Re-Engineering Coal-Fired Generating Plants for Low Pollutant Emissions and Extended Competitive Life

Meet EPA’s Cross State Air Transport Rules (CSAPR) and Mercury and Air Toxic Standards (MATS) with low-cost Coal Beneficiation and Hybrid Coal-Gasification

By
CastleLight Energy Corp
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CastleLight Energy Corp.

- CastleLight Energy Corp. comprises the technical team from Rockwell International - from 1980’s rocket engine modeling programs.
- Developed the Clean Combustion System™ (CCS) - Control of $\text{SO}_2$ & $\text{NO}_x$ with improved efficiency
- Coal Beneficiation Processes
  - Remove water, ash, & mercury from coal
  - Recover oil values from coal
- Commercial Field Demonstrated Technology
- Provide Technology Management & Licensing
Observation
EPA’s Strict New Environmental Regulations

- Cross State Air Transport Rules (CSAPR)
  - Focus on SO\textsubscript{2} & NO\textsubscript{x} (particularly in summer months)
- Mercury and Air Toxic Standards (MATS)
  - Focus on Particulates, SO\textsubscript{2} Mercury, HAPS
- Green House Gas Performance (GHG) - No CO\textsubscript{2} increase allowed

Impact:
- The older, smaller (<400MW) coal-fired generating plants may be abandoned due to cost of emissions compliance.

Solution / Approach:
- Re-Engineer plant with Clean Combustion System (CCS) for:
  - SO\textsubscript{2}, NO\textsubscript{x}, and mercury emissions compliance
  - Higher Efficiency (No CO\textsubscript{2} increase)
  - Construction Permit with waiver of PSD - No NSR
  - Lower Retrofit & Operating Cost = Competitive Dispatch
Conventional Emission Controls

SO$_2$ = FGD + Limestone; NO$_x$ = SCR + Ammonia;
SO$_3$ = Trona, Hg = Activated Carbon
CCS Hybrid Coal-Gasification

SO$_2$ & NO$_x$ Control Right in the Combustion Step

<table>
<thead>
<tr>
<th>SO$_2$ Emission Reduction</th>
<th>NO$_x$</th>
<th>Plant Efficiency</th>
<th>Power Output</th>
<th>Plant Life</th>
<th>Incremental Electricity Cost</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 - 90+</td>
<td>HIGH</td>
<td>No Change</td>
<td>No Change</td>
<td>Slight Extension</td>
<td>2-4 M/MILLION/KWH</td>
<td>$75-110 PER KW</td>
</tr>
</tbody>
</table>

* CONVENTIONAL COAL-FIRED ELECTRIC POWER PLANT
Hybrid Coal Gasification Schematic
The Clean Combustion System (CCS)

CCS Gasification Chamber replaces coal burners & wind box

Existing Boiler Furnace
LNS-CAP Facility
ESSO Site, Cold Lake, Alberta Canada
50 mmBtu/hr – 3T/hr PRB Coal
Demonstrated Emissions
SO₂ - 0.2 lb./mmBtu & NOₓ - 0.15 lb./mmBtu
ESSO LNS-CAP Facility, Cold Lake, Alberta, Canada
CCS-Stoker® Project Description

- **Objective:**
  - Reduce operating cost by half
    (switch to low-cost high-sulfur Illinois coal – 2.5 lb. SO₂/mmBtu)
  - Construction Permit w/ waiver NSPS, PSD; no NSR
  - Emissions Warrantee: <0.9 lb. SO₂/mmBtu, <0.25 lb. NOₓ /mmBtu

- **Project Initiated:** Oct 2005,
  **Commissioning:** Jan 2007

- **CEC Scope:** Process Design & Engineering;
  - Supply all equipment, hardware, electrical, instrumentation / controls
  - Provide Commercial Warrantee & License

- **Client Scope:** Site Construction Management;
  - Equipment Installation, as directed by CLPRC
  - Commissioning & Start-up

- **Project Support:** In part, by the Illinois Department of Commerce and Economic Opportunity through the Illinois Clean Coal Institute and the Office of Coal Development.
Coal-Fired Stoker Boiler (typical)

CCS Retrofit Modifications

Remove:
- Stoker Feeders,
- Ash Hopper,
- Brick over stoker grate
- Control Panel

