Clean Combustion System™ (CCS) Retrofit of Power Boilers for SO₂ and NOₓ Control with Improved Efficiency

CCS Re Engineering Proposal - Phase 1 Concept Study

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# CCS Re Engineering Proposal - Phase 1 Study

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1. INTRODUCTION

Castle Light Energy Corp, a technology management firm located in Oxnard, California, is pleased to propose a Phase I Concept study to re-engineer a coal-fired power boiler with the Clean Combustion System™ (CCS).

The CCS emissions performance objective for this program is to update a power plant firing PRB Sub bituminous coals to meet the strict EPA air quality regulations for SO₂ emissions (<0.2 Lb. SO₂ / MMBtu), NOₓ emissions (< 0.1 Lb. NOₓ / MMBtu), and to improve the boiler efficiency to meet the proposed EPA Clean Power Plan for CO₂ reduction (~6%). An existing bag house or ESP is to provide particulate control.

The Clean Combustion System (CCS) is a patented field-demonstrated combustion technology that provides coal-fired electric generating plants control of SO₂, SO₃, and NOₓ emissions right in the combustion step. The CCS features improved boiler efficiency (reduced CO₂) and minimizes ash and corrosion deposits on the furnace wall and back-pass sections. There are no hazardous or toxic chemicals or water requirements. The only “chemical” required is limestone. As the CCS technology installation qualifies as an emissions reduction program, construction permits are available with waivers of NSPS & PSD and no New Source Review (NSR) trigger.

The CCS technology was developed from fundamental combustion theory at Rockwell International in the 80’s with some $60 million in utility pier reviewed R&D testing and field-demonstration operation. The CCS may retrofit nearly all boilers types including cyclone, wall-fired, tangential and stoker, and is capable of converting gas and oil-fired boilers to coal firing.

The CCS installation costs are expected to be less than one-third the cost of conventional SCR/ammonia system (for NOₓ control) and an FGD/limestone scrubber system (for SO₂ control). A CCS re-engineered plant promises to provide the boiler owner / operator emissions compliance and many more years of competitive dispatch operation.

1.1 PHASE I PROPOSAL OBJECTIVES

The Phase I retrofit study objectives are to:

1.) Confirm the CCS technology will meet the boiler owner’s emissions and performance targets with the selected coal,
2.) Collect project and site information, documentation, fuel specifications and boiler specifications and drawings to develop the appropriate CCS retrofit design (see Appendix A - List of Information Needed),
3.) Review the boiler and plant facility to fit and accommodate the CCS equipment,
4.) Prepare recommendations for the engineering, design and hardware supply.
5.) Deliver a CCS re-engineering proposal and cost estimate.
1.2 CCS RETROFIT PROGRAM

A CCS retrofit is a custom modification of the coal-fired boiler and its coal preparation equipment. A retrofit entails the engineering, design and analysis to facilitate:

- The removal the existing burners and wind box, including the burner water-wall section of the boiler,
- The addition of new larger fabricated ports to the boiler water-wall.
- Installation of the new CCS burners and gasification chamber(s) to fire through the new ports on the boiler,
- Addition of new over-fire air ducting and ports to the boiler as required,
- Modify the existing pulverized coal system to an “indirect fired” system,
- Add new pulverized coal metering feeders to the CCS burners.
- Equipment to meter powdered limestone to the coal pulverizers,
- Modify / add a new slag/bottom ash collection/disposal system,
- Revisions to the Operator HMI Panel; Burner Management and Plant DCS controls and instrumentation as required for the new CCS equipment, including revisions to the MCC.

1.3 CCS TECHNOLOGY TECHNICAL APPROACH:

1.3.1 Coal Preparation and Drying:

The CCS fires standard grind powdered coal (70% through 200 mesh) from the plant’s coal mill(s). Powdered limestone is metered to the mill at a rate of ~100 pounds CaCO₃ per Ton of coal. Typical sub bituminous PRB coals contain ~30% water. For improved combustion efficiency and to reduce CO₂ emissions, we will dry the coal to remove surface water.

