A Novel Integrated Oxy-Combustion and Flue Gas Purification Technology: A Near Zero Emissions Pathway

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Presentation Outline

- Background of WRITECoal™ Process
- Integration into Oxy-combustion
- Development Areas
- Modeling and Integrated System Performance
- Status / Next Steps
Project Team

Participants/Collaborators:

Western Research Institute: WRITECoal™ Oxy-combustion Development
Southern Research Institute: 1 MWth Oxy-combustion Facility
Foster Wheeler North America: Advanced Oxy-Burner Design
Etaa Energy: WRITECoal™ System Integration
Nalco: WRITECoal™ Water Recovery / Treatment
Praxair: CO₂ Purification Process
Energy and Construction URS: Economics

Co-Sponsors/Funding Sources:

UW School of Energy Resources State of Wyoming Clean Coal Program
Industry / Utilities
U.S. Department of Energy-National Energy Technology Laboratory
Objectives & Development Areas

Project Objectives:

Optimize and test at 1 MWth scale WRITECoal™ oxy-combustion system to achieve 90% CO₂ capture at <35% increase in COE for retrofit applications.

Developmental Areas:

- WRITECoal™ Process Performance
- Water Treatment / Re-use
- Advanced Burner Development
- CO₂ Purification
- Possible CO₂ Re-use

All areas need to be integrated in order to lower parasitic power and lower the potential increase in COE.
In order to reduce COE to <35% increase, it is necessary to reduce both capital and parasitic power load  (Reference: Ciferno, 2007)
**CO₂ Purification Requirements**

Current DOE (2007) CO₂ quality for compression, transport and storage are very stringent, requiring lower cost CO₂ cleanup options.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Saline Formation O₂ Restricted</th>
<th>Saline Formation O₂ Unrestricted</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>Not limited</td>
<td>Not limited</td>
</tr>
<tr>
<td>Water</td>
<td>Dehydration (0.015, vol. %)</td>
<td>Dehydration (0.015, vol. %)</td>
</tr>
<tr>
<td>N₂</td>
<td>Not limited</td>
<td>Not limited</td>
</tr>
<tr>
<td>O₂</td>
<td>&lt;100 ppmv</td>
<td>Up to 3%</td>
</tr>
<tr>
<td>SO₂</td>
<td>&lt;3 vol. %</td>
<td>&lt;3 vol. %</td>
</tr>
<tr>
<td>NOₓ</td>
<td>uncertain</td>
<td>uncertain</td>
</tr>
</tbody>
</table>
WRI’s patent pending integrated system incorporates several technologies including WRITECoal™ into oxy-combustion system to improve efficiency, reduce parasitic power and lower current estimated COE.
WRITECoal™ Process - provides the industry with an economical method of environmental compliance for both existing plants as well as for new greenfield PRB coal-fired plants. The benefits to retrofitting the existing fleet of PRB coal-fired plants include:

- Removal mercury and other volatile species (arsenic and selenium) prior to combustion allowing compliance with forthcoming mercury control regulations.
- Removal moisture from the coal, allowing recovery for use in the plant and reducing raw water plant consumption.
- Reduction of NO\textsubscript{X} emissions by up to 30%.
- Increase in plant efficiency - a 1% increase in existing plant efficiency would reduce fleet CO\textsubscript{2} emissions by 20 million tons/year.
- Deployment in connection with carbon capture can be staged to allow for preferred financing.
### WRITECoal™ Process

**WRITECoal™ Process Upgrades the Fuel and Reduces Hg and As**

<table>
<thead>
<tr>
<th>Proximate Analysis (wt%)</th>
<th>Raw (Dry)</th>
<th>Treated (Dry)</th>
<th>Ultimate Analysis (wt%)</th>
<th>Raw (Dry)</th>
<th>Treated (Dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>6.97</td>
<td>7.00</td>
<td>Carbon</td>
<td>69.62</td>
<td>72</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>47.66</td>
<td>43.64</td>
<td>Hydrogen</td>
<td>4.87</td>
<td>4.54</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>45.37</td>
<td>49.36</td>
<td>Nitrogen</td>
<td>0.95</td>
<td>1.01</td>
</tr>
<tr>
<td>Total Moisture (as rec.)</td>
<td>28.36</td>
<td>&lt;1.0</td>
<td>Sulfur</td>
<td>0.44</td>
<td>0.43</td>
</tr>
<tr>
<td>Mercury (ppm)</td>
<td>0.126</td>
<td>0.025</td>
<td>Oxygen</td>
<td>17.15</td>
<td>14.84</td>
</tr>
<tr>
<td>Arsenic (ppm)</td>
<td>4.2</td>
<td>1.4</td>
<td>Heating Value (Btu/lb)</td>
<td>11,991</td>
<td>12,184</td>
</tr>
</tbody>
</table>
WRITECoal™ Economics

