range, efficiency at reduced load, and noise
Power, MWe	

The required FOM were combined with the instrumentation needed for plant control to generate a comprehensive instrumentation list, as shown in Table 2. The list describes the type of measurement, quantity, plant area, and a description of its location.

Table 2. Instrument List Quantity and Type

Item	Component	Amount	Cycle Area	Location Description
P1	Pressure	1	Boiler Island	Oxygen Outlet
T1	Temperature	1	Boiler Island	Oxygen Outlet
F1	Flow Rate	1	Boiler Island	Oxygen Outlet
F2	Flow Rate	1	Boiler Island	Quencher Bypass
F3	Flow Rate	1	Boiler Island	Coal Feed
	Particle Size	1	Boiler Island	Coal Line after Slurry
F4	Flow Rate	1	Boiler Island	Water to Mill and Slurry
P2	Pressure	1	Boiler Island	Water to Mill and Slurry
T2	Temperature	1	Boiler Island	Water to Mill and Slurry
	Composition	1	Boiler Island	Coal Feed
F5	Flow Rate	1	Boiler Island	Coal Feed after Pump
F6	Flow Rate	1	Boiler Island	Recycle to Boiler
P3	Pressure	1	Boiler Island	Recycle to Boiler
P4	Pressure	1	Boiler Island	Flue Gas to Turbo-expander
T3	Temperature	1	Boiler Island	Flue Gas to Turbo-expander
F7	Flow Rate	1	Boiler Island	Flue Gas to Turbo-expander
F8	Flow Rate	1	Boiler Island	Recycle to Turbo-expander Bypass
T4	Temperature	1	Boiler Island	Recycle to Turbo-expander Bypass
F9	Flow Rate	1	Boiler Island	Service Steam Injection Lance
T5	Temperature	12	Boiler Island	Once Through Steam Generator
T6	Temperature	1	Boiler Island	Quencher Fumes to OTSG
P5	Pressure	1	Boiler Island	OTSG Recycle
T7	Temperature	1	Boiler Island	OTSG Recycle
P6	Pressure	1	Boiler Island	OTSG Outlet to HP Turbine
T8	Temperature	1	Boiler Island	OTSG Outlet to HP Turbine
F10	Flow Rate	1	Boiler Island	Pre-heated Water to OTSG
P7	Pressure	1	Power Island	OTSG Outlet to Service Steam
T9	Temperature	1	Power Island	OTSG Outlet to Service Steam
P8	Pressure	1	Power Island	Preheated Feed Water after Deaerator
P9	Pressure	1	Power Island	Turbo-expander to ECO1
T10	Temperature	1	Power Island	Turbo-expander to ECO1
T11	Temperature	1	Power Island	Preheating Water to ECO1 Inlet
T12	Temperature	1	Power Island	ECO1 Water Outlet
T13	Temperature	1	Power Island	Vapor Outlet of Scrubber
P10	Pressure	1	Power Island	Vapor Outlet of Scrubber
P11	Pressure	1	Power Island	Scrubber Solution Outlet
F11	Flow Rate	1	Power Island	Scrubber Solution Outlet
T14	Temperature	1	Power Island	Scrubber Cooler Solution Outlet
F12	Flow Rate	1	Boiler Island	Propane Line for Combustor Startup
P12	Pressure	1	Boiler Island	Coal Slurry Input to Combustor
P13	Pressure	1	Boiler Island	Recycle and O_2 Inlet to Combustor
T15	Temperature	1	Power Island	Fumes after Water Vapor Condenser
P14	Pressure	1	Power Island	Fumes after Water Vapor Condenser
F13	Flow Rate	1	Power Island	From Condensate Cooler to Cooler
T16	Temperature	1	Boiler Island	Oxygen before Recycle
	Particle Size	1	Boiler Island	Gas Leaving the Direct-contact Condenser
F14	Flow Rate	1	Power Island	Slag Out

Item	Component	Amount	Cycle Area	Location Description
T17	Temperature	1	Power Island	Slag Out
	Composition	1	Power Island	Slag Out
P13	Pressure	1	Boiler Island	Cool Fumes Blower Surge
T18	Temperature	1	Boiler Island	
T18	Temperature	1	Boiler Island	Flue Gas Quencher 1
T19	Temperature	1	Boiler Island	Flue Gas Quencher 2
F15	Flow Rate	1	Boiler Island	Flue Gas Quencher 1
F16	Flow Rate	1	Boiler Island	Flue Gas Quencher 2
T20	Temperature	1	Power Island	
T21	Temperature	1	Power Island	
P14	Pressure	1	Power Island	
P15	Pressure	1	Power Island	
F17	Flow Rate	1	Boiler Island	Line between CO5 and CO19
P16	Pressure	1	Power Island	Deaerator Steam Feed
F17	Flow Rate	1	Power Island	Deaerator Vent

5.2 PHASE III CONTROL AND OPERATIONS PHILOSOPHY

The preliminary control and operations philosophy were provided in the form of a report. It is partially reproduced in this section.

5.2.1 FUEL ADMISSION CONTROL

FPO uses a coal slurry to inject fuel into the combustion reactor. The slurry preparation system is controlled to minimize water content in the slurry while maintaining the 'pumpability' of the slurry into the reactor. The water content is continuously reduced while monitoring the pump outlet pressure. When a sharp increase from the normal delivery pressure curve value is detected, this 'viscosity ramp' marks the point at which further water reduction is not recommended. The water injection system will then increase until the pump outlet pressure decays back to the expected value. During the transient conditions of the startup process, the system will allow a small excess of water to account for the variation in fuel flow rate.

5.2.2 COMBUSTION CONTROL

Unlike traditional pulverized coal combustion control strategies, the FPO system does not utilize fuel admission as the primary driver for heat input. The FPO system controls the oxygen injection by manipulating the thermal input. This is because of the flue gas recycle (FGR), which is required to moderate temperatures, the combustor reactor configuration, and the relatively slow control response possible with direct fuel control. Fuel admission is also controlled as a secondary response loop. Variation in the fuel heat content, slurry moisture content, rheological characteristics, and overall injection rate can result in rapid changes in the flue gas composition. Fast-acting oxygen control is therefore needed.

5.2.3 REACTOR TEMPERATURE CONTROL

The primary objective of the reactor temperature control is to maintain the combustor flue gas outlet temperature within desired limits (specified by the materials of construction of the downstream pressure parts and insulation arrangements). The action used to achieve this objective is to control the flow rate of the flue gas inlet stream that is fed to the reactor vessel along with oxygen to form the flue gas. The control signal is based on refractory skin sensors (as conventional temperature measurements, e.g., from thermocouples, do not respond fast enough to facilitate sufficient control of the gas temperature). These skin sensors are in three sections (with a maximum continuous linear length of 1.2 m) at the top section (1st Zone), the middle section (2nd Zone), and the bottom section (3rd Zone) of the combustion reactor – all sections are measured in duplicate for redundancy.

5.2.4 FLUE GAS RECYCLE INLET FLOW CONTROL

To enable the FPO reactor to operate correctly, the inlet velocity of the FGR steam into the reactor needs to be maintained at a constant velocity to ensure a consistent firing cone depth is maintained through a broad firing range (as wide as 5–100%). The ratio of oxygen inflow to different ports in the reactor inlet is used to stage the combustion reaction and thus controls thermal NOx formation. A further secondary imperative is to modulate the reactor mid-point temperature to the mean temperature – this is adjusted by controlling the degree of staging the FGR into the reactor.

5.2.5 MOLTEN SLAG DISCHARGE CONTROL

The FPO reactor operates at very high temperatures, and most of the coal ash introduced into the reactor is maintained in molten form and accumulates on the refractory of the reactor walls. This molten slag is drawn down by gravity to the bottom of the reactor vessel where it is discharged. As the FPO process is pressurized, the slag removal system is a pre-assembled module that is installed at the bottom of the combustor with a flanged connection.

5.2.6 ONCE-THROUGH STEAM GENERATOR CONTROL

The design principles for the OTSG are taken from air-fired supercritical heat recovery steam generator (HRSG) designs. These units typically require the flue gas entering the convective sections to be at a constant temperature and to achieve a consistent flow rate throughout the convective bank stages, ensuring a predictable temperature profile can be maintained across all operating loads. Throughout low-load operation and during startup, the flue gas outlet temperature needs to be maintained using economizer recycle (preheating the feedwater and reducing the overall flue gas temperature loss). This recycle control logic changes through the load range to ensure that the flue gas to water temperature difference is maintained, avoiding a temperature pinch.

Although this is a once-through system at full load, to maintain appropriate metal temperatures in the evaporation banks and to manage two-phase flow at reduced operating pressure, the system uses steam separator vessels at the outlet of the evaporator to capture liquid water and recycle it back to the evaporator inlet. The sliding-pressure operation ensures that the evaporation saturation temperature at reduced load is lower than at higher loads, thereby partially compensating for reduced outside heat transfer coefficient on the evaporator tube bank due to the reduced gas side mass flux.

5.2.7 FLUE GAS PRESSURIZED LOOP CONTROL

Because of the recycling nature of the FPO system, control actions at one location of the system can impact the control response systemwide. Consequently, the FPO system is held in balance in real-time by modeling the process and calculating the mass balance. When an upset in flow or temperature causes the tempering valve to move its position, an interaction occurs with all other control loops, causing undesirable fluctuations that may last long after the initial control has stabilized. The mass balancing equations avoid this by using a feed-forward approach to adjust all the other controllers such that the changes in real-time are anticipated, and hence, do not fluctuate. An example of this would be if a flow controller adjusts the damper opening.

5.2.8 TURBO-EXPANDER CONTROL

During the startup process, the generated flue gas is passed through the outlet valve and is vented to a safe location. Pressurization is induced by control from this valve, and the admission to the turbo-expander block is permitted when there is sufficient heating in the flue gas to ensure that condensation will be minimized when the turbo-expander begins preheating. The gas will pass through the economizers and the flue gas treatment systems before being vented. This will initially be carried out at atmospheric pressure until sufficient flow is established (and an appropriate pressure ratio across the turbo-expander) to facilitate pressurization of the gas processing modules.

