Pre-Project Planning for a Flameless Pressurized Oxy-combustion (FPO) Pilot Plant

DOE National Energy Technology Laboratory

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Project Team: SwRI, ITEA, EPRI, GE Global Research, Jacobs, PRA

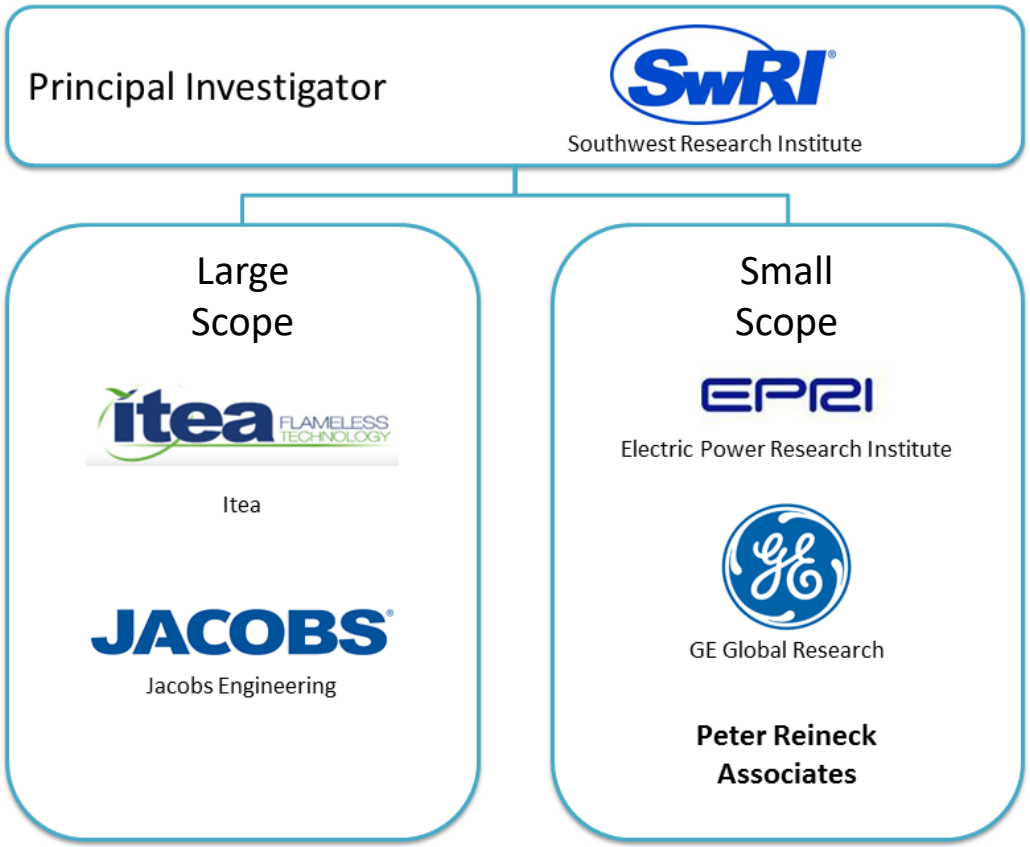
Overview

- Project Summary
- Project Team
- Technology Premise and Background
- Project Goals
- Project Developments and Progress

Project Summary

- Part of DOE goal for advancing Transformational Coal Technologies
- Planning of a demonstration facility
  - Cycle analysis
  - Site Selection
  - Layout
  - Pre-FEED cost estimate
- Develop economic analysis and technology maturation pathway to commercialization