New Equipment:
- CCS Burner,
- Gasification Chamber,
- Combustion Air Heater
- Boiler Instruments,
- Coal Mill, Bag house, FD fan, BM & Combustion Sys,
- HMI & PLC Controls
- New MCC

Operators (one/shift):
- Was all manual operation;
- Now with HMI - from cold start to automatic full load operation in 5 hrs.
CCS-Stoker® Retrofit
30 MW (Thermal) - 125 mmBtu/hr – 5 T/hr Coal
Gasification Chamber Installation
Gasification Chamber Installation

- McBurney Corp designed and supplied the GC
- Connected to the boiler drums for natural circulation water cooling
- Shop fabricated membrane wall studded and refractory lined.
CCS-Stoker® Equipment and Operation
Pulverizer

- Refurbished 453 CE/ Raymond mill
- “Indirect Firing” Scheme
- Uses hot combustion flue gas (<10% O₂)
- Fixed sweep gas flow, variable coal flow
- Gas temperature adjusted to give 150F at exit
- Dry powdered coal to bag house
CCS-Stoker® Equipment and Operation
Coal-Air Separator

- Separates coal from sweep gas
- No air (O₂) added for bag cleaning
- Hopper w/ level switches maintains ~30min. coal supply
- Gate & spouts to rotary feeders - meters PC to CCS burners
CCS-Stoker® Operation Observations

Operation @ MCR – Steam Overboard
### CCS-Stoker® Retrofit Performance
#### Preliminary Results – Full Load Operation

<table>
<thead>
<tr>
<th>Item</th>
<th>Stoker Base Line Test</th>
<th>Preliminary CCS Performance</th>
<th>% Change from Base Line</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SO₂ Stack Emissions (lb/MMBtu)</strong></td>
<td>1.80</td>
<td>0.72</td>
<td>- 67.0 %</td>
</tr>
<tr>
<td><strong>NOₓ Stack Emissions (lb/MMBtu)</strong></td>
<td>0.50</td>
<td>0.14 (88 ppm)</td>
<td>- 72.0 %</td>
</tr>
<tr>
<td><strong>Boiler Efficiency</strong></td>
<td>77.0</td>
<td>86.9</td>
<td>+ 12.8 %</td>
</tr>
<tr>
<td><strong>CO₂ Emissions - Ton/yr GW credits (% Reduction)</strong></td>
<td>94,019</td>
<td>73,720</td>
<td>20,300T/y (- 21.6 %)</td>
</tr>
<tr>
<td><strong>Project Cost Recovery (from firing lower cost coal)</strong></td>
<td></td>
<td>~ 3 years</td>
<td></td>
</tr>
</tbody>
</table>
CCS-Tangential™ Boiler Retrofit
100 to 300 MW
600 MW B&W PC Fired Boiler
CCS Re-Engineered PC Boiler
600 MW – 6 GC’s, 24 Burners
## Capital & O&M Cost Assessment

**FGD + SCR + Baghouse** vs. **CCS + Baghouse**  
600 MW Power Plant - PRB Coal (Estimated)

<table>
<thead>
<tr>
<th>Control Technology</th>
<th>Retrofit Cost ($/kW)</th>
<th>Fuel Cost ($/Yr)</th>
<th>Fixed + Variable O&amp;M Cost ($/Yr)</th>
<th>Operating Cost ($/kW-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGD + SCR + Bag house</td>
<td>$ 1,165</td>
<td>$ 80,000,000</td>
<td>$ 24,000,000</td>
<td>$ 0.0200</td>
</tr>
<tr>
<td>CCS + Bag house</td>
<td>$ 425</td>
<td>$ 70,000,000</td>
<td>$ 11,000,000</td>
<td>$ 0.0154</td>
</tr>
<tr>
<td><strong>Delta Savings</strong></td>
<td>64%</td>
<td>14%</td>
<td>54%</td>
<td>23%</td>
</tr>
</tbody>
</table>