5.2.9 FGD AND WATER CONDENSATION CONTROL

The FGD scrubber module operates near adiabatically; however, the temperature of the flue gas entering the scrubber is above the water vapor saturation. Subsequently, there is evaporative cooling in the lower packing sections of the scrubber. The circulating stream is not actively cooled, and the water evaporated in the scrubber is lost to this system (as the higher moisture content in the flue gas). This water balance is restored by the addition of water recovered from the downstream condenser module, where this subcooled water is mixed with gypsum and the working solution before being fed to the scrubber top. The recirculating flowrate setpoint and solution composition vary depending on the sulfur dioxide (SO_2) and HCl load imposed from a given fuel being fired. Additionally, the required purge flow (removing reacted solution) also varies greatly with load and fuel composition (impacting the sulfur and chloride loads). The purge stream is cooled via a forced-air cooler module before being passed to the gypsum recovery system.

6. FACILITY SAFETY ASSESSMENT AND GUIDELINES

The facility hazards were identified, and a report discussing the preliminary methods for handling facility hazards was produced. A portion of the report addressing the hazardous areas of the facility and the appropriate governing codes is provided in this section.

6.1 GOVERNING CODES

Standards, specifications, manuals, codes, and other publications of nationally recognized organizations and associations are referenced in Table 3. References to these documents are to the latest issue date of each document, unless otherwise indicated, in this design criteria or the Adopted Building Code together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of the FPO Pilot Plant design and construction as applicable. Methods, equipment, and materials specified in this design criteria will comply with the specified and applicable portions of the referenced documents, in addition to federal, state, or local codes having jurisdiction. Acronyms will be used throughout the text of this design criteria to refer to the applicable organizations.

Table 3. Industry Codes and Standards

AASHTO - American Association of State Highway and Transportation Officials
ABMA - American Boiler Manufacturers Association
ABMA - Anti-friction Bearing Manufacturers Association
ACI - American Concrete Institute
ACI 318 - Building Code Requirements for Structural Concrete and Commentary as stipulated by International Building Code
ACI 543R - 2000 - Recommendation for the Design, Manufacture and Installation of Concrete Piles
AISC - American Institute of Steel Construction
ANSI - American National Standards Institute
API - American Petroleum Institute
API STD-620 - Design and Construction of Large Welded, Low-pressure Storage Tanks
Applicable Air Movement and Controls Association (AMCA) Standards
Applicable American Gear Manufacturer Association (AGMA) Standards
Applicable Code of Federal Regulations (CFR)
Applicable Conveyor Equipment Manufacturer's Association Standards
ASCE - American Society of Civil Engineers
ASCE 20-96 - Standard Guidelines for the Design and Installation of Pile Foundations
ASCE 7 - Minimum Design Loads for Buildings and Other Structures
ASME B31.1 - Power Piping Code
ASTM - ASTM International: By Standard Specification, Test Method, Practice or Guide Specified
AWS - American Welding Society
AWS A2.4 - Standard Symbols for Welding, Brazing and Nondestructive Examination

AWS A3.0 - Welding Terms and Definitions
AWS A5.1 to A5.31 - Specification for Welding Electrodes
AWS A6.1 - Recommended Safe Practice for Gas-Shielded Arc-Welding
AWS D1.1 - Structural Welding Code - Steel
AWS D1.2 - Structural Welding Code - Aluminum
AWS D1.3 - Structural Welding Code - Sheet Steel
AWS D14 - Rotating Equipment
AWWA - American Water Works Association
AWWA D100 - Welded Steel Tanks for Water Storage
BVPC Section I - Rules for Construction of Power Boilers
BVPC Section VIII - Pressure Vessels, Division 1
BVPC Section VIII - Pressure Vessels, Division 2, Alternative Rules
CRSI - Concrete Reinforcing Steel Institute, Manual of Standard Practice
EPA Standard Methods for Emissions Testing
Factory Mutual Loss Prevention Data Sheets
Heat Exchange Institute Standard for Power Plant Heat Exchangers
IEEE - Institute of Electrical and Electronics Engineers
International Building Code (IBC), 2018 Edition
International Energy Conservation Code, 2018 Edition
International Fire Code, 2018 Edition
International Fuel Gas Code, 2018 Edition
International Mechanical Code, 2018 Edition
International Plumbing Code, 2018 Edition
International Residential Code, 2018 Edition
ISA - Instrumentation Society of America
Manual of Steel Construction, Allowable Stress Design (ASD) - 13th Edition
MBMA - Metal Building Manufacturer's Association, Metal Building Systems Manual
NEC - National Electric Code
NEMA - National Electrical Manufacturers Association
NFPA - National Fire Protection Association
NFPA 101 - Life Safety Code
NFPA 15 - Water Spray Fixed Systems
NFPA 30 - Flammable and Combustible Liquids Code
NFPA 85 - Boiler and Combustion Systems Hazards Code
NFPA 850 - Recommended Practice of Fire Protection for Electric Generating Plants
NIST - National Institute of Standards & Technology
OSHA - Occupational Safety & Health Administration 29 CFR Part 1910 Occupational Safety & Health Standards
RCSC - Research Council on Structural Connections - Specification for Structural Joints Using ASTM A 325 or A 490 Bolts, Endorsed by the American Institute of Steel Construction, Inc.

Seismic Provisions for Structural Steel Buildings, 1997 Edition, including Supplement No. 1 dated 1999 and Supplement No. 2 dated 2000 as stipulated by International Building Code
SSPC - Society for Protective Coatings: By Practice or Guide Specified
UL - Underwriters Laboratories
WYDOT - Wyoming Department of Transportation
Wyoming Building Code

Design specifications and construction of the Project will also be in accordance with all applicable local, state, and federal regulations, including but not limited to those listed in Table 4.

Table 4. Federal, State, and Local Regulations

Americans with Disabilities Act
Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Clean Air Act and Amendments
Environmental Protection Agency Regulations
Federal Aviation Administration Regulations
Federal Energy Regulatory Commission Regulations
Federal Power Act
Noise Control Act of 1972
Occupational Safety and Health Act
Occupational Safety and Health Standards
Resource Conservation and Recovery Act (RCRA)
Safe Drinking Water Act
Solid Waste Disposal Act
Superfund Amendments and Reauthorization Act of 1988
Toxic Substances Control Act

6.2 NOISE CRITERIA

The equipment for the FPO Pilot Plant will be specified such that near-field noise emissions for each equipment component furnished will not exceed a spatially-averaged free-field A-weighted sound pressure level of 85 dBA measured along with the equipment envelope at a height of 5 feet above floor/ground level and any personnel platform during normal operation. The equipment envelope is defined as the perimeter line that encompasses the equipment package 3 feet horizontally from the equipment face. The near-field noise emissions include the contribution of all noise associated with the equipment component.

During off-normal and intermittent operation such as startup, shutdown, and upset conditions, the equipment sound pressure level will be specified not to exceed a maximum of 110 dBA at all locations along with the equipment envelope, including platform areas, that are normally accessible by personnel. Personnel Protective Equipment (PPE) and OSHA warning signs for hearing protection requirements will be posted for areas with the equipment.

Far-field noise will not be an issue because the FPO Pilot Plant equipment is similar in type and smaller in size than comparable equipment located at the nearby Neil Simpson, Wyodak, and

Wygen power plants. In addition, the Wyodak Resources Development Corporation property where the FPO Pilot Plant will be located consists of 5,750 acres, and the FPO Pilot Plant will be located approximately one mile from the nearest residence.

6.3 ELECTRICAL HAZARDOUS AREA CLASSIFICATION

The FPO Pilot Plant areas and electrical equipment will be classified in accordance with NFPA / NEC 70 Article 500 and NFPA 497 to reduce or eliminate the risk of electrical equipment igniting a potentially explosive atmosphere within a room or area. The following subsections contain brief descriptions of plant areas with flammable gases and flammable/combustible liquids, solids, and dusts. Each area is evaluated for potential hazards relative to the electrical classification.

A classification for areas containing combustible liquids is appropriate if the process or equipment surface temperatures are above the ignition temperature of the expected hazard, or if electrical equipment within the area is considered a potential ignition source. Most liquid fuels have ignition temperatures above equipment surface temperatures, and classification is not typically appropriate based on the presence of material alone.

The decision to classify an area is based on the probability that flammable gases, vapors, or dust may be present. Possible sources of release include vents, flanges, valves, drains, tanks, pumps, compressors, and conveyors. The criteria considered in the classification of an area are:

- Combustible material
- Vapor density of the material
- Temperature of the material
- Process or storage pressure
- Size of release (flow rate and storage capacity)
- Ventilation

NFPA 497 Table 5.7.4 provides a guideline to quantify relative magnitudes of process equipment as an aid to determine classification dimensions. The guideline categorizes the process in accordance to system size, pressure, and flow rate. Table 5 reproduces NFPA 497 Table 5.7.4.

Table 5. Relative Magnitudes of Equipment that Handle Combustible Materials

Process Equipment	Units	Small (Low)	Moderate	Large (High)
Size	Gallons	< 5,000	5,000–25,000	> 25,000
Pressure	Psig	< 100	100–500	> 500
Flow Rate	Gpm	< 100	100–500	> 500

Diagrams in standards NFPA 497, NFPA 30A, and API RP 500 illustrate how typical sources of combustible material should be classified and the recommended extent of various classifications. NFPA 497 diagrams refer to NFPA Table 5.7.4. The diagrams aid in developing an electrical classification of operating units, process plants, and buildings. NFPA 497 refers to API RP 500 as the stricter guideline and suggests continuous processes should follow API RP 500. Where applicable, the more conservative radiuses are employed until a specific system can be evaluated from a supplier.

System design is also considered for hazardous classifications. The system is evaluated for normal and abnormal releases according to vent, flange, valve, and enclosure configuration. Evaluated systems (e.g., natural gas) are typically within welded and sealed piping systems, and the risk of leaks is reduced. Hazard classifications will take these mitigation measures into consideration.