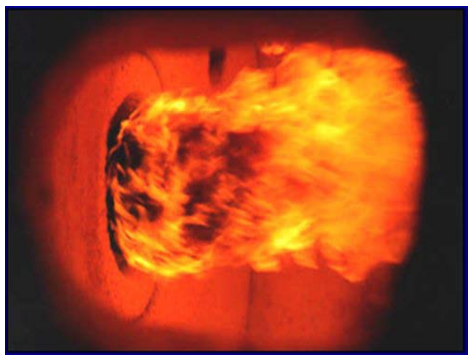
Project Team



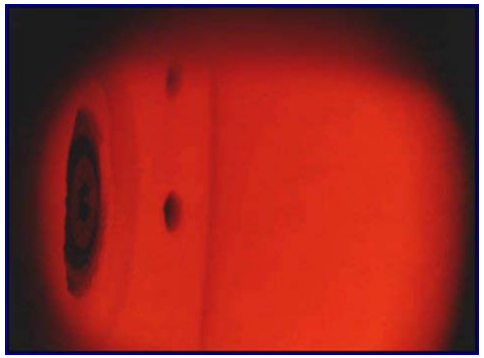
FPO Combustion

- Pressurized atmosphere of water and CO_2 under "volume expanded combustion" avoids traditional flame fronts
  - FPO combustion is more locally controllable with more uniform temperatures
  - Pressurized firing also improves cycle efficiency

Traditional Combustion with Flame Front



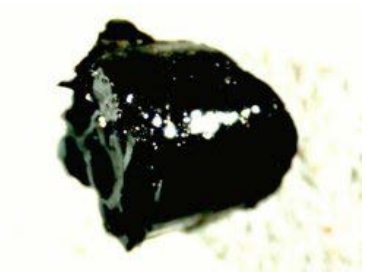
Flameless Pressurized Combustion



- Conversion of carbon to CO_2 is over 99%
  - Almost zero carbon content in incombustible products
  - Traditional: flying and falling ash particles
  - FPO: slag with near-zero carbon content and tiny particulate

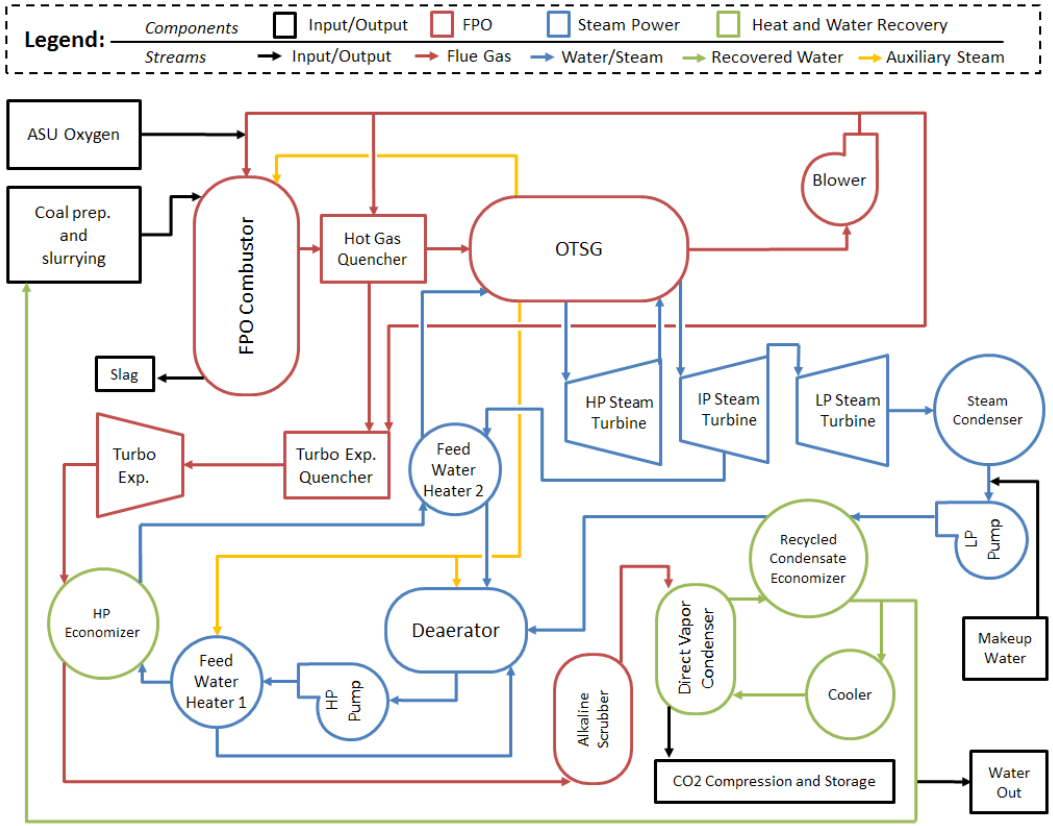
Traditional Combustor Products: Particulate