Recall that the conventional “direct-fired” boiler uses hot air from the air pre-heater to provide the primary combustion air that conveys the coal through coal-mill(s) and to the burner(s). However, as the CCS gasification process requires much less combustion air than typical coal burners, we must first convert the coal mill to an “indirect fired system”. See Figure 1.
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We will add a small bag house to each coal mill and re-direct the pulverized coal and sweep gas to the bag house; to separate the powdered coal from the sweep gas. Also, rather than use hot air primary air as the mill sweep gas, we will extract hot, inert flue-gas (oxygen <10%) from the plants exhaust. As the coal is pulverized, the very hot sweep gas evaporates the coal’s surface moisture, drying the fine coal particles to <10% moisture. Our coal-drying process is very fast (about one second) and prevents fire and puffs for safer mill /bag house operation.

The dry powdered coal is then collected in the bag house hopper and directly metered and conveyed to the CCS burners as required to meet plant load. The coal’s residence time in the bag house hopper is limited to <15 minutes. The now cool and wet sweep gas from the bag house is rerouted around the furnace to the plant’s exhaust.

By removing the coal moisture from the furnace, we improve the coal’s quality (Btu/Lb values) for improved combustion efficiency (reduces latent heat water loss), reduced coal consumption and CO₂ emissions. For the sub bituminous PRB type coals, this step can meet EPA’s “Clean Power Plan” for CO₂ reduction of ~6%. The estimated cost of this modification is ~ $30/kW, plus installation.

1.3.2 CCS Working Principle:

Described as a “Hybrid of Coal-Gasification” and “Over Fire Air Staged Combustion” process, the CCS replaces the boiler’s existing coal-burners and wind box with the same number of new CCS Burners.

The CCS burners fire into one or more Gasification Chambers that are mounted directly on the boiler’s water-wall (replacing the wind-box & burners). See Figure 2. CCS Schematic.

The Gasification Chamber(s), formed of studded and refractory lined water-wall, provides the necessary fuel-rich combustion conditions and residence time (fractions of a second) required for the CCS sulfur capture and NOx destruction process.

The gases exit from the Chamber directly into the bottom of the boiler furnace.

Figure 2. CCS Schematic
All of the CCS equipment and instrumentation is familiar to the operators. The boilers start-up, shut down, and burner and mill out-of-service procedures will remain the same as before the modifications.

1.3.3 Carbon Oxidation:
All of the pulverized coal and limestone is metered to the CCS burners with a limited quantity of hot air. The coal lights off and quickly consumes all available oxygen, to create a hot, very-fuel-rich gas. Sufficient residence time is provided in the Gasification Chamber for the combustion kinetics and chemistry to reach equilibrium. In this very-fuel-rich environment, the hot carbon particles are aggressive for oxygen from any source, including water and carbon dioxide (H₂O & CO₂). As this is an endothermic process, gas temperatures will tend to drop. The result is a clear hot bright orange gas of nitrogen (N₂), carbon monoxide (CO), and hydrogen (H₂), with some free carbon particles that exits the chamber into the furnace section.

1.3.4 Sulfur Capture in Combustion:
Engineers are aware that sulfur can be captured right in the initial coal combustion step. The fluidized bed combustor (FBC) is a well known commercial process which burns coal at rather low temperatures (~1600F) in a bed of sand and limestone, fluidized with hot combustion air. As the carbon is oxidized and creates heat, the calcium from the limestone captures the sulfur in the coal (as calcium sulfate - CaSO₄). The FBC combustion process is rather slow, requiring several seconds of residence time to burn the coal. The FBC combustion process requires large horse power, high pressure air blowers to circulate the bed. The FBC is limited boiler size (<200 MW) and suffers lower combustion efficiencies. It is best suited to fire low quality, high sulfur fuels.

