Summary Results of EPRI’s Post-Combustion Capture Retrofit Studies
For Various North American Sites

Presenter: Dr. Desmond Dillon  EPRI

IEA Cost Workshop
Thursday Nov 8th, 2013
Sites and Locations

- Site: Coal Creek
  - Owner: Great River Energy
  - Location: North Dakota

- Site: Powerton
  - Owner: MidWest Generation
  - Location: Illinois

- Site: Lingan
  - Owner: Nova Scotia Power
  - Location: Nova Scotia

- Site: Intermountain
  - Owner: Intermountain Power
  - Location: Utah

- Site: Bayshore
  - Owner: FirstEnergy
  - Location: Ohio
<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Bayshore</th>
<th>Lingan</th>
<th>Powerton</th>
<th>Coal Creek</th>
<th>Intermountain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owners</td>
<td>First Energy</td>
<td>Nova Scotia power</td>
<td>Edison Mission (Midwest Generation)</td>
<td>Great River Energy</td>
<td>Intermountain Power Agency</td>
</tr>
<tr>
<td>Type</td>
<td>CFB</td>
<td>Subcritical PC</td>
<td>Subcritical PC</td>
<td>Subcritical PC</td>
<td>Subcritical PC</td>
</tr>
<tr>
<td>Fuel Type</td>
<td>Petcoke</td>
<td>Bituminous</td>
<td>Sub-bituminous</td>
<td>Lignite</td>
<td>Blend of Bituminous &amp; Sub-bituminous</td>
</tr>
<tr>
<td>As received fuel Btu/lb (HHV)</td>
<td>13,350</td>
<td>10,958</td>
<td>8,700</td>
<td>7,045</td>
<td>11,010</td>
</tr>
<tr>
<td>Net Power Output (Prior to Capture)</td>
<td>1 x 129 MW</td>
<td>4 x 154 MW</td>
<td>2 x 750 MW</td>
<td>2 x 550 MW</td>
<td>2 x 900 MW</td>
</tr>
<tr>
<td>Location</td>
<td>Ohio, USA</td>
<td>Nova Scotia, Canada</td>
<td>Illinois, USA</td>
<td>North Dakota, USA</td>
<td>Utah, USA</td>
</tr>
<tr>
<td>De-SOx Equipment</td>
<td>Installed</td>
<td>None currently (Planned)</td>
<td>None currently (Planned)</td>
<td>Installed</td>
<td>Installed</td>
</tr>
<tr>
<td>De-NOx Equipment</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
Plant Performance Prior to Retrofit

![Bar chart showing net/gross power output for different plants](chart.png)

- **BAYSHORE**: 1 CFB Unit
- **LINGAN**: 4 PC Units
- **POWERTON**: 2 PC Units
- **COAL CREEK**: 2 PC Units
- **INTERMOUNTAIN**: NEW BUILD, BASELINE
- **NEW USC PC**: 1 PC Unit
Plant Performance Prior to Retrofit

- **Net / Gross Power Output (MWe)**

- **Net Plant efficiency (% HHV)**

### Plant Performance

- **BAYSHORE**
  - 1 CFB Unit

- **LINGAN**
  - 4 PC Units

- **POWERTON**
  - 2 PC Units

- **COAL CREEK**
  - 2 PC Units

- **INTERMOUNTAIN**
  - 2 PC Units

- **NEW USC PC**
  - 1 PC Unit

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Plant Performance After Retrofit

![Graph showing plant performance after retrofit. The vertical axis represents Net/Gross Power Output (MWe), ranging from 0 to 1000. The horizontal axis represents Net Plant efficiency (% HHV), ranging from 0 to 100. The graph compares various power plants, including BAYSHORE (1 CFB Unit), LINGAN (4 PC Units), POWERTON (2 PC Units), COAL CREEK (2 PC Units), INTERMOUNTAIN (2 PC Units), and NEW USC PC (1 PC Unit). The graph also highlights NEW BUILD BASELINE.]
Capital Cost Comparison of Retrofit vs New Build for the PC Units

Total Plant Cost, $/kW (2009 $)

New USC Plant With Capture
LINGAN Retrofit With Capture
POWERTON Retrofit With Capture
COAL CREEK Retrofit With Capture
INTERMOUNTAIN Retrofit With Capture
BAYSHORE

BASELINE

FGD AND SCR COST

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Capital Cost Comparison of Retrofit vs New Build for the PC Units

For retrofit: Significant difference in upfront capital. But...For new build: you are adding new power capacity.