- WRITECoal™ Process Shows a 17.6% and 12.5% Advantage Over ACI and TOXECON Processes

Present Worth of Revenue Requirements (PWRR)

- ACI Injection: $1,575
- TOXECON: $1,460
- WRITECoal™ Process: $1,298
WRI, Etaa Energy and Foster Wheeler have conducted CFD studies of the WRITECoal™ process in a PRB subcritical power plant. Results indicate no negative impact. Furnace performance still within design limits.
Four subsystems need development or confirmation as part of an integrated system.
WRI has teamed with SRI to conduct subsystem testing and process integration at SRI’s 1 MWth Oxy-combustion Test Facility.
WRI has designed and fabricated a mobile WRITECoal™ pilot plant capable of producing coal for a 1-2 MWth-scale oxy-fired plant.

Photograph of the WRI’s Mobile 1-2 MWth Pilot-scale WRITECoal™ Unit
(CHX shown in blue on the left)
Foster Wheeler is partnering with WRI to develop and test an advanced oxy-burner.

Testing of burner requires a minimum 1 MWth-scale oxy-combustor.

Low NOx Burner. Proposed changes not shown - Proprietary
WRI has teamed with Praxair to assess their CO$_2$ purification process as a part of WRI’s integrated process.

The novel flue gas purification process development is being conducted by Praxair with direct support from the U.S. DOE.

<table>
<thead>
<tr>
<th>Oxyfuel Technology</th>
<th>Current Technology</th>
<th>SO$_x$/NO$_x$</th>
<th>SO$_x$/NO$_x$ + VPSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>COE Increase, %</td>
<td>74</td>
<td>61</td>
<td>65</td>
</tr>
<tr>
<td>CO$_2$ Recovery, %</td>
<td>90</td>
<td>90</td>
<td>98</td>
</tr>
<tr>
<td>CO$_2$ Capture, $/ton$</td>
<td>47.7</td>
<td>40.1</td>
<td>38.6</td>
</tr>
<tr>
<td>FGD/SCR</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
**Modeling - Performance**

- **Scenario Basis:** Several scenarios for the reduction of parasitic power and lowering of the increase in COE for oxy-fired combustion with the WRITECoal™ process are being evaluated. As an example, the following basis was evaluated for a 550MWe (net) PRB coal-fired sub-critical retrofit plant:
  - Maximize WRITECoal™ performance with waste heat and recover water / steam for plant use.
  - Minimize oxygen use (ASU) to reduce parasitic power and reduce capital costs.
  - Integrate advanced flexible burner design to reduce emissions and minimize flue gas recycle rates.
  - Maximize O₂ recovery / recycle and reduce COE via novel CO₂ purification (Praxair).
  - Reduce parasitic power from CO₂ compression through CO₂ use / recycle.

**Results:** 90% CO₂ capture can be achieved at < 35% increase in COE.
Status:

- WRI pilot-scale unit has been constructed and tested and is ready for shipment to SRI for integrated tests,
- Advanced burner has been designed and is being fabricated,
- Working with SRI on the process integration details, and
- Integrated modeling effort is continuing.

In summary, the current program will be completed in the next 24 months and will establish the integrated operation of the system at a 1 MWth-scale and its economic benefits and will also define engineering issues / solutions for scale-up.
Special thanks to the following organizations for their participation and financial support:

University of Wyoming School of Energy Resources/State of Wyoming Clean Coal Technology Program
Arch Coal
Etaa Energy
Foster Wheeler North America
Nalco
Praxair
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Southern Company
URS-Energy and Construction

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