However by comparison, the CCS is a fast, very fuel-rich sulfur capture process. As the carbon is oxidized, the sulfur is released from the coal into the hot gasses. Normally, under fuel-rich combustion, the sulfur would form a hydrogen sulfide (H₂S) compound. However, as we have added calcium to the coal (as limestone), the calcium beats out hydrogen for the sulfur, and forms calcium sulfide (CaS), a solid particle even at these high temperatures. Note that if any oxygen were to later contact the CaS, this compound oxidizes to SO₂.

1.3.5 Coal Ash and Sulfur Disposal:
To complete the sulfur capture process, we have learned how to generate sufficiently high temperatures that cause the coal ash (silica - SiO₂, and alumina - Al₂O₃), to mix with the calcium sulfide (CaS) and melt. You may recall that the formula for glass is; silica, alumina and calcium oxide (CaO). However, since we have substituted sulfur for the oxygen (in the CaS) the products melt together and encapsulate the sulfur in the liquid glass (ash/slag) product. The sulfur is bound tightly in the slag product and will not leach into water. About half of the melted ash contacts the walls of the gasification chamber and drain as bottom ash into a water quench tank for disposal. This slag
product has commercial values (~ $3/T) and is suitable for grit blasting metal, roof grit, etc. The remaining fine ash droplets are carried into the furnace section and become fly ash.

1.3.6 \( \text{NO}_x \) Formation and Destruction:

In coal combustion, the nitrogen in the coal (typically ~ 1%) is the major source of \( \text{NO}_x \) (~85%) in power plant flue-gas. \( \text{NO}_x \) formed from the high temperature oxidation of nitrogen (>2300F) in the combustion air; so called “thermal” \( \text{NO}_x \) comprise the balance.

In the late 70’s, combustion research at Rocketdyne by Dr. Axworthy showed that the nitrogen in the coal forms \( \text{NO}_x \), or the precursors of \( \text{NO}_x \) - such as ammonia (\( \text{NH}_3 \)), and cyanide (HCN), at the same time and place as the carbon is oxidized. Further, he demonstrated that this fuel-\( \text{NO}_x \) formation process cannot be avoided; such as with low temperature combustion processes, as used to avoid thermal \( \text{NO}_x \) formation when firing natural gas.

However, careful observations of Fluid Bed Combustion (FBC) showed that something was effectively reducing the fuel-\( \text{NO}_x \) levels in the bed. And a theory evolved to look for a \( \text{NO}_x \) destruct catalysis that may be found in the combustion step. A lab furnace was set up to duplicate the FBC combustion bed conditions. The minerals and compounds found in coal were exposed to \( \text{NO}_x \) under combustion conditions and any change in \( \text{NO}_x \) inlet / outlet levels were noted. It was determined that calcium sulfide (CaS) was a gang buster \( \text{NO}_x \) destruct catalysis, especially under the fuel-rich, high-temperature conditions such as found in an FBC bed.

This was a remarkable discovery, as Rockwell was developing a new coal-fired burner for \( \text{SO}_2 \) control; with fuel-rich combustion featuring sulfur capture with calcium. Calcium sulfide is a very reactive compound; it quickly oxidizes to \( \text{H}_2\text{S} \) in air, so it must be created when and where needed.

In the 1 T/hr R&D burner development, we observed that the CaS destroyed fuel-\( \text{NO}_x \) to “single digit ppm levels” right in the initial combustion step – only some 30 inches from the burner face.

Rockwell now had a new coal-fired burner concept with \( \text{SO}_2 \) capture that included synergistic \( \text{NO}_x \) destruction …………..at no extra charge nor toxic chemicals required!