6.4 COAL HANDLING AREA CLASSIFICATION

The coal unloading and handling system consists of an outdoor bucket elevator, storage silo, dust collector, weigh feeders, and conveyors. Coal handling and storage systems present two hazards: coal dust and methane gas. Coal that is conveyed, transferred, and milled results in the presence of coal dust in coal handling areas that must be removed. The presence of coal dust is a serious spontaneous combustion and explosion hazard. Coal dust in enclosed areas warrants Class II Division 1 electrical classification. The coal handling and preparation equipment areas for the FPO Pilot Plant will be classified Class II Division 1. Electrical equipment and devices will be rated Class II, Division 1, Explosion-Proof Group F, as defined in NEC Article 500 (NFPA 70) and will be suitable for washdown.

Methane gas is a byproduct of material decomposition from anaerobic bacteria present in the coal. Methane is an explosive gas. In outdoor areas and areas that are adequately ventilated, methane will not be present at levels that warrant electrical classification. However, the FPO Pilot Plant coal silo presents an enclosed area where methane gas could potentially build up. The coal silo will be located outdoors and will be equipped with methane detection, dust collection, and a CO_2 inerting system. The coal silo will also be equipped with an explosion panel.

6.5 FUEL GAS AREA CLASSIFICATION

The fuel gas system consists of an outdoor Metering and Regulating (M&R) station and downstream piping to the combustor injection sets, all of which will be of mostly welded construction. The fuel gas M&R station area will be Class I, Division 2, Group D as fuel gas is not anticipated to be present in the area and would be the result of an infrequent failure of seating or sealing surfaces, resulting in leakage. The Class I, Division 2, Group D area will extend a radius of 15 ft. from flanged and threaded connections and outlet vent, drain, and relief piping throughout the system.

6.6 OTHER AREA CLASSIFICATION CONSIDERATIONS

The indoor coal handling equipment will be enclosed in a separate room in the combustor enclosure to prevent the spread of coal dust to other areas. The indoor coal handling room will be maintained at a lower pressure than other areas of the combustor enclosure. An explosion panel will be included on an outdoor wall of the coal handling room. Ledges in the room will be provided with sloped surfaces to prevent accumulation of coal dust and wash down hose stations will be located in the room.

7. TEST PROGRAM AND SCHEDULE

The team defined the test program with associated fuel firing campaigns, generating a test schedule.

7.1 PILOT PLANT TEST CAMPAIGN

The test campaign will demonstrate FPO technology on a variety of solid and gaseous fuels, including natural gas, coal, and biomass. While this technology has been tested at smaller scales for over 30,000 hours cumulatively, the project will, for the first time, demonstrate the FPO core technology in conjunction with commercially-available energy recovery technology integrated at the 25 MWth scale with limited duration tests as high as 50 MWth. The major efforts of the commissioning and test campaign are listed below.

- **Cold Commissioning**
  - Process Check (P&ID Checkout)
  - Cold-process Circulation Check
  - Control-loop Calibration
  - Inventory Management System Check
- **Hot Commissioning**
  - Pre-startup Safety Review
  - Verify Hot Firing and Performance with Natural Gas
  - Verify Hot Firing and Performance with PRB Coal
  - Commissioning Reporting and Authorization of Test
- **Operate with Natural Gas (8 hrs on weekdays)**
  - 25 MWth Study 3 Oxygen Purities
  - 25 MWth Vary CO_2 Recycle Ratios
  - 25 MWth Vary Oxygen Feed Rates
  - Inspection & Maintenance_1 & Performance Report
- **Operate with Low Sulfur PRB Coal (8 hrs on weekdays)**
  - 50 MWth Low Sulfur PRB Test 1
  - 25 MWth Vary 3 coal sizes [Excess O_2 Fixed]
  - 25 MWth Vary Coal/Water Slurry [Ex O_2 Fixed]
  - 25 MWth Vary O_2 Purity/O_2 Feed rates at Opt coal size, slurry
  - 50 MWth Low Sulfur PRB Test 2
  - Inspection & Maintenance_2 & Performance Report
- **Operate with High BTU Kemmer Coal (8 hrs on weekdays)**
  - 25 MWth Vary Excess O_2. Use Opt Coal Size/Slurry Conc./O_2 Staging
  - Inspection & Maintenance_3 & Performance Report
- **Operate with Higher Sulfur PRB Coal and Biomass (8 hrs on weekdays)**
  - 50 MWth High Sulfur PRB/Biomass Test 1
  - 25 MWth Vary Excess O_2 and CO_2 Recycle Temp. Use Optimal Process Conditions
  - 50 MWth High Sulfur PRB/Biomass Test 2
  - Inspection & Maintenance_4 & Performance Report
- **Data Review, Analysis and Reporting**
- **Low Sulfur PRB Coal Demonstration Run (24/7 continuous running)**
  - 25 MWth Demonstration Run 24/7 Using PRB Coal at Optimal Process Conditions
  - Inspection & Maintenance_5 & Performance Report
- **Decommissioning**

Figure 20 provides the overall schedule for commissioning and testing.

7.2 PROJECTED SCHEDULE FOR THE PILOT TEST CAMPAIGN

Task Name	Duration	Start	Finish
Cold Commissioning	**21 days**	**Mon 11/4/24**	**Mon 12/2/24**
Process Check (P&ID Checkout)	7 days	Mon 11/4/24	Tue 11/12/24
Cold-process circulation check	5 days	Wed 11/13/24	Tue 11/19/24
Control-loop calibration	5 days	Wed 11/20/24	Tue 11/26/24
Inventory management system check	4 days	Wed 11/27/24	Mon 12/2/24
Hot Commissioning	**129 days**	**Tue 12/3/24**	**Fri 5/30/25**
Pre-startup safety review	7 days	Tue 12/3/24	Wed 12/11/24
Verify hot firing and performance with Natural Gas	37 days	Thu 12/12/24	Fri 1/31/25
Verify hot firing and performance with PRB Coal	72 days	Mon 2/3/25	Tue 5/13/25
Commissioning Reporting and Authorization of Test	12 days	Wed 5/14/25	Thu 5/29/25
Operate with Natural Gas (8 hrs on weekdays)	**35 days**	**Mon 6/2/25**	**Fri 7/18/25**
25MWth Study 3 Oxygen Purities	7 days	Mon 6/2/25	Tue 6/10/25
25MWth Vary CO2 Recycle Ratios	7 days	Wed 6/11/25	Thu 6/19/25
25MWth Vary Oxygen Feed Rates	7 days	Fri 6/20/25	Mon 6/30/25
Inspection & Maintenance_1 & Performance Report	14 days	Tue 7/1/25	Fri 7/18/25
Operate with Low Sulfur PRB Coal (8 hrs on weekdays)	**40 days**	**Mon 7/21/25**	**Fri 9/12/25**
50MWth Low Sulfur PRB Test 1	2 days	Mon 7/21/25	Tue 7/22/25
25MWth Vary 3 coal sizes [Excess O2 Fixed]	7 days	Wed 7/23/25	Thu 7/31/25
25MWth Vary Coal/Water Slurry [Ex O2 Fixed]	7 days	Fri 8/1/25	Mon 8/11/25
25MWth Vary O2 Purity/O2 Feed rates at Opt coal size, slurry	7 days	Tue 8/12/25	Wed 8/20/25
50MWth Low Sulfur PRB Test 2	2 days	Thu 8/21/25	Fri 8/22/25
Inspection & Maintenance_2 & Performance Report	15 days	Mon 8/25/25	Fri 9/12/25
Operate with High BTU Kemmer Coal (8 hrs on weekdays)	**20 days**	**Mon 9/15/25**	**Fri 10/10/25**
25 MWth Vary Excess O2. Use Opt Coal Size/Slurry Conc/O2 Staging	7 days	Mon 9/15/25	Tue 9/23/25
Inspection & Maintenance_3 & Performance Report	13 days	Wed 9/24/25	Fri 10/10/25
Operate with Higher Sulfur PRB Coal and Biomass (8 hrs on weekdays)	**20 days**	**Mon 10/13/25**	**Fri 11/7/25**
50MWth High Sulfur PRB/Biomass Test 1	2 days	Mon 10/13/25	Tue 10/14/25
25MWth Vary Excess O2 and CO2 Recycle Temp. Use Opt Coal Size/Slurry Conc/O2 Staging	6 days	Wed 10/15/25	Wed 10/22/25
50MWth High Sulfur PRB/Biomass Test 2	2 days	Thu 10/23/25	Fri 10/24/25
Inspection & Maintenance_4 & Performance Report	10 days	Mon 10/27/25	Fri 11/7/25
Data Review, Analysis and Reporting	**105 days**	**Mon 11/10/25**	**Fri 4/3/26**
Low Sulfur PRB Coal Demonstration Run (24/7 continuous running)	**26 days**	**Mon 4/6/26**	**Fri 5/1/26**
25MWth Demonstration Run 24/7 Using PRB Coal at Optimal Process Conditions	14 days	Mon 4/6/26	Sun 4/19/26
Inspection & Maintenance_5 & Performance Report	12 days	Mon 4/20/26	Fri 5/1/26
Decommissioning	**20 days**	**Mon 5/4/26**	**Fri 5/29/26**