FPO Combustor Products: Near-zero carbon, neutral slag



FPO Cycle

- Slurry of milled coal and water combusted under pressure
- Hot combustor gas is quenched through mixing
- Enters Once-Through Steam Generator (OTSG)
- A large percentage of combustion products are recycled
  - Some recycled flow used for quenching before OTSG
  - The remainder of recycled flow is mixed with pressurized oxygen and injected into the combustor
- New iteration of cycle splits before boiler and includes turbo-expander



Project Tasks and Goals

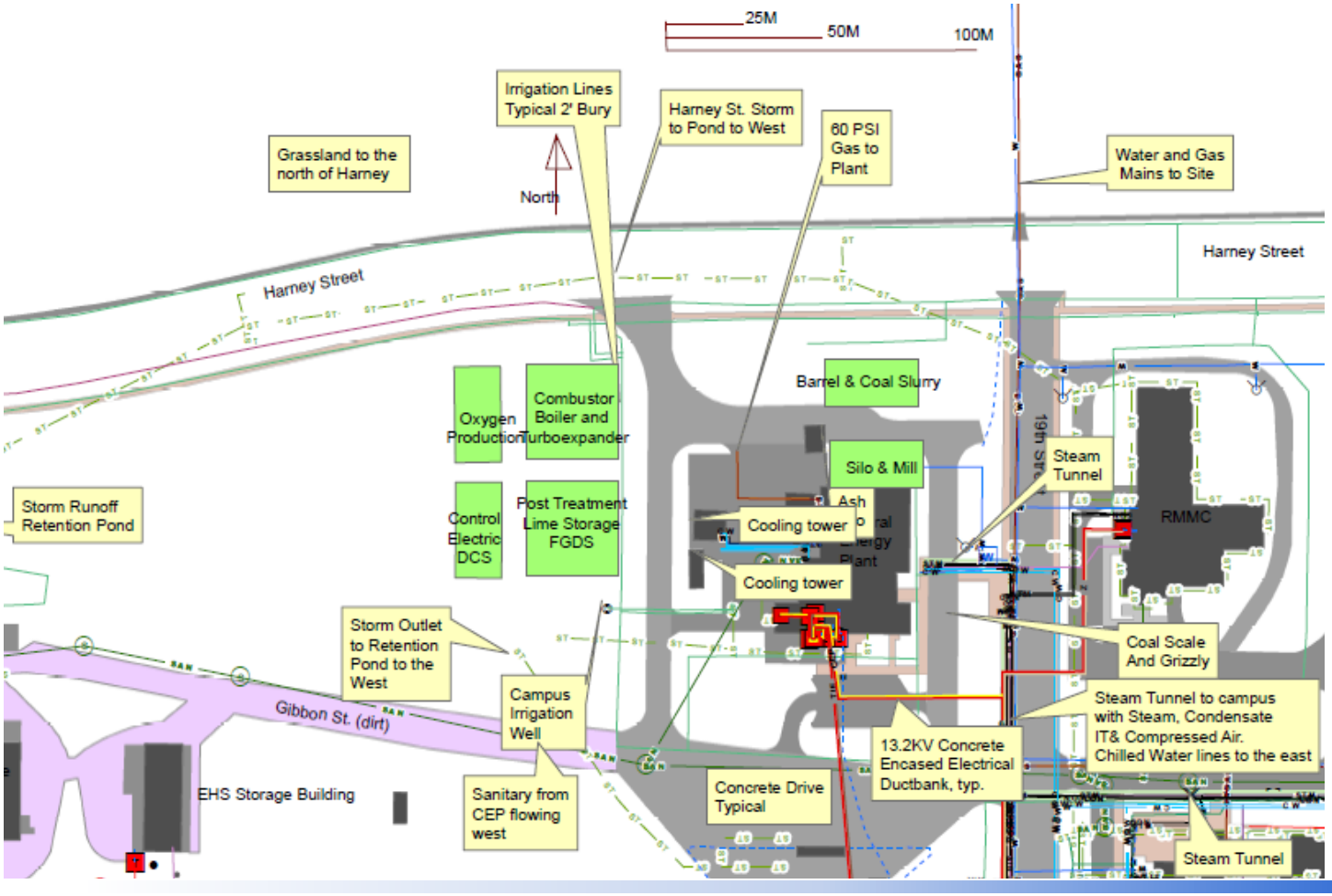
- Choose a location to host the pilot facility
  - Should already have coal receiving and handling infrastructure available
  - Must meet local regulatory requirements
- Design and layout a 50 MWth pilot facility
  - Includes engineering of coal slurrying, combustion loop, turbo-expander, and once-through steam generator
  - Generate cost estimates
- Create a testing program that addresses knowledge gaps and advances FPO technology readiness level
- Prove that FPO development path can meet DOE cost and emissions targets for transformational coal technologies with techno-economic assessment