1.3.7 Boiler Furnace Over Fire Air (OFA) Staged Combustion:

The hot fuel-rich gases of \( \text{N}_2 \), CO, and \( \text{H}_2 \) exit the gasification chamber into the boiler furnace where the relatively “cold, water cooled walls” begin to cool the gases and generate steam. As we are concerned for and wish to avoid any “thermal \( \text{NO}_x \)” formation, so we must wait for the gasses to cool to <2300F. At these temperatures, any ash droplets carried over quickly solidify to form fly ash (~10 micron) particles.
We can then carefully stage over-fire-air into the furnace with a multiple of ports to complete the combustion of CO to CO$_2$ and H$_2$ to water with sufficient air to exit the furnace into the boiler’s back pass (super heater section) at ~ 3% O$_2$ and at the same design conditions as was before the CCS retrofit. A clear bright orange gas, free of flame fills the furnace. The furnace walls are clean, without slagging, fouling and corrosive sulfur deposits. An ESP or bag house provides the necessary final particulate control before the smoke stack.

The Figure 3, CCS Retrofit Concept shows a cross-section of a CCS modification of a wall-fired boiler design. The wind box and burners are replaced with factory manufactured water-wall sections and new CCS Burners. Over fire air ports are added to the furnace to complete the combustion in the furnace section. The bottom ash system is modified to collects bottom ash for disposal.

![Figure 3. CCS Boiler Retrofit](image)
2. CCS EMISSIONS PERFORMANCE SUMMARY

2.1.1 SO₂ Emissions Control:
When burning low-rank sub-bituminous type coals (Wyoming Powder River Basin), the CCS has demonstrated control of sulfur dioxide (SO₂) emissions to low levels (<0.2 lb. SO₂/MBtu or ~105 ppm). See Figure 4. Notice that as the sulfur has been removed, there is near-zero SO₃ in the exhaust gasses, enabling lower furnace exit temperatures for improved plant efficiency. The CCS carbon conversion to energy is excellent, with very little carbon (LOI) in the final fly ash product.

2.1.2 NOₓ Emissions Control:
The CCS synergistic NOx destruction process, resulting from sulfur capture as described herein, reliably demonstrates very low NOx emissions for all coals:

Low NOₓ/SOₓ Coal Application Plant (LNS-CAP)- Cold Lake, Alberta, Canada:
3 T/hr.: firing western sub-bituminous coal – see Figure 4.<0.15 Lb NOₓ/MBtu (<110ppm NOₓ)

- Industrial Stoker Boiler, Cario, IL, USA:
  30 MWT firing high sulfur Illinois coal;
  @ < 90% MCR; 0.04 to 0.07 Lb NOₓ /MMbtu (30 to 50 ppm NOₓ) @ 100 % MCR; 0.12 Lb NOₓ /MMBtu (~0.88 ppm NOₓ)

2.1.3 CO₂ Emissions Reduction & Fuel Cost Savings:
Western sub bituminous PRB type coals contain ~30% water. As discussed earlier, drying the coal provides a significant combustion efficiency improvement with reduced...
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CO₂ emissions. This performance directly addresses EPA’s CLEAN POWER PLAN requiring CO₂ reduction for coal-fired powered plants. As an example, for a 600 MW plant firing PRB coals dried to ~9% moisture:

- Btu/lb (HHV) = 10,667: Improved 26%
- Boiler Efficiency: Improved 3.0%
- CO₂ Emissions: Reduced 4.2%
- Coal Consumption: Reduced 483,000 T/yr
- Fuel Cost Savings @ $30/T $14 million/yr

2.1.4 Commercial Retrofit Project: 30 MW T CCS Stoker® Boiler

Phenix Limited, LLC, the predecessor to CastleLight Energy, contracted to re-engineer a 1940’s industrial Stoker boiler to fire low-cost, high-sulfur Illinois coal with SO₂ and NOₓ control. The contract scope included the CCS process design & engineering and to supply the project with all the equipment, hardware, electrical, instrumentation and controls with a limited commercial warrantee & license. The plant owner installed the equipment.