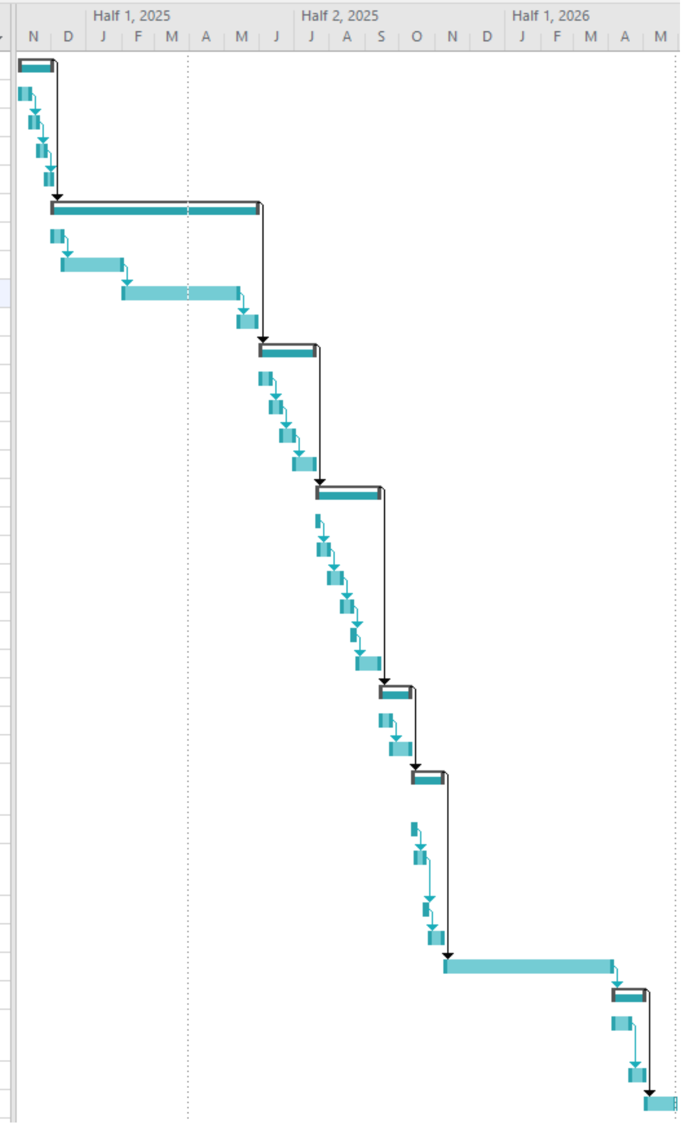

Figure 20. Overall Testing Schedule

8. MODELLING THE COMBUSTION REACTOR

The team completed work on an analytical model of the combustion reactor. This model is useful in scale-up activities for validating performance at the full commercial scale.

8.1 PREVIOUS CFD MODELING WORK

8.2 SUMMARY OF PREVIOUS MODELING WORK

The previous efforts to model FPO undertaken by ENEL, MIT, and the Polytecnico Bari all used the commercial CFD software ANYS – FLUENT. Although there have been small differences in choices of sub-models, the basic modeling approach can be summarized as follows:

- Steady-state RANS modeling with simple two-equation models (realizable k-epsilon or k-omega) for turbulence closure.
- Fast chemistry models based on single or two-step global reactions for the volatile combustion with a mixing limitation using the Eddy Breakup Model to account for turbulence chemistry interaction.
- Thermal radiation modeling using a gray- gas method with the spatially varying absorption coefficient calculated using the Smith Weighted Sum of Gray Gas (WSGG) model. The RTE was typically solved with the P1 or the DOM approximations.
- Lagrangian treatment of the dilute dispersed coal/water droplet phase using Fluent's DPM model with a random walk model to account for turbulent dispersion.
- Coal and water from the slurry atomizer is injected as a single combined "wet coal" particle.
- Particle heat up, water evaporation and boiling, coal devolatilization, and char combustion are modeled sequentially.
- Devolatilization has been modeled with single, two-step competing or the CPD model. The volatiles have been described as a "constant mixture" which are then reacted with the single or two-step global reactions.
- Char combustion and gasification have been modeled using kinetics-diffusion limited models.

8.3 PREVIOUS MODEL LIMITATIONS

Using this basic modelling approach, 3-d simulations of the 5 MW reactor located in Gioia del Colle, Italy, and operated by ITEA and the simulations of a proposed 50 MW reactor have been performed. Based on several discussions with ITEA's lead technology developer, Dr. Massimo Malavasi, the main shortcoming of these previous modeling efforts was that the experimentally observed very high coal burnout could not be predicted in the CFD models developed using classical combustion description algorithms. FPO uses a coal slurry injection with an effervescent atomizer, and the coal is ground only to a particle size distribution $d_p \approx 200 - 1500\mu m$ and not pulverized $(d_p \approx 20 - 200\mu m)$ as is more common in conventional coal combustion. In all previous modeling efforts, pulverized coal $(d_p \approx 20 - 200\mu m)$ was injected to achieve coal burnout predictions in agreement with observations from the 5 MW unit trials. Thus, there is a need for an improved description of the coal burnout of the large coal particles that also accounts for coal fragmentation.

8.4 CFD MODEL IMPROVEMENTS

The FPO modeling effort developed an improved description of the FPO combustion performance. The team focused on using the open-source CFD code OpenFOAM platform. Using OpenFOAM allows us to leverage the high performance xomputing facilities available at UW and provides model developers complete freedom to modify or implement new models. The basic modeling approach, as outlined above, is available in OpenFOAM and was used as a starting point. Three important improvements have been introduced early on: a more accurate devolatilization model based on the Flash-Chain mechanism that accounts for the different devolatilization rates of different species and also for the swelling of the coal during devolatilization, an improved representation of the coal – water slurry injection, and an improved homogenous (gas phase) reaction model to account for finite rate chemistry which is crucially important when modeling flameless combustion. More details on these improvements are given below.

The CFD results obtained with the UWYO approach for the Trial 6 conditions also indicated insufficient burnout when the large coal feed particle size distribution was simulated compared to the 5 MW reactor experimental results. However, when the reaction rates of the char combustion model were increased, large particles could be injected, and sufficient burnout was simulated. In addition, the predicted value for particulate emission (mostly ash and some not completely burnt char particles) was orders of magnitude higher than the values observed during Trial 6.

These findings have been shared with Dr. Malavasi and throughout several discussions, we have identified three possible shortcomings with the previous modeling approaches that could cause the observed disagreement between experimental findings and CFD model predictions:

1. Model inaccuracies for the radiative heat transfer at elevated pressures and high CO_2 and H_2O concentrations.
2. Possibility of coal fragmentation during slurry spraying, devolatilization, or char combustion.
3. Char combustion models developed for atmospheric pulverized coal-air combustion are inadequate to describe FPO.
4. Slag formation and potential for "trapping" of char/ash particles in the slag layer formed on the walls

All of these models were improved upon and incorporated into the detailed CFD model during the project activities.

8.5 SIMPLIFIED FPO REACTOR MODEL

To enable a very fast analysis of the global characteristics of the FPO process at any scale, the team also developed a basic FPO model using a global mass and energy balance for the FPO reactor and assuming chemical equilibrium. A schematic of the model is shown in Figure 21.

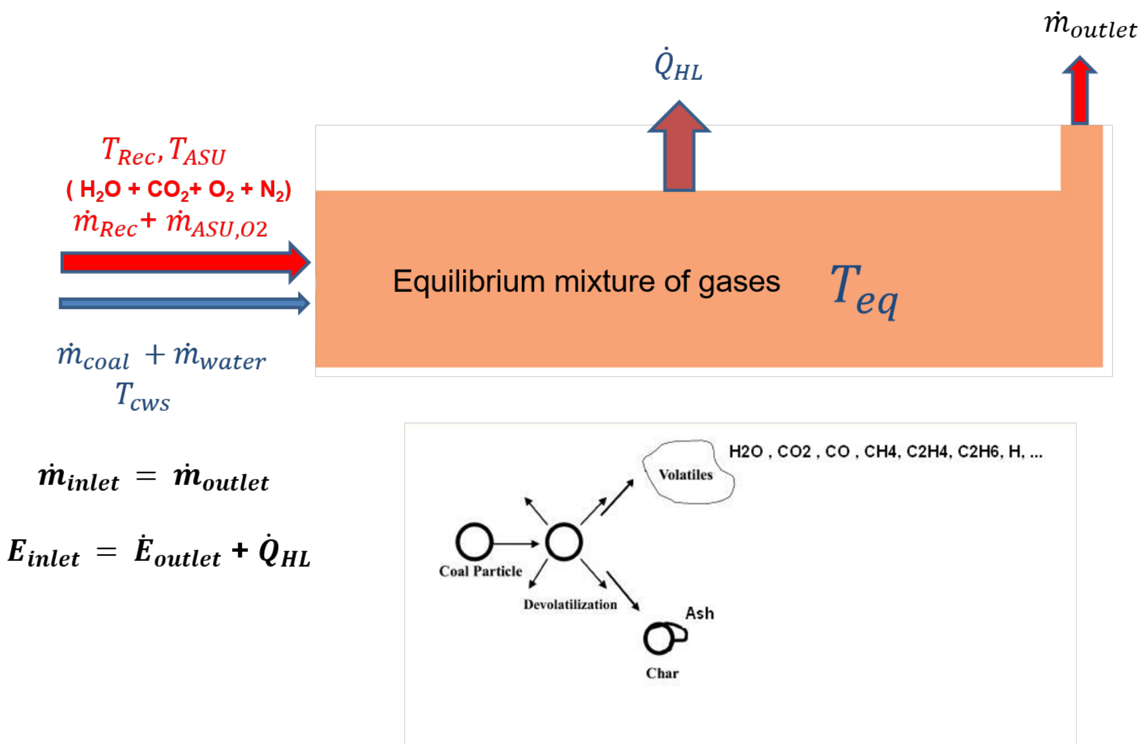

Figure 21. Simple FPO Model Based on Mass and Energy Conservation and Chemical Equilibrium.

This model predicts a single temperature and composition within the FPO reactor assuming perfect mixing and infinite residence time (i.e. chemical equilibrium and complete char burnout). If provided with a reasonable estimate for the heat loss to the surroundings, the model is capable of estimating the temperature and the CO_2, H_2O, and O_2 concentrations at the reactor outlet. However, this is only true if the FPO reactor actually works as intended, which in turn, can only be demonstrated with experimental or CFD studies.

9. TASK 5.0: UPDATED TECHNO-ECONOMIC ANALYSIS

In this task, the team provided a review of the pilot plant cost estimation and the commercial Techno-economic Analysis (TEA). A detailed TEA will be developed for the FPO technology by the end of Phase II. It will present three cases: one case for the pilot plant and two commercial plant cases.

9.1 COMMERCIAL FPO PROCESS AREAS

The basic configuration of the established commercial FPO cycle can be understood as shown in Figure 22. In addition, the ASU, the solids receiving and handling, CO_2 purification, the balance of plant equipment, and other miscellaneous areas make up the commercial system. Descriptions of the process areas and a full equipment list have been previously provided but are not reproduced here for brevity. An update to the TEA added a second reheat to the system because the OTSG can support this addition within a single casing. This resulted in notably improved efficiency and economics.