SwRI itea FLAMELESS TECHNOLOGY EPRI JACOBS GE

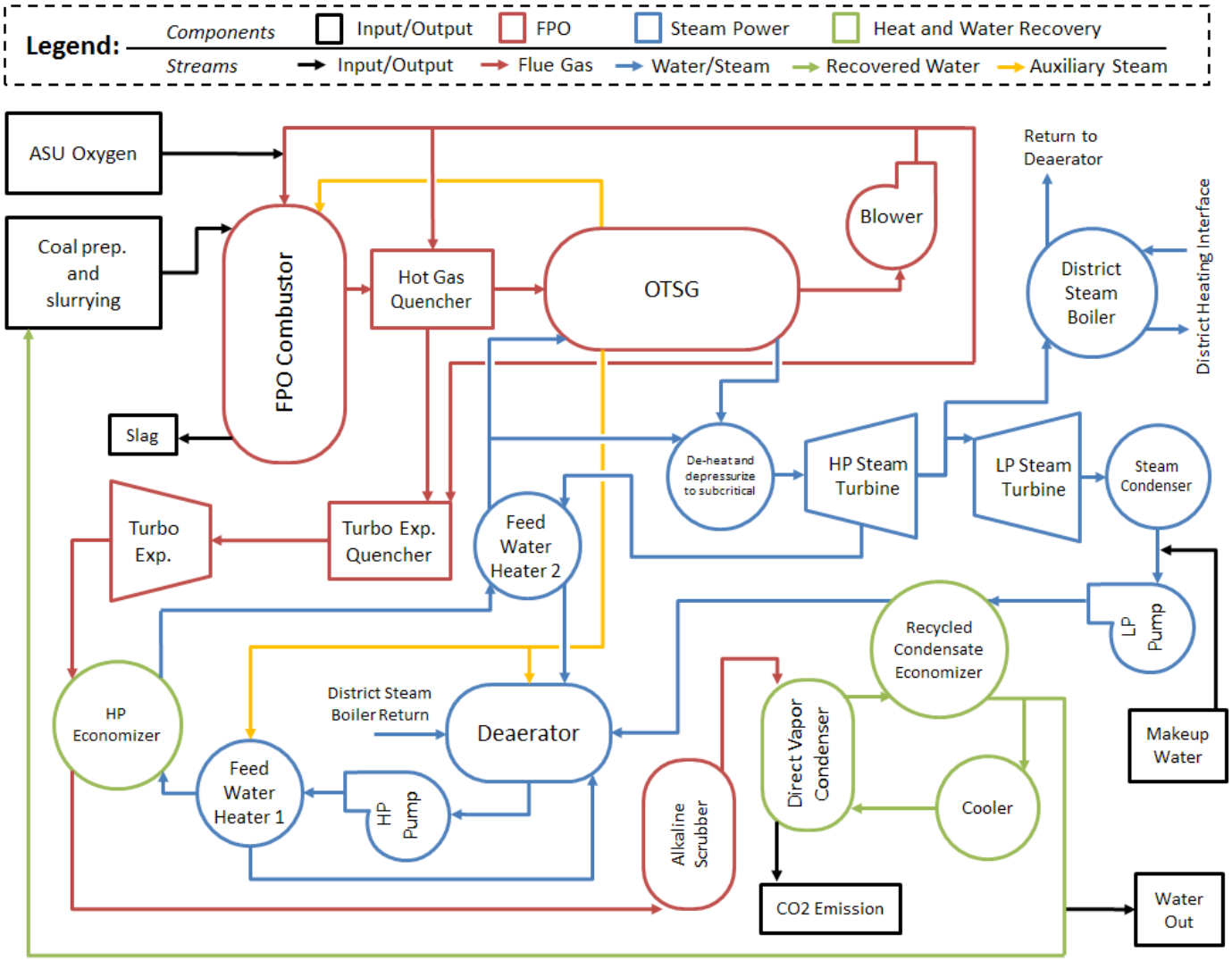
Site Selection Progress

- Weighted criteria selection process
  - Availability of funding
  - Availability of staffing
  - Permitting process
- Narrowed down to a primary and secondary site
  - Primary: University of Wyoming Central Energy Plant (UW CEP)
  - Secondary: National Carbon Capture Center (NCCC)
- Focus shifted to layout and cost of pilot

UW CEP Proposed Site



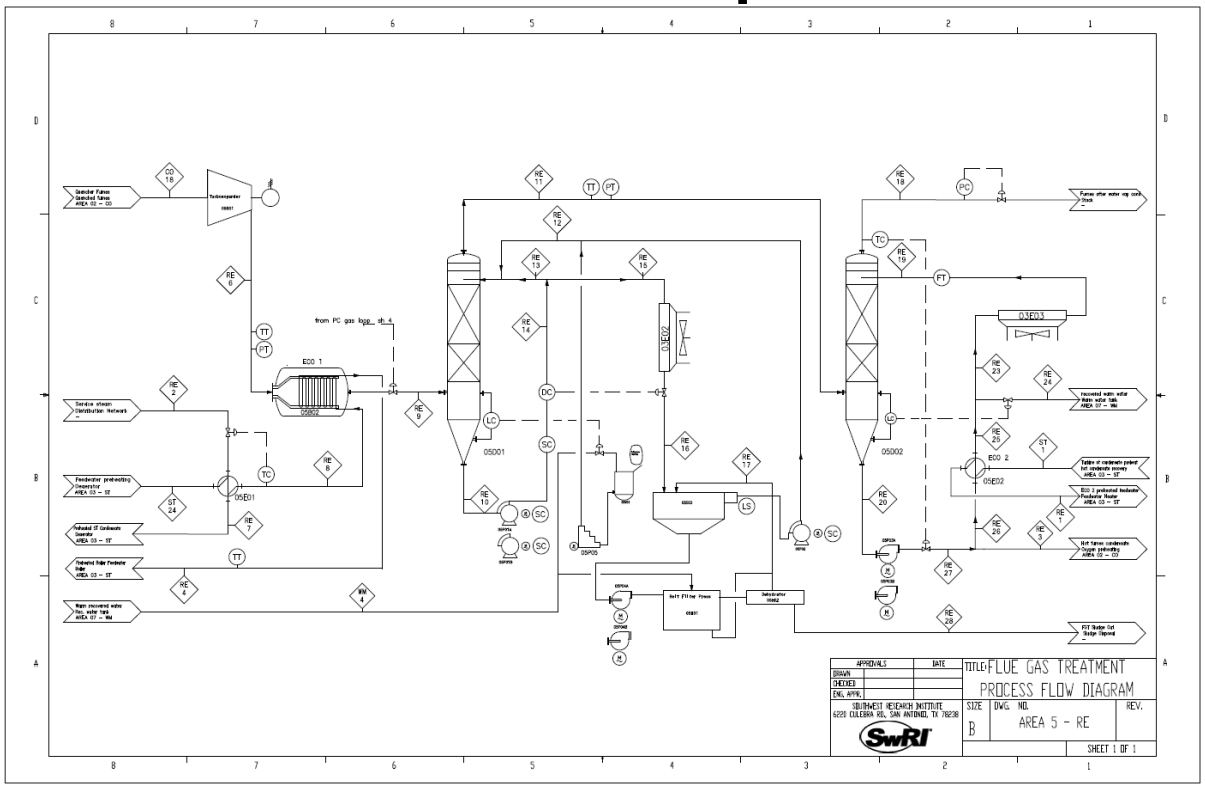
UW CEP Cycle Overview



UW CEP Permit Plan

- Provided documentation from UW
- Local Permits and Ordinances
  - State and local review
- Sound Issues
  - Need identified to keep below a threshold “hospital-grade acoustical design”
- Air Quality and Emissions
  - Possibly tied in with UW CEP existing Title V permit
  - Possibility of waiver
- Water Permits
  - No requirement for zero liquid discharge
  - Polish plant water products for reuse to minimize usage and cost cost
- NEPA Study
  - Goal of a Categorical Exclusion or Environmental Assessment with a Finding of no Significant Impact