This project was completed on time and on budget and commenced commissioning. As a first of a kind project, it took time to sort out the details, particularly related to ease of start up. The operators were able to demonstrate a cold start up to full load operation in five hours from the HMI panel. This project provided a lot of experience and data and confirmed the potential of the CCS process.

Around this time, the cost of natural gas dropped. The owner decommissioned the CCS boiler and installed a NG fired boiler.

For more details about this project, please see the paper titled; “OPERATING EXPERIENCE OF A COAL-FIRED BOILER RETROFIT WITH AN ADVANCED HYBRID OF COAL GASIFICATION FOR SO₂ & NOₓ EMISSIONS CONTROL AND REDUCED OPERATING COST”

2.1.5 Ash Deposition on Furnace Walls:

About one-half of the coal ash from the CCS gasification chamber passes through the furnace as a dry, fine particulate fly ash. Figure 5. shows the CCS-Stoker® Furnace Ash deposition after about 6 months of operation. Notice that the CCS ash does not deposit on the furnace water walls or back pass sections. Nearly all the ash product was conveyed to the boilers bag house. Very little fly ash collected in the stoker’s back pass ash hoppers. About three inches of dust covered the boiler floor.

Figure 5. CCS-Stoker® Furnace Ash Deposition
3. CCS TECHNOLOGY MATURITY

3.1.1 CCS- Boiler Retrofit

As an example of a CCS retrofit, Figure 6. CCS Power Boiler Retrofit (3 View) shows a typical 600 MW opposed-wall electric generating power plant.

In this example, the 24 coal-burners will be removed, and the burner ports bricked over or reconfigured as CCS over-fire air ports.

The wind box and ducting (green) will be removed, leaving the boiler water walls. (The SCR unit is not required)

To re-engineer this unit with the CCS, 24 new CCS Burners mounted on six new CCS Gasification Chambers will be pre-fabricated at a boiler shop and delivered ready for installation.

Openings for the CCS Gasification Chamber(s) will be saw-cut through the furnace hopper water-wall section. The CCS Gasification Chamber assembly will be inserted into the openings. Bottom ash is collected from each GC section.

New fabricated water-wall sections will connect the openings in the furnace to maintain the furnace water-wall cooling flow as before. Much of the boilers air combustion air will be ducting to new OFA ports in the upper furnace walls.

Figure 6. CCS Power Boiler Retrofit (3 View)
3.1.2 CCS-Tangential® Boiler Retrofit
CastleLight developed a proposal for Indianapolis Power & Light to participate in a Department of Energy Clean Coal Technology demonstration. The CCS technology was to be installed on their 100 MW Unit #6 tangential boiler at the Harding Street Station. At that time, the retrofit approach was to add two CCS gasification chambers, one on each side of the furnace, each with 8 CCS burners, replacing the existing tangential burners on the four corners. OFA was to be provided by the SOFA and corner ports. See Figure 7. CCS-Tangential® Boiler Retrofit Concept.

Figure 7. CCS-Tangential® Boiler Retrofit Concept
4. CCS RETROFIT APPROACH

4.1 SUMMARY OF PROJECT PHASES

Figure 8. entitled “CCS Retrofit Project Flow Diagram” illustrates the steps planned to complete a CCS retrofit installation on a power boiler.

CastleLight will report to the Client’s designated Project Manager as the CCS technology manager. CastleLight will supply the proprietary CCS technology, engineering, design, analysis (including advanced CFD and PEPSE), and will supply the hardware and instrumentation needed to modify the boiler.

The client is responsible for all on site activity, including demolition, construction and installation services, as required to install the CCS hardware.

CastleLight will provide onsite support during the construction through to the plants start-up and commissioning, so as to assure the CCS is properly installed.

This proposal is for a Phase I “Retrofit Study” only.