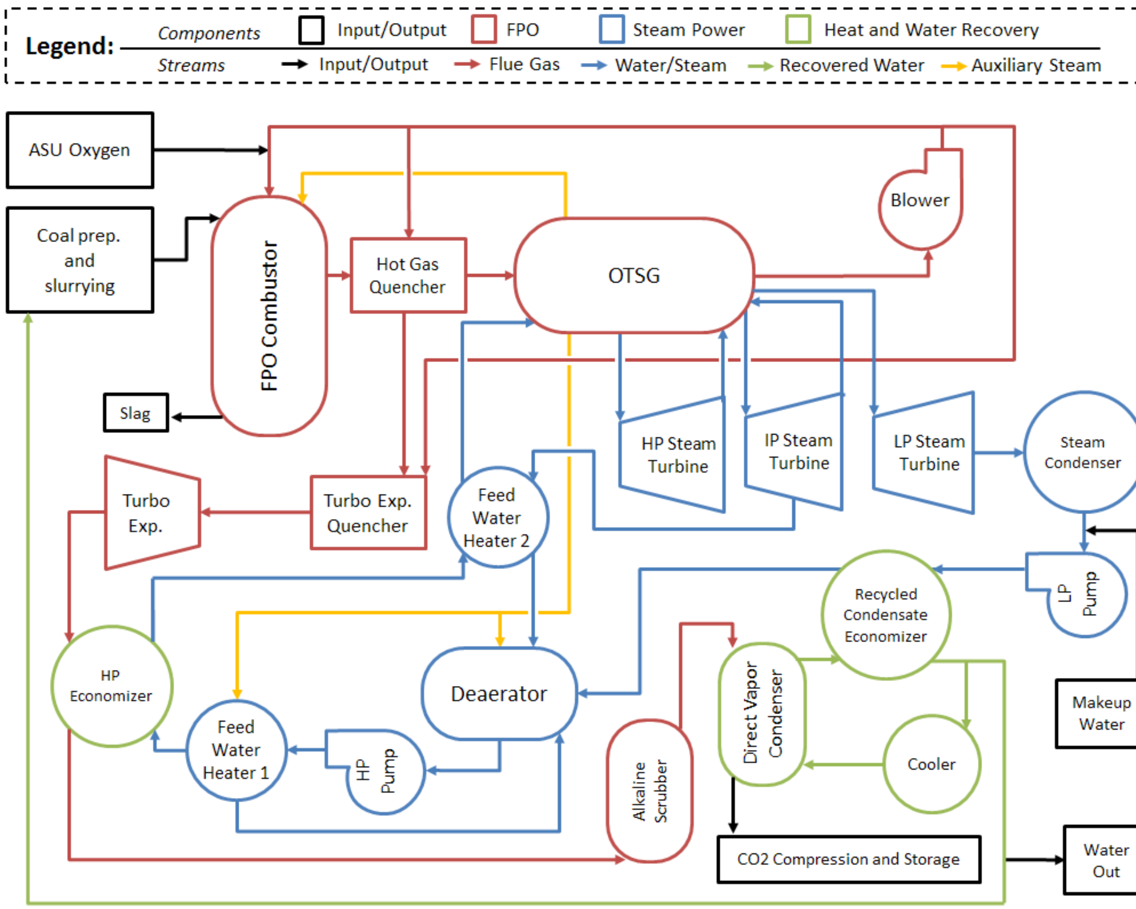

Figure 22. Commercial FPO Configuration

9.2 FPO COMMERCIAL PLANT PERFORMANCE RESULTS

The FPO cycle was modeled in Aspen Plus, and the results were compiled. Figure 23 shows the basic process flows of the plant cycle firing PRB coal. The streams in Table 6 correspond to Figure 23.

Table 7 shows the parasitic losses in a PRB-fired 550 MWe net plant. The parasitic losses were derived from the Aspen Model, proprietary estimates of power requirements, and scaling flows relative to S12B [2] and S12F [3] where appropriate. The PRB-fired FPO plant achieved a 33.2% net efficiency relative to the higher heating value (HHV) of coal with carbon capture. Without carbon capture, the net efficiency is 36.1% HHV.

Environmental performance and heat and mass balance were analyzed in the TEA but not included in this document for brevity.