PFD Development



- PFD for identification of major components and streams
  - Establishing a naming and tagging convention
  - Showing system interconnection/balance of plant
  - Identifying key streams and figures of merit
  - Showing scope breaks for project management
  - Showing material selection for components and streams

Component Specification

- Based on the “super-compliance” PRB coal published by NETL
- Heat and mass balance in Aspen Plus
- Combustion gas characterization from ITEA testing and custom codes
- Specification of major components
  - Combustor
  - OTSG
  - Turbo-expander
  - Water pumps
  - Economizers
  - Feedwater heaters
  - Water vapor condenser
  - Flue-gas desulfurization (FGD) scrubber

Coal name	PRB
Coal seam nomenclature	Wyodak/Anderson
Mine	Rochelle Coal Co.
ASTM D388 Rank	Subbituminous C

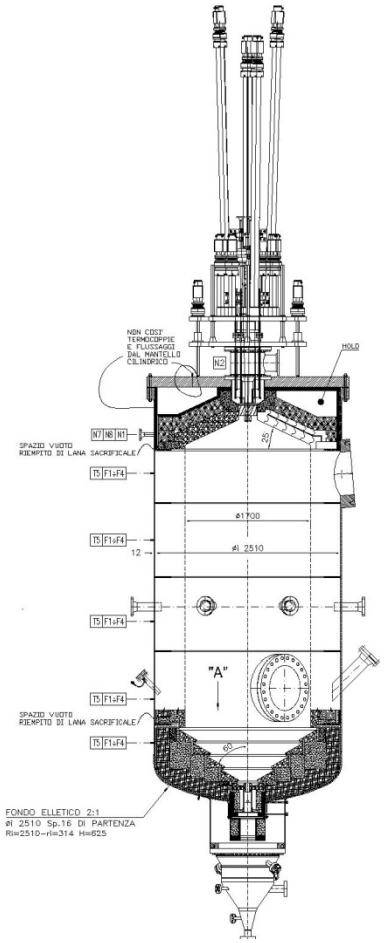
Proximate Analysis[5]	**As-Received**	**Dry**
Moisture	27.42%	0.00%
Volatile Matter	31.65%	43.61%
Ash	4.50%	6.20%
Fixed Carbon	36.43%	50.19%
Total	100.00%	100.00%

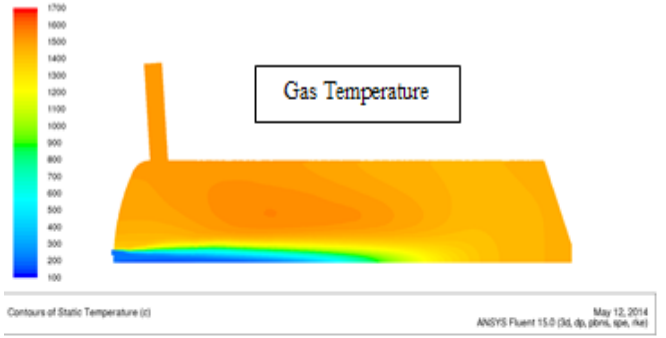
Ultimate Analysis[5]	**As-Received**	**Dry**
Carbon	50.23%	69.21%
Hydrogen	3.41%	4.70%
Nitrogen	0.65%	0.89%
Sulfur	0.22%	0.30%
Chlorine	0.02%	0.03%
Ash	4.50%	6.20%
Moisture	27.42%	0.00%
Oxygen	13.55%	18.67%
Total	100.00%	100.00%