Figure 8. CCS Retrofit Project Flow Diagram

4.2 CCS RETROFIT INSTALLATION

CastleLight will work closely with Client’s during the engineering phase to coordinate a well-planned CCS retrofit, and proactively identify outage issues and installation cost estimates.

The estimated cost for a CCS retrofit vary, primarily due to site-specific issues, but are modest when compared to typical FGD and SCR installations. The CCS Retrofit of the furnace are largely modifications to the water-wall, and familiar to the boiler manufacturer. The design concept show nearly all of the modifications can fit within the existing boiler and wind box area.
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An example of a CCS Gasification Chamber installation is shown in Figure 9.

Figure 9. Gasification Chamber Installation
4.3 MODELING OF BOILER MODIFICATIONS

The first step in Phase I study will be to develop a detailed 3 view model of the furnace and plant, complete with all major piping and building structures. This model enables the design and evaluation the CCS modifications and the assessment of any interferences or installation issues. CFD and PEPSE programs are used to assess the heat transfer affects from adding the new CCS gasification chamber to the boiler steam circuits. We use CFD modeling extensively to determine how best to locate new OFA (over-fire air) ports in the furnace. We assess CO combustion and any potential for new NOx formation. CFD also addresses boiler operation at different load profiles to assure that the gas temperatures entering the boiler superheat section are the same as before retrofit.

4.4 OUTAGE PLAN

The key to minimize retrofit cost is to schedule the work around the boilers annual outage, as loss of power production equates as an added cost to the retrofit. Therefore, project planning and engineering will focus on minimizing the retrofit outage period.

A detailed inspection will be conducted to assess any onsite issues typically not shown on drawings. A Base Line performance test is conducted to develop needed design information.

Before the outage, and while the unit is still in operation, supports and braces will be installed to hold major boiler sections in place during the modifications. Monorails and lifting gear will be installed. Other equipment, such as the limestone preparation and ash handling systems can be installed and checked out. The required CCS retrofit hardware, such as the CCS burners, water wall modifications, OFA ports and ducting, bottom ash equipment, etc. will be shop fabricated and delivered to the site.

During a scheduled outage, the existing PC burners, and portions of the boiler water-wall and wind-box ducting are removed. Shop-fabricated CCS burners, a new gasification chamber assemblies, ducting, OFA ports, etc. are delivered to minimize the boiler outage schedule. During the retrofit project, the new hardware is moved into place and welded to the existing water-wall, along with the new over-fire air ports and ducting, according to design specifications.

The actual retrofit then is a carefully scheduled sequence of boiler water-wall modifications, wherein existing air ducting and water-wall sections are cut away and removed. As a section is removed, the new shop fabricated water-wall sections are maneuvered to match the existing tubing and welded. This sequence will minimize the requirements for support and bracing of the remaining boiler. Typical boiler water-wall replacement schedules take about three weeks, scheduled with two 10-hour shifts per day, six days a week with Sundays off.
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5. PHASE 1 - SCOPE OF WORK

CastleLight proposes to conduct a **Phase I Study** to retrofit the CCS technology on a selected coal-fired power boiler firing a selected coal. The Phase I study is planned as a thirteen week program (after receipt of plant data - see Figure 3 titled “CCS Retrofit Phase I Schedule”) that comprise the following tasks:

5.1 TASK A: PROJECT KICK-OFF MEETING

Castle Light will conduct an on-site kick-off meeting and briefing of the client’s management team. This meeting is a forum for the management teams; to clarify the project goals and objectives, define individual responsibilities and reporting roles, review the contract to reaffirm all tasks and assumptions previously made, and make appropriate changes to obtain mutual commitments to the project’s success.

The first step for CastleLight is to gather all relevant boiler specifications, drawings, operating procedures and schematics applicable to the project. **Addendum A** list the information needed. The next step is to conduct an engineering analysis and develop a CCS process flow sheet based on the client’s coal specifications (proximate, ultimate and ash analysis).