9.3 PROCESS BLOCK DIAGRAM AND STREAM TABLE

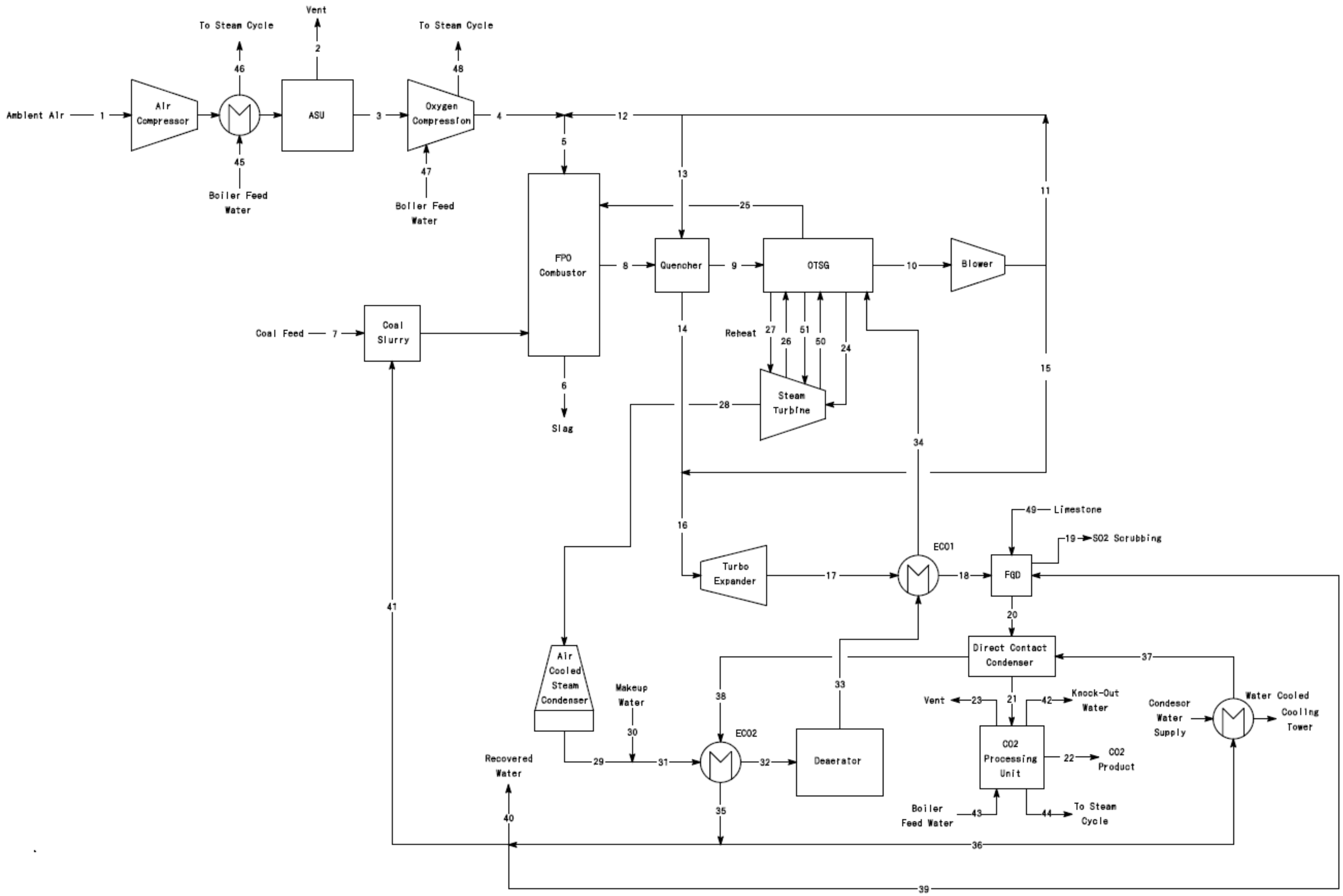

Figure 23. PRB-Fired Plant Block Flow Diagram

Table 6. PRB-Fired Plant Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
V-L Mole Fraction																
H20	0.0064	0.0081	0.0000	0.0000	0.4636	0.0000	0.0000	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748
N2	0.7759	0.9826	0.0163	0.0163	0.0112	0.0000	0.0000	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099
O2	0.2081	0.0064	0.9495	0.9495	0.1952	0.0000	0.0000	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143
AR	0.0093	0.0025	0.0342	0.0342	0.0195	0.0000	0.0000	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160
SO2	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000	0.0000	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0003	0.0004	0.0000	0.0000	0.3088	0.0000	0.0000	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829
CACO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0000	0.0000	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**	**0.0000**	**0.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
V-L Flowrate (kmol/hr)	71313	56057	15256	15256	78863	0	0	96205	184075	184075	184075	63606	113797	25926	6672	32598
V-L Flowrate (kg/hr)	2060604	1569267	491337	491337	2317743	0	0	2762436	5285572	5285572	5285572	1826406	3267594	744458	191572	936030
Solids Flowrate (kg/hr)	0	0	0	0	0	24513	299390	0	0	0	0	0	0	0	0	0
Temperature (K)	279	290	288	416	510	288	298	1650	1079	525	529	529	529	1079	529	973
Pressure (Bar)	0.90	1.01	1.40	12.30	12.30	0.90	0.90	12.30	12.30	12.00	12.30	12.30	12.30	12.30	12.30	12.30
Enthalpy (kJ/kg)	-77.74	-84.81	-9.90	105.41	-7718.13	---	---	-8001.58	-8988.48	-9827.40	-9822.80	-9822.80	-9822.80	-8988.48	-9822.80	-9159.23
Density (kg/cum)	1.1	1.2	1.9	11.5	8.7	---	---	2.6	3.9	8.1	8.2	8.2	8.2	3.9	8.2	4.4
V-L Molecular Weight	28.8951	27.9941	32.2058	32.2058	29.3897	---	---	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
V-L Mole Fraction																
H20	0.5847	0.5847	0.8786	0.5913	0.0112	0.0000	0.0048	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
N2	0.0097	0.0097	0.0000	0.0096	0.0232	0.0000	0.1323	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2	0.0140	0.0140	0.0000	0.0129	0.0311	0.0000	0.1779	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR	0.0156	0.0156	0.0000	0.0154	0.0373	0.0000	0.2132	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SO2	0.0020	0.0020	0.0000	0.0001	0.0002	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.3739	0.3739	0.0001	0.3707	0.8969	1.0000	0.4702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CACO3	0.0000	0.0000	0.0612	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0600	0.0000	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**	**1.0000**
V-L Flowrate (kmol/hr)	33376	33376	1002	33839	13990	11392	2452	71225	2067	71225	71225	67445	67445	3178	23955	70623
V-L Flowrate (kg/hr)	950041	950041	32798	956660	599059	501360	95082	1283130	37246	1283130	1283130	1215040	1215040	57250	431556	1272289
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (K)	734	432	313	384	298	300	286	882	530	709	886	305	294	288	294	397
Pressure (Bar)	2.40	2.38	0.90	2.36	2.35	153.10	28.48	240.99	20.00	80.00	76.92	0.05	0.05	0.05	3.95	3.80
Enthalpy (kJ/kg)	-9567.47	-9991.03	-12668.78	-10113.68	-8306.64	-9196.06	-4832.74	-12443.33	-13050.33	-12738.66	-12295.27	-13567.49	-15884.49	-15910.03	-15885.15	-15450.05
Density (kg/cum)	1.1	1.9	18.2	2.1	4.1	691.0	50.9	66.7	8.8	27.3	19.5	0.0	998.0	999.1	998.3	939.9
V-L Molecular Weight	28.4649	28.4649	32.7351	28.2712	42.8217	44.0098	38.7718	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
V-L Mole Fraction																
H20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
N2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CACO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0000	0.0000	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**	**1.0000**
V-L Flowrate (kmol/hr)	74262	71225	133157	113308	113308	133157	1488	11004	7358	145	19434	19434	22136	22136	5097	5097
V-L Flowrate (kg/hr)	1337855	1283130	2398954	2041353	2041353	2398954	26816	198251	132570	2616	350117	350117	398789	398789	91827	91827
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (K)	420	496	368	368	288	382	368	368	369	288	294	405	294	409	294	409
Pressure (Bar)	284.00	260.00	2.05	2.05	2.35	2.35	2.36	2.05	30.00	0.90	3.95	3.80	3.95	3.80	3.95	3.80
Enthalpy (kJ/kg)	-15336.28	-15006.82	-15652.38	-15652.38	-16018.95	-15589.93	-15652.34	-15652.38	-15648.60	-15908.26	-15885.15	-15414.87	-15885.15	-15397.79	-15885.15	-15397.79
Density (kg/cum)	935.2	856.1	923.3	923.3	1004.0	908.9	923.3	923.3	923.0	1000.0	998.3	933.0	998.3	929.5	998.3	929.5
V-L Molecular Weight	18.0153	18.0153	18.0160	18.0160	18.0160	18.0160	18.0160	18.0160	18.0160	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153

	49	50	51
V-L Mole Fraction			
H20	0.0000	1.0000	1.0000
N2	0.0000	0.0000	0.0000
O2	0.0000	0.0000	0.0000
AR	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000
CACO3	1.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0000
Total	**1.0000**	**1.0000**	**1.0000**
V-L Flowrate (kmol/hr)	126	69473	69473
V-L Flowrate (kg/hr)	12600	1251580	1251580
Solids Flowrate (kg/hr)	0	0	0
Temperature (K)	288	717	886
Pressure (Bar)	2.38	26.00	25.00
Enthalpy (kJ/kg)	-12067.20	-12634.46	-12259.92
Density (kg/cum)	2714.3	8.1	6.2
V-L Molecular Weight	100.0872	18.0153	18.0153

9.4 PERFORMANCE RESULTS

Table 7. FPO Plant Performance Power Summary

Power Balance		
Heat Input		
Coal Feed Flowrate	299,390	kg/hr
Thermal input (HHV)	1,656,627	kWth
Thermal input (LHV)	1,596,083	kWth
Condenser Heat Duty	2,815	GJ/hr
Cooling water heat rejection	968	GJ/hr
Power Output		
Steam Turbine Power	662,992	kWe
Turbo Expander Power	91,201	kWe
Auxiliary Power Load		
HP Feedwater Pump	14,514	kWe
LP Feedwater Pump	182	kWe
Gas Recycle Blower	6,964	kWe
ASU Primary Fan	80,921	kWe
ASU Oxygen Compressor	32,651	kWe
ASU Auxiliaries	1,000	kWe
Air Condenser Fans (0.81% kWe/kWth)	6,334	kWe
Cooling Tower Fans (0.73% kWe/kWth)	1,962	kWe
Circulating Water Pumps (1.14% kWe/kWth)	3,064	kWe
Coal Bar Mill (18 kWe/kg/s coal)	1,497	kWe
Slurry Pump (7.7 kWe/kg/s coal)	640	kWe
Slag Handling (1.7 kWe/kg/s coal)	141	kWe
Steam Turbine Auxiliaries	329	kWe
Direct Contact Condenser Recycle Pump	34	kWe
Coal Handling and Conveying	629	kWe
FGD Auxiliaries (0.1% kWe/kWth)	16	kWe
Balance of Plant	2,000	kWe
Transformer Losses	2,629	kWe
CO2 Purification Loads		
CO2 LP Compressor Power	34,088	kWe
CO2 HP Compressor Power	14,390	kWe
Plant Performance		
Gross Power output	754,194	kWe
Net Auxiliary Load	155,508	kWe
Net CO2 Purification Load	48,478	kWe
Net Plant Power	550,208	kWe
Gross Power Efficiency (HHV)	45.5%	
Net Exported Power Efficiency (HHV)	33.2%	
Net Plant Heat Rate (HHV)	10,839	kJ/kWhr
Net Exported Power Efficiency without CO2 Capture (HHV)	36.1%	
Gross Power Efficiency (LHV)	47.3%	
Net Exported Power Efficiency (LHV)	34.5%	
Net Plant Heat Rate (LHV)	10,443	kJ/kWhr
Net Exported Power Efficiency without CO2 Capture (LHV)	37.5%	

9.4.1 TEA Commercial Plant Cost

The costs for the commercial FPO power plant were estimated, following NETL's methodology.

9.4.1.1 Capital Cost Results

The estimated capital cost for the commercial 550-MWe FPO supercritical power plant is summarized in Table 8. These estimates are consistent with the code of accounts format as expressed in the Oxy-combustion Baseline Report [3]. The TPC costs for systems common to the Case S12F costs are capacity-factored from that report, with appropriate scaling parameters and exponents derived from the Cost Estimation Methodology QGESS Report [4].

Table 9 shows the owner's costs breakdown and assumptions used to calculate the TOC for the 550-MWe FPO supercritical power plant. Table 10 shows the plant's estimated annual O&M costs based on an 85% capacity factor. All costs were escalated to 2018 dollars. A further breakdown of the costs was provided in the TEA but is not included here for brevity.

Table 8. Updated Near-term and Long-term Plant Capital Cost Estimate for 550-MWe FPO Power Plant

Acct No.	Item/Description	Updated TEA FPO PRB-Fired TOTAL PLANT COST $1,000	$/kW
1	COAL & SORBENT HANDLING	58,868	107
2	COAL & SORBENT PREP & FEED	49,776	91
3	FEEDWATER & MISC BOP SYSTEMS	93,456	170
4	PC BOILER & ACCESSORIES	779,389	1,417
5	FLUE GAS CLEANUP	41,314	75
5B	CO2 REMOVAL & COMPRESSION	177,603	323
6	TURBOEXPANDER	92,120	167
7	HRSG, DUCTING & STACK	14,889	27
8	STEAM TURBINE GENERATOR	249,874	454
9	COOLING WATER SYSTEM	46,915	85
10	ASH/SPENT SORBENT HANDLING SYS	0	0
11	ACCESSORY ELECTRIC PLANT	105,642	192
12	INSTRUMENTATION & CONTROL	33,275	60
13	IMPROVEMENTS TO SITE	18,358	33
14	BUILDINGS & STRUCTURES	65,154	118
	TOTAL PLANT COST	**1,826,635**	**3,321**

Table 9. Owner's Costs for the 550-MWe FPO Power Plant

Description	$/1,000	$/kW
Preproduction Costs		
6 months All Labor	$12,355	$22
1 Month Maintenance Materials	$1,940	$4
1 Month Non-Fuel Consumables	$478	$1
1 Month Waste Disposal	$556	$1
25% of 1 Months Fuel Cost at 100% CF	$1,190	$2
2% of TPC	$36,533	$66
Total	**$53,052**	**$96**
Inventory Capital		
60 day supply of fuel at 100% CF	$9,386	$17
60 day supply of non-fuel consumables at 100% CF	$944	$2
0.5% of TPC (spare parts)	$9,133	$17
Total	**$19,463**	**$35**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$900	$2
Other Owner's Cost	$273,995	$498
Financing Costs	$49,319	$90
Total Overnight Costs (TOC)	**$2,223,364**	**$4,042**

Table 10. Long-term Plant Operating Cost Estimate for 550-MWe FPO Power Plant

INITIAL & ANNUAL O&M EXPENSES			
Case:	SwRI FPO Supercritical Oxycombustion Plant		
Plant Size (MWe)	**550**	**Heat Rate (Btu/kWh):**	10,839
Primary/Secondary Fuel:	**Wyoming PRB**	**Fuel Cost ($/MMBtu):**	
Design/Construction	5 years	**Book Life (yrs):**	20
TPC (Plant Cost) Year	Jun-18	**TPI Year:**	2018
Capacity Factor (%)	85	**CO2 Captured (TPD)**	13349

OPERATING & MAINTENANCE LABOR

Operating Labor

Operating Labor Rate (base):	$39.70	$/hr
Operating Labor Burden:	30.0	% of base
Labor Overhead Charge	25.0	% of labor

Operating Labor Requirements per Shift	**units/mod**	**Total Plant**
Skilled Operator	2.0	2.0
Operator	9.0	9.0
Foreman	1.0	1.0
Lab Tech's etc	2.0	2.0
TOTAL Operating Jobs	14.0	14.0