### 600MW Boiler

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GIVEN / ASSUMED</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stack Temperature</td>
<td>325 F</td>
<td></td>
</tr>
<tr>
<td>Heat Rate - Net</td>
<td>9600 Btu/kWh</td>
<td></td>
</tr>
<tr>
<td>Plant efficiency</td>
<td>35.5 %</td>
<td></td>
</tr>
<tr>
<td>Main Steam Pressure</td>
<td>2440 psig</td>
<td></td>
</tr>
<tr>
<td>Main Steam Temperature</td>
<td>980 F</td>
<td></td>
</tr>
<tr>
<td>Main Steam Flow</td>
<td>4250 KLB/h</td>
<td></td>
</tr>
<tr>
<td>Boiler Feed Water Temperature</td>
<td>425 F</td>
<td></td>
</tr>
<tr>
<td>Boiler Feed Water Flow</td>
<td>4250 KLB/h</td>
<td></td>
</tr>
<tr>
<td>Low NOx Burners - LOI</td>
<td>7 %</td>
<td></td>
</tr>
<tr>
<td>Coal Cost - PRB, Black Thunder</td>
<td>40 $/ton</td>
<td></td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>80 %</td>
<td></td>
</tr>
<tr>
<td>FGD - SCR Systems</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>
Re-Engineered Power Plant with CCS & Coal Beneficiation Processes

Stack Emissions Estimate* firing PRB coals (1.2 lb. SO$_2$/mm Btu Coal)

- $\text{SO}_2 = < 0.2 \text{ lb./mmBtu} (< 105 \text{ ppm})$
  - ~80% reduction
- $\text{NO}_x = < 0.10 \text{ lb./mmBtu} (< 75 \text{ ppm})$
- $\text{CO} = < 100 \text{ ppm}$
- $\text{LOI} = < 1\%$ (very low carbon in ash)
- $\text{SO}_3 = < 0.1 \text{ ppm}$ (condensable particulate)
- Mercury = $< 40 \text{ ppb}$
- Particulate = $< 0.03 \text{ lb./mmBtu}$ (bag house)
- Boiler Efficiency = $2 – 10\%$ increase

* Preliminary estimates of performance, includes bag house – no guarantees
CCS Features
Improved Operability, Availability & Reliability

- All equipment off-the-shelf & familiar to the Operators
  - Safe, stable operation,
  - Same startup, shutdown and turndown as a PC burner
- Bottom Ash (slag) removed before furnace
  - low particulate/ash load; clean furnace, less soot blowing
- Sulfur removed from furnace gases - near-zero SO$_3$:
  - Allows for lower furnace exit temperatures
  - Minimize water-wall wastage & corrosion,
  - Can use hot boiler exhaust for pulverizer sweep air:
    - Dry the coal – reject moisture
    - Improves coal pulverizer safety from fire & puffs (low O$_2$)
- Improved Boiler Efficiency (2 to +10%)
  - Reduce CO$_2$ emissions
  - High combustion efficiency (LOI < 1%)
- Limestone is only “chemical” required
- No waste water for disposal
CCS Summary
(Key Strategic Issues)

- From Fundamental Combustion Theory to Commercial Operation
- Fire lower cost coals - reduce plant operating cost
- Meets EPA’s new stringent CAIR initiatives for SO$_2$ & NO$_x$
- Allow power plant upgrade with waiver of NSPS & PSD - No NSR
- May generate CO$_2$ – SO$_2$ – NO$_x$ emission credits
- Low Retrofit Cost; maintain older, smaller power boilers competitive - improve capacity factor & dispatch
- Fits within Plant & Boiler Site Footprint
- No waste water discharge
- Coal waste is inert and may be land filled
- Ash products have value (sell bottom ash & fly ash)
- No Hazardous or Toxic Chemicals Required

It’s ADVANCED COAL GASIFICATION TECHNOLOGY!
CastleLight Energy Corp
Re-Engineering Programs

- CastleLight Energy Corp. provides advanced environmental engineering consulting services.
- Re-engineer / upgrade gas, oil and coal-fired plants:
  - To burn coal with reduced operating cost
  - Extend competitive life for 20 or more years
  - And meet stringent new EPA emission regulations.

Contact Castle Light Energy Corp.
5776D Lindero Canyon Road
Westlake Village, CA 91362
805-551-0983
E-mail: keith@castle-light.com
Web Site: www.phenix-limited.com