5.2 TASK B: DEVELOP CCS REQUIREMENTS:

The Castle Light team will perform an engineering analysis of the boiler and system heat balance, mass balance and process requirements. This information provided the basis to design and size the CCS burner(s), identify the fuel and air requirements and prepare a preliminary P&ID and Flow diagram. The balance of plant site modifications and requirements for coal preparation and ash handling are then addressed. The selected coal and it's additives for sulfur capture will be assessed.

5.3 TASK C: BOILER MODIFICATIONS AND EQUIPMENT SCOPE

3 view drawing(s) of the existing plant site will be developed from plant files. These drawings will be revised to show the proposed CCS burner and gasification chamber, to demonstrate fit to the existing boiler configuration. Furnace OFA and suggested ducting concepts will be developed. Other major equipment items and any recommended modifications will be shown. A review of these design concepts will be discussed with the Plant Operators and Plant Management for comments and suggestions. Specific issues that require further engineering analysis; such as criteria for boiler start-up, operation, control and safety will be identified and discussed at this time.
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5.4 TASK D: BALANCE OF PLANT

The balance of plant equipment from the coal pile to the CCS interface and from the boiler flue gas exit to the plant stack will be identified and evaluated. Included are the expected modifications to facility, equipment, coal and additive requirements, bottom ash disposal, particulate control requirements. This information will be included in the 3-D view drawing to show the general arraignment for the major equipment items including OFA duct routing, with consideration for installation issues / interferences, and the overall planned equipment operation.

5.5 TASK E: DELIVERABLES

A. CCS Retrofit Design Report:

The Phase I retrofit study will be provided in a summary report. The report will include an assessment of the CCS system design, its application to the selected boiler, the expected benefits, issues to be addressed and suggested approaches for integration and solution. The process and analysis will include:

- Preliminary Mass & Heat Balance for the retrofitted CCS operation;
- Preliminary Process Flow Diagram;
- Estimated plant Efficiency;
- Estimated plant stack gas emissions and byproduct solids output;
- Estimated coal and additives required;
- Technical issues requiring further detailed assessment;
- Technical stipulations and advantages of the retrofit, including expected start-up operation and turndown, and shutdown requirements;
- Draft CCS Retrofit specifications: CCS Burner, fuel preparation and delivery, additives and auxiliary equipment requirements.
- CCS retrofit cost estimate (+/- 20%) and suggested technical recommendations.

B. On-Site Briefing:

This briefing will include review of the CCS design criteria selected for this project and any issues with the facility equipment, such as MCC capacity, instrumentation interface with the CCS burner management or combustion control systems and other items as appropriate.

C. Incorporate Client Comments - Design Review.

With the objective to address Client questions and operational issues, Castle Light will lead Design Review discussions related to the study report materials, technical assessments and findings based on the data analysis, application feasibility and overall findings as applied to the plant retrofit. To minimize effects on schedules and additional travel costs, we propose that the design review meetings be conducted over Web-Link interactive media sessions. Action items from the Design Review will be developed and estimated for inclusion in the Phase II tasks.
D. Issue a Proposal for the Engineering, Design and Hardware Supply:

The Phase I study is expected to provide confidence in the CCS retrofit feasibility and practical application. The deliverable product from this Phase I study will be a formal proposal for the Phase II – Design, Engineering and Hardware Supply. Information developed in the Phase I task will provide the basis for the Phase II design and engineering required for the technology retrofit program.

5.6 PHASE I SCHEDULE

The Phase I project information and reports will be completed approximately 13 weeks from receipt of the all necessary data, plant specifications and required drawings from the site (see Appendix A). Please refer to Figure 10. CCS Retrofit Phase I Schedule for the WBS and task breakdown details.
Figure 10. CCS Retrofit Phase I Study Schedule
6. PROJECT TEAM

6.1 PROJECT MANAGEMENT ORGANIZATION

The Castle Light team will include consultants and specialists with extensive technical experience in advanced combustion modeling, design, boiler modifications, repair, operation and maintenance. A suggested Project Management Organization is shown in Figure 11.