	Annual Cost $
Annual Operating Labor Cost	$6,329,450
Maintenance Labor Cost	$12,935,374
Administration & Support Labor	$4,756,908
Property Taxes and Insurance	$37,216,208
TOTAL FIXED OPERATING COSTS	**$61,237,941**

VARIABLE OPERATING COSTS

Maintenance Material Cost					$19,403,062
Consumables	Consumption Initial	Consumption /Day	Unit Cost	Initial Fill Cost	
Water(/1000 gallons)	0	2,280	1.87	**$0**	**$1,236,360**
Chemicals					
MU & WT Chem (lb)	0	11035	0.30	$0	**$957,541**
Limestone (ton)	0	248	37.38	$0	**$2,685,793**
Subtotal Chemicals				**$0**	**$3,643,334**
Waste Disposal:					
Slag (ton)	0	698	28.03	$0	**$5,674,592**
Subtotal Waste Disposal				**$0**	**$5,674,592**
By-products & Emissions					
Gypsum (tons)	0	652	0.00	$0	$0
Subtotal By-Products				**$0**	**$0**
TOTAL VARIABLE OPERATING COSTS				**$0**	**$29,957,348**
Fuel (tons)	**0**	**8520**	**19.63**	**$0**	**$48,533,941**

9.4.1.2 Cost Estimate Comparison

Compared to the S12B [2] air-fired supercritical power plant with CO_2 capture, the PRB-Fired FPO power plant has a total plant cost that is about 19.9% lower at $3,321/kW vs. $4,147/kW. Substantial savings have been realized in the FPO firing system, flue gas cleanup, and CO_2 recovery and compression systems compared to Case S12B. This is more than enough to offset the major additional costs associated with the ASU, oxygen compressor, and pressurized flue gas turbo-expander units for the 550-MWe FPO power plant. After factoring in pre-production, inventory capital, and other costs, the 550-MWe FPO plant has a lower TOC ($4,042/kW vs. $5,057/kW) compared to the air-fired S12B case.

For O&M costs, the FPO plant has lower fixed operating costs at $61.2MM/year compared to the S12B power plant at $74.3MM/year. This is due to the FPO plant having lower operating labor requirements and lower fixed operating costs associated with the overall plant capital costs (maintenance labor and property taxes and insurance). Its variable operating cost is also substantially lower ($48.5MM/year vs $59.4MM/year at 85% capacity factor), due to the higher chemical costs associated with amine-based capture. Finally, as the FPO plant has a lower heat rate than the S12B case (10,839 Btu/kWh vs. 12,634 Btu/kWh), it uses less coal and thus has a lower fuel cost.

The methodology for developing levelized cost of electricity (LCOE) and other costs is described in the TEA, but not included here for brevity.

9.4.1.3 First-Year Power Costs and LCOE Summary

Table 11 compares the first-year power costs, broken down into their components, for the NETL baseline cases S12A, S12B [2], and the FPO case. The projected first-year power cost for the FPO case only increased by 51.6% over that of the NETL-based case without CO_2 capture (S12A), compared to a 92.3% increase in first-year power cost for NETL's amine scrubbing based case with CO_2 capture (S12B). The FPO case shows potential cost reductions over Case S12B in capital (20.1%), operating and maintenance cost (26.9%), and fuel cost (18.6%). The O&M cost reduction is primarily due to the elimination of amine solvent expense, while the fuel cost reduction is due to the improved net plant efficiency.

Table 11. LCOE Comparisons (in 2018$)

	NETL Case S12A	NETL Case S12B	PRB-Fired FPO
Capital	44.7	84.2	67.3
Fixed O&M	11.1	18.2	15.0
Variable O&M	6.9	12.5	7.3
Fuel Cost	10.1	14.5	11.8
CO_2 T&S Cost	0.0	11.1	9.0
First Year Power Cost, $/MWh	**72.8**	**140.4**	**110.4**
LCOE, $/MWh	**92.3**	**178.1**	**140.0**

Table 11 also compares the LCOE for the base and test cases. The FPO case is 21.4% reduced when compared to the S12B case. Similar conclusions can be drawn to those for the first-year power costs, as relative differences between the NETL baseline cases and the FPO case are similar.

9.4.1.4 Cost of CO_2 Avoided and Captured Summary

Table 12 shows the CO_2 avoided and captured costs for the NETL baseline cases S12B [2] and the FPO case. The costs are relative to the NETL supercritical PC without CCS (Case S12A) [2], and the cost of CO_2 captured does not include T&S.

The cost of CO_2 avoided is 46.1% less for the FPO case than for NETL baseline capture case S12B. On a cost of CO_2 captured basis, the FPO case advantage is 38.0% relative to baseline case S12B.

Table 12. CO_2 Avoided and Captured Costs (in 2018$)

	NETL Case S12A	NETL Case S12B	Long-term FPO
Cost of CO_2 Avoided, $/tonne	Base	91.8	49.5
Cost of CO_2 Captured, $/tonne (excludes T&S Cost)	Base	51.1	31.7

9.4.2 TECHNO-ECONOMIC ASSESSMENT FOR LIGNITE COAL

Lignite coal is an alternate low-rank coal that may present a valuable feedstock for FPO. The ability of FPO to use low-rank feedstock, including waste incineration, allows it to be adopted at lignite coal resources, such as what is present in North Dakota or Texas. The team authored a new TEA which highlights North Dakota lignite coal as an alternate feedstock to the Montana PRB coal in the original TEA. The model was completed and analyzed for performance.

9.4.2.1 Coal Characteristics

For this case, the North Dakota Lignite coal was used. This matches the input coal for the S12B case [1]. The characteristics of this coal are reproduced in Table 13.

Table 13. Characteristics of the North Dakota Lignite Coal

Proximate Analysis		Dry Basis, %	As Received, %
Moisture		0.0	36.08
Ash		15.43	9.86
Volatile Matter		41.48	26.52
Fixed Carbon		43.09	27.54
Total		100.0	100.0
Ultimate Analysis		**Dry Basis, %**	**As Received, %**
Carbon		61.88	39.55
Hydrogen		4.29	2.74
Nitrogen		0.98	0.63
Sulfur		0.98	0.63
Chlorine		0.00	0.00
Ash		15.43	9.86
Moisture		0.00	36.08
Oxygen[1]		16.44	10.51
Total		100.0	100.0
Heating Value		**Dry Basis**	**As Received, %**
HHV, kJ/kg		24,254	15,391
HHV, Btu/lb		10,427	6,617
LHV, kJ/kg		23,335	14,804
LHV, Btu/lb		10,032	6,364
Hardgrove Grindability Index		N/A	
Ash Mineral Analysis			**%**
Silica	SiO_2		35.06
Aluminum Oxide	Al_2O_3		12.29
Iron Oxide	Fe_2O_3		5.12
Titanium Dioxide	TiO_2		0.58
Calcium Oxide	CaO		14.39
Magnesium Oxide	MgO		6.61
Sodium Oxide	Na_2O		5.18
Potassium Oxide	K_2O		0.64
Sulfur Trioxide	SO_3		16.27
Phosphorous Pentoxide	P_2O_5		0.00
Barium Oxide	Ba_2O		0.56
Strontium Oxide	SrO		0.27
Manganese Dioxide	MnO_2		0.02
Unknown	---		3.01
		Total	100.0
Trace Components			**ppmd**
Mercury	Hg		0.116

9.4.2.2 Block Flow Diagrams

Diagrams that summarize the flow conditions were created. The flows for the FPO system with gas clean-up is shown in Figure 24. The flow conditions for the steam loop and heat recovery are shown in Figure 25.