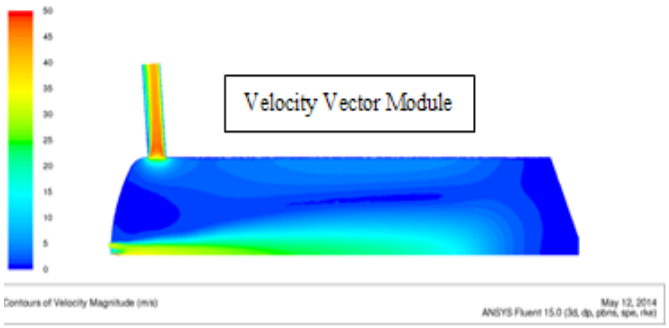
Heating Value[2,5]	**As-Received (Reported)**	**Dry (Dulong calc.)**
HHV (Btu/lb)	8,800	11,546
LHV (Btu/lb)	8,486	11,113
HHV (kJ/kg)	20,469	26,856
LHV (kJ/kg)	19,738	25,850

Combustor Design

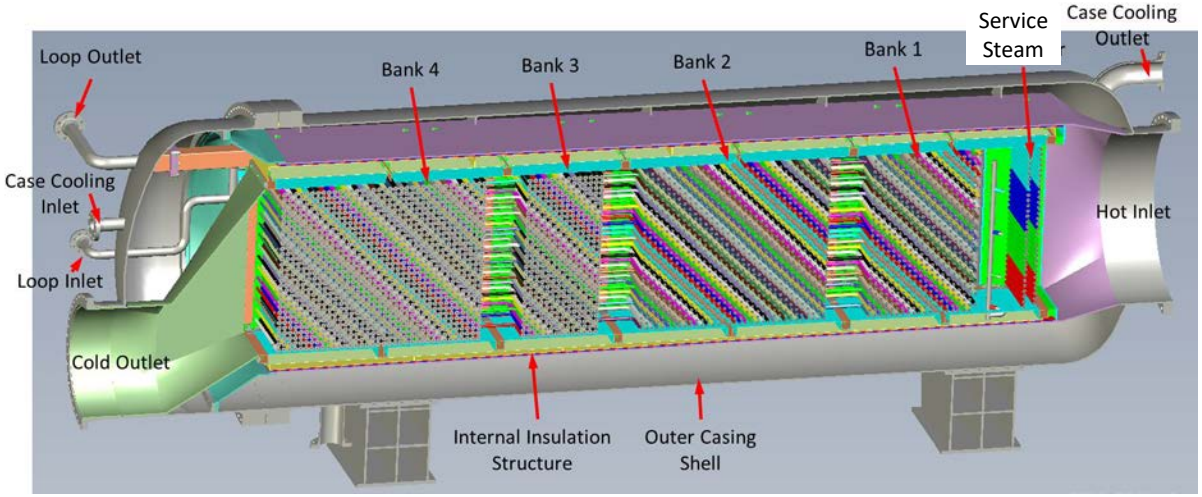
- Vertical design
  - Evolution from the horizontal combustor in the 5 MWth pilot
  - Close to design of ITEA 15MWth commercial plant
  - Refractory lined
- Expanded volume cone
  - Gas and slurry injected at top
  - Temperature and velocity tuned with CFD
  - Cone reaches to the bottom of the combustor before traveling back up the sides to the exit
- Flue gas quenching occurs at exit







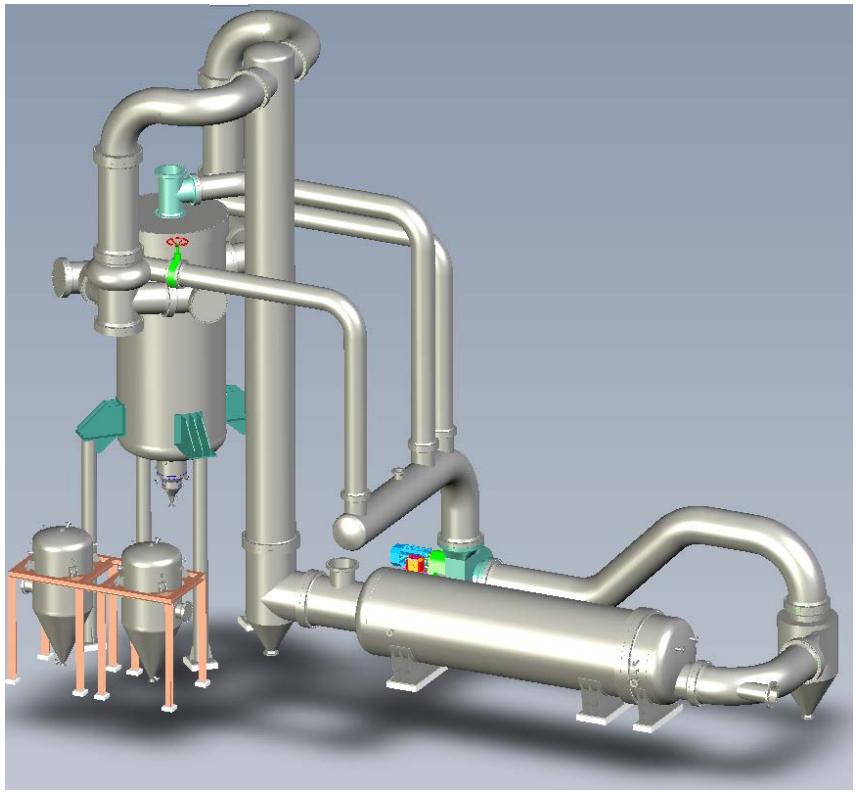
Once-Through Steam Generator (OTSG)