![Project Management Organization Diagram]

**Figure 11. Project Management Organization**

6.2 CAPABILITIES OF CASTLELIGHT ENERGY CORP.

The principal members of CastleLight have been together since the initial combustion concept was conceived at Rockwell International in the early 1980’s.

**Keith Moore - President,** BS EE, - Has 30+ years of technical and management experience in advanced environmental emissions control technologies for utility fossil-fueled power plants. At Rockwell, he was Manager, Business Development of the “Dry” Flue Gas Scrubber technology. Moore participated in the CCS technology development from its inception in 1980 through the early R&D and field demonstration projects in the U.S. and Canada. As Vice President of TransAlta Technologies, Inc., he provided the business development, utility marketing and related business development to promote...
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the CCS technology for emissions control of coal-fired power plants. Some 2000 MW of CCS engineering retrofit studies have been conducted. A 5 ton/hr Stoker boiler was retrofitted with the CCS technology and operated to full MCR ratings. CastleLight now retains all rights to the CCS technology. Moore’s role is the point of contact for all elements of CastleLight responsibilities.

Larry Martin P.E. - CCS Technology Manager - BS, MS - ME; has extensive experience with utility power plant emissions control projects and the CCS technology. Mr. Martin was the project manager on the earlier CCS R&D combustion programs, and at TransAlta Technologies, Inc., managed the two technology demonstration projects in the U.S. and Canada. Mr. Martin provides the CCS process and CFD analysis, thermal modeling, and the P&I and flow diagrams, for the burner and gasification chamber design and specifications.

6.3 PROPRIETARY PROGRAM

The CCS Burner technology is an advanced innovative combustion process that uses emission control concepts not available in the published literature. The actual design and theory that describe the CCS Burner were developed with private funds and are proprietary trade secrets. All participants needing access to CCS design information, including vendors and construction contractors are expected to sign and maintain confidentiality agreements with CastleLight Energy Corp.
The following documents, drawings and specifications are needed for CastleLight to conduct a Phase 1 study:

**Plot plan and site layout drawings and specifications for all relevant equipment**

- **Boiler drawings for all affected operations** (elevation, plan, and cross section)
- **Permitted allowable emissions as fired, and target emissions for the CCS retrofit**
- **Overall P&ID and PFD** (with material balance) of existing plant including any modifications
- **Coal specification and Analysis:**
  1. Proximate analysis
  2. Ultimate analysis
  3. Coal ash analysis
  4. Ash Fusion characteristics - T250 temperature
  5. Fuel Cost: $/MMBtu or $/Ton

- **Boiler data**
  1. Make of boiler
  2. Date of installation
  3. Boiler operating loads (Max, Min, Avg, and turndown required)
  4. Boiler start-up (time required, procedures)
  5. Boiler utilization and number of startups per year
  6. FD fan – Flow, head, HP for operating and design conditions
  7. Process control system – Type; can it incorporate the CCS?
  8. Geographic location and elevation above sea level
  9. Modifications to boiler, plant and related equipment post installation
  10. Maintenance plans

- **Heat Rate & Steam Balance data:**
  1. Heat Rate Diagram and Size of Unit (including temperature at super heater inlet)
  2. Turbine – Generator Manufacturer
  3. List of Auxiliary Motors

- **Pulverizer Data – if available**
  1. Capacity - Lb/Hr.
  2. Pulverizer sweep gas; pressure, flow rate and temperature

- **Description of fly ash collection system** – Type, maximum grain loading and particulate emission limits, capacity

- **Continuous Emissions Monitor** – Emissions and Instrument Specification

- **Comments** – Please note any particular requirements, unique equipment modifications, operational requests, instrumentation, controls, and optional fuel specifications.