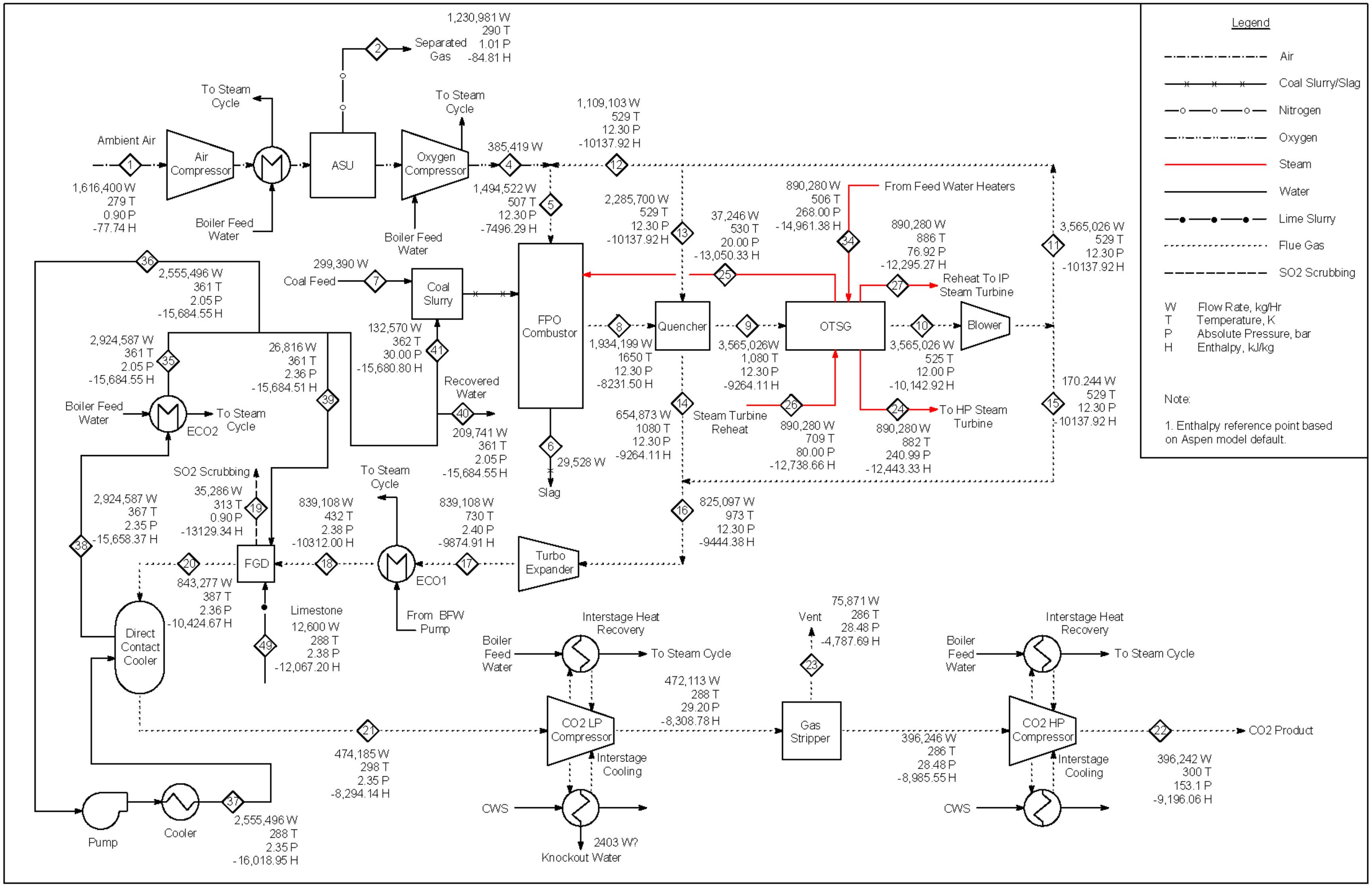

Figure 24. Block Flow Diagram for the FPO Loop and Gas Cleanup

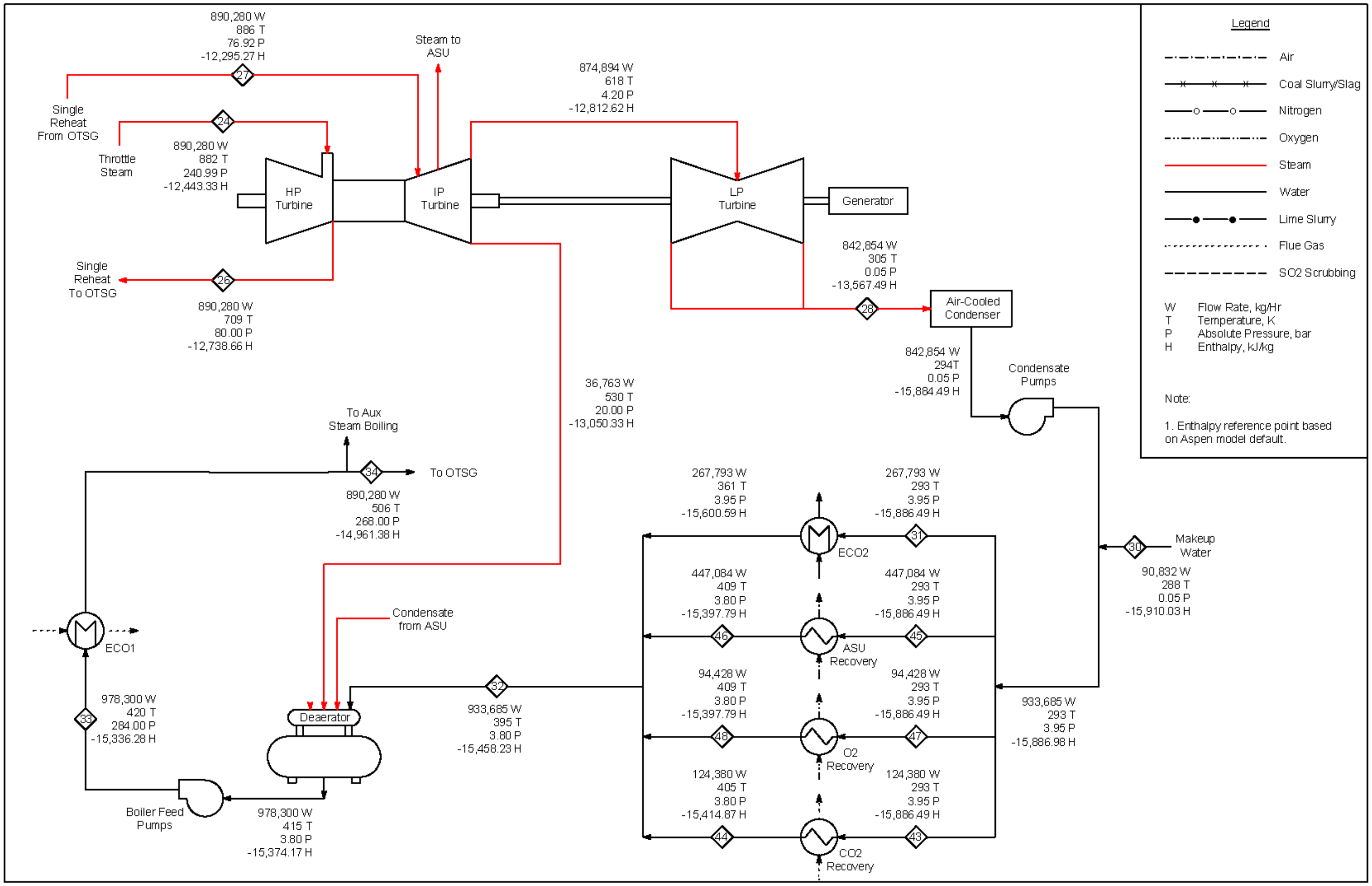

Figure 25. Block Flow Diagram for the Steam Cycle and Heat Recovery

9.4.2.3 Performance Summary

The performance of the studied FPO system on lignite coal is shown in Table 14.

Table 14. Summary of Power Requirements and Performance for the Lignite TEA

Power Balance		
Heat Input		
Coal Feed Flowrate	299,390	kg/hr
Thermal input (HHV)	1,279,977	kWth
Thermal input (LHV)	1,231,160	kWth
Condenser Heat Duty	1,953	GJ/hr
Cooling water heat rejection	1,116	GJ/hr
Power Output		
Steam Turbine Power	460,953	kWe
Turbo Expander Power	85,021	kWe
Auxiliary Power Load		
HP Feedwater Pump	10,613	kWe
LP Feedwater Pump	133	kWe
Gas Recycle Blower	4,970	kWe
ASU Primary Fan	63,477	kWe
ASU Oxygen Compressor	25,613	kWe
ASU Auxiliaries	1,000	kWe
Air Condenser Fans (0.81% kWe/kWth)	4,394	kWe
Cooling Tower Fans (0.73% kWe/kWth)	2,263	kWe
Circulating Water Pumps (1.14% kWe/kWth)	3,534	kWe
Coal Bar Mill (18 kWe/kg/s coal)	1,497	kWe
Slurry Pump (7.7 kWe/kg/s coal)	640	kWe
Slag Handling (1.7 kWe/kg/s coal)	141	kWe
Steam Turbine Auxiliaries	229	kWe
Direct Contact Condenser Recycle Pump	42	kWe
Coal Handling and Conveying	629	kWe
FGD Auxiliaries (0.1% kWe/kWth)	9	kWe
Balance of Plant	2,000	kWe
Transformer Losses	1,830	kWe
CO2 Purification Loads		
CO_2 LP Compressor Power	27,004	kWe
CO_2 HP Compressor Power	12,066	kWe
Plant Performance		
Gross Power output	545,974	kWe
Net Auxiliary Load	123,015	kWe
Net CO_2 Purification Load	39,070	kWe
Net Plant Power	383,889	kWe
Gross Power Efficiency (HHV)	42.7%	
Net Exported Power Efficiency (HHV)	30.0%	
Net Plant Heat Rate (HHV)	12,003	kJ/kWhr
Net Exported Power Efficiency without CO_2 Capture (HHV)	33.0%	
Gross Power Efficiency (LHV)	44.3%	
Net Exported Power Efficiency (LHV)	31.2%	
Net Plant Heat Rate (LHV)	11,545	kJ/kWhr
Net Exported Power Efficiency without CO_2 Capture (LHV)	34.4%	

9.5 COST ESTIMATE COMPARISON

Table 15 summarizes the overall capital cost estimate for the DOE baselines and the FPO plants with various fuels. S12A and S12B were provided from previous TEA updates. L12A and L12B are included for reference. The escalation of costs for L12A and L12B to 2018 US dollars was done by using factors derived from the escalation study of S12A and S12B. The previous results from a TEA that uses FPO with PRB coal are also used for comparative purposes. While the cost of electricity does increase with Lignite fuel, FPO still provides a savings relative to adding post combustion carbon capture when compared to both the S12B and L12B cases.

Table 15. Comparison of Baseline Cases and FPO with Different Fuel Types

Cost Basis: 2018$	**S12A**	**S12B**	**L12A**	**L12B**	**FPO PRB**	**FPO Lig.**
Net Power (MW)	550	550	550	550	550	384
Fuel Type	PRB	PRB	ND Lignite	ND Lignite	PRB	ND Lignite
Total Plant Cost ($/1000)	1,293,050	2,281,194	1,404,658	2,037,145	1,860,650	1,238,848
Total Plant Cost ($/kW)	2,351	4,147	2,554	4,518	3,383	3,227
Total Overnight Cost ($/1000)	1,578,500	2,781,354	1,713,580	3,028,697	2,264,900	1,518,139
Total Overnight Cost ($/kW)	2,870	5,057	3,115	6,717	4,118	3,955
Total As Spent Capital ($/kW)	3,255	5,765	3,534	6,277	4,695	4,509
Capital ($/MWh)	44.7	84.2	48.6	91.7	68.6	65.9
Fixed O&M ($/MWh)	11.1	18.2	12.0	19.7	15.5	17.6
Variable O&M ($/MWh)	6.9	12.5	8.3	14.8	7.7	10.8
Fuel Cost ($/MWh)	10.1	14.5	9.7	14.2	12.6	26.6
CO_2 T&S Cost ($/MWh)	0.0	11.1	0.0	11.5	9.6	10.5
First Year COE ($/MWh)	72.8	140.4	78.3	152.0	114.0	131.4
LCOE ($/MWh)	**92.3**	**178.1**	**99.2**	**192.7**	**144.5**	**166.6**

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