- New USC Plant With Capture: 4000 $/kW
- LINGAN Retrofit With Capture: 2500 $/kW
- POWERTON Retrofit With Capture: 1500 $/kW
- COAL CREEK Retrofit With Capture: 1000 $/kW
- INTERMOUNTAIN Retrofit With Capture: 500 $/kW
- BASELINE: 1235 $/kW
- BAYSHORE: 3300 $/kW
Capital Cost Comparison of Retrofit vs New Build for the PC Units

For retrofit: Significant difference in upfront capital. But…For new build: you are adding new power capacity
LCOE Comparison of PC units with and without 90% CO₂ Capture

(Note: LCOE includes $10 /Tonne for CO₂ transport and storage)
LCOE Comparison of PC units with and without 90% CO$_2$ Capture

(Note: LCOE includes $10 /Tonne for CO$_2$ transport and storage)

Retrofitting PCC to an older paid–off asset can result in CO$_2$ capture with a lower LCOE than a new build plant with capture.
Cost of Avoided CO$_2$ for PC units

(Note: LCOE includes $10 /Tonne for CO$_2$ transport and storage)
Cost of Avoided CO$_2$ for PC units

(Note: LCOE includes $10/Tonne for CO$_2$ transport and storage)

Select the correct plant to retrofit - CO$_2$ avoided cost varies by 30 $/ton

$30/ton

Cost of Avoided CO2 $/ton (Constant 2009$)
## Estimated Performance of Intermountain Base Plant and Post-PCC Retrofit Case

<table>
<thead>
<tr>
<th></th>
<th>Unit 1 Baseline w/o CCS</th>
<th>Unit 1 with CCS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heat of Regeneration, Btu/lb-CO(_2)</strong></td>
<td>1,380(^{(1)})</td>
<td>900(^{(2)})</td>
</tr>
<tr>
<td></td>
<td>(kJ/kg -CO(_2))</td>
<td>3,209</td>
</tr>
<tr>
<td><strong>Gross output, MW</strong></td>
<td>947</td>
<td>798(^{*})</td>
</tr>
<tr>
<td><strong>Auxiliary load, MW</strong></td>
<td>50</td>
<td>178</td>
</tr>
<tr>
<td><strong>Net output, MW</strong></td>
<td>897</td>
<td>620</td>
</tr>
<tr>
<td><strong>Drop in net output from baseline, MW</strong></td>
<td>278</td>
<td>227</td>
</tr>
<tr>
<td><strong>Loss in efficiency, percentage points</strong></td>
<td>- 11.0</td>
<td>- 8.5</td>
</tr>
</tbody>
</table>

\(^{(1)}\) 30\%(wt) MEA with process optimization and integration  
\(^{(2)}\) Envisaged improvements with more advanced solvent

Future solvent improvements have a significant part to play in lowering the current estimated CCS efficiency penalty for retrofits.
Comparison Summary

- Despite the variances in base plants, all the sites can be retrofitted with 90% PCC
  - No technical showstoppers with the available technology
  - Cogeneration lowers generating efficiency of Bayshore unit making it an unattractive capture option. (Not a reflection on CFB!)

- The capital investment required can vary considerably:
  - Approximately $2000/kW difference in the PC sites studied

- The LCOE after capture plant can vary considerably:
  - Approximately $37/MWhr difference in the sites studied

- The CO₂ avoided cost can vary between sites:
  - Approximately $30/ton difference in the sites studied

- The more advanced solvents, currently in development, lower the efficiency penalty by ~2.5 percentage points
What Features Make the Intermountain Site a Good Candidate for PCC Retrofit?

• Good Baseline Efficiency - *Net plant efficiency 35.6% HHV*
• Suitable IP/LP crossover pressure
• Good turndown characteristics of the existing LP turbine
• Age - *Commissioned 1987, 24 yrs old (25yrs + of continued operation?)*
• Size - *2x 950 MWe Gross (Good economies of scale)*
• Existing AQCS - *FGD system with potential for upgrade*
• Lots of space available and in the right areas
• Favorable construction / labor costs
• Existing stack can be utilized
• Base loaded operation
Together…Shaping the Future of Electricity

*EPRI would like to acknowledge the following contributors to this work:*
  * Nexant Inc. and Bechtel Power Corporation*
  * Staff at each of the 5 participating host sites*

*Contact: ddillon@epri.com*
### Study Assumptions:

**Key economic assumptions included in this study:**

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No contingency applied to PCC equipment</td>
<td>90% capacity factor applied</td>
</tr>
<tr>
<td>Coal price:</td>
<td>All capital costs have been adjusted to 2009 dollars</td>
</tr>
<tr>
<td>PRB $1.80/MMBtu (HHV), $30/ton as-received. (17% price increase added for Bituminous &amp; blend)</td>
<td>For retrofits assumed paid off base plant</td>
</tr>
<tr>
<td>Costs estimate were based on a +/- 30% accuracy from pre-front-end engineering and design studies</td>
<td>12.5 % annual capital carrying charge factor applied</td>
</tr>
<tr>
<td>LCOE based on investor-owned utility revenue requirement analysis</td>
<td>Captured CO&lt;sub&gt;2&lt;/sub&gt; is compressed to 2205 psig (152 barg)</td>
</tr>
<tr>
<td>Optimized 30% wt. MEA system used on all cases (1380 Btu/lb-CO&lt;sub&gt;2&lt;/sub&gt; Heat of Regeneration)</td>
<td></td>
</tr>
<tr>
<td>Constant value of $9.1/ton ($10/tonne) was applied to account for transport and storage.</td>
<td></td>
</tr>
<tr>
<td>The TPC used, is defined as the sum of the following: Capital cost (broken into materials and installation including labor, subcontracts, field indirect costs, no sales tax assumed) / Engineering and other Home Office Overhead, including Fee / Warranty costs / Any Contingencies applied.</td>
<td></td>
</tr>
</tbody>
</table>