- Banks of finned tubes contained in a pressure vessel
  - Square duct supported and inserted into a circular pressure vessel
  - Between duct and pressure vessel is pressurized with cooler gas from the recycle blower
- Modular tube bank design can include multiple reheats
  - Banks can be assembled in different orders that optimize gas temperature profile
  - Fast startup and shutdown improves flexibility
- Size can improve ease of manufacturing and cost
  - Design of each OTSG could be kept small enough for off-site fabrication and transport
  - Multiple OTSG units may be needed, depending on plant scale

FPO 50 MW Loop Layout

- ITEA design
- Batching of quenched slag at bottom of elevated combustor
- OTSG horizontal for minimal support
- Refractory lining for combustor/pipe sections at 1380°C
- Footprint for layout in overall facility

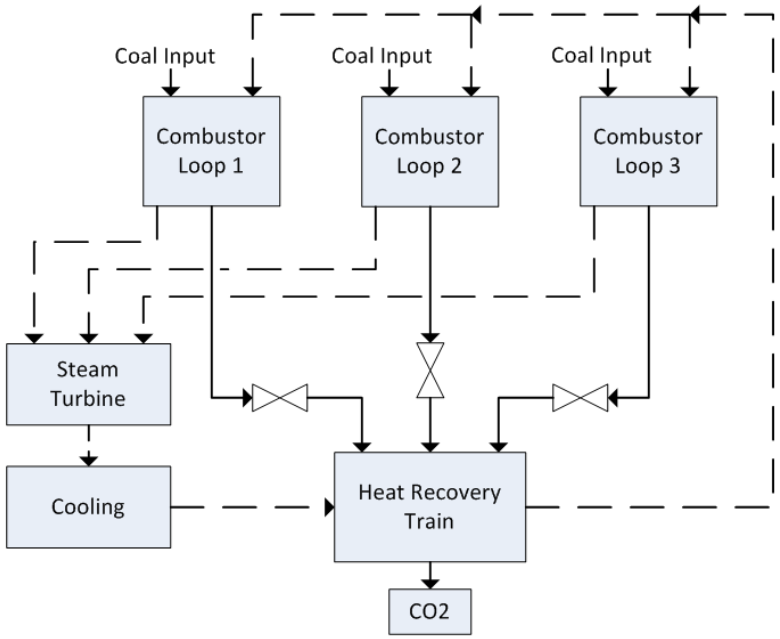


Preliminary Test Plan

- Test plan being developed to target areas of risk and advance TRL of FPO
- Includes multiple phases of testing that mitigate risk
  - Subscale slurrying and firing trials
  - Cold commissioning of the 50MWth plant
  - Hot commissioning and shakedown
  - Steady-state, flexibility, and dynamic load testing
  - Inspection outages
  - Performance testing on-design
  - Off-design condition testing

Commercial FPO

- ITEA study with ENEL showed that cost greatly increases above 500MWth boiler
- To achieve 500MWe output, modular approach needed
- FPO loops would include combustor, OTSG, turbo-expander
- All other elements would be consolidated into single packages
  - Steam power
  - Flue gas treatment
  - Heat recovery package
  - Carbon capture



Thank You