Coal Fired IGCC Power Plants In Wyoming

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Wyoming Coal

• Wyoming leads the Nation in Coal production.

• In 2008, Wyoming produced 467.6 million tons of coal.

• Coal underlies 54% of the state (53,000 sq miles).

• Wyoming “in place” coal resources estimated at 1.45 trillion tons.

• Wyoming “in place” coal reserves estimated at 67.5 billion tons.
## Wyoming Coal

<table>
<thead>
<tr>
<th>Proximate Analysis</th>
<th>Wyodak Coal (As Received) (%)</th>
<th>Illinois #6 Coal (As Received) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>26.6</td>
<td>11.1</td>
</tr>
<tr>
<td>Ash</td>
<td>5.8</td>
<td>9.7</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>33.2</td>
<td>35.0</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>34.4</td>
<td>44.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ultimate Analysis</th>
<th></th>
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<tbody>
<tr>
<td>Carbon</td>
<td>73.9</td>
<td>80.5</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>5.2</td>
<td>5.7</td>
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<tr>
<td>Nitrogen</td>
<td>1.3</td>
<td>1.6</td>
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<tr>
<td>Chlorine</td>
<td>xx</td>
<td>0.3</td>
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<tr>
<td>Oxygen</td>
<td>18.6</td>
<td>8.6</td>
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<tr>
<td>Sulfur</td>
<td>0.9</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

| High Heating Value (Btu/lb)         | 8,630                         | 11,666                            |
Coal Gasification

• Can Serve as the first step in the production of:
  – Electricity
  – Liquid fuels
  – Synthetic “natural gas”
  – Chemical feed stocks

• Allows for capture and sequestration of CO$_2$.
  – Use for enhanced recovery of Wyoming oil and gas.
Current Objectives

• Compare effect of gasifier type on net power generation.
• Determine effects of $\text{CO}_2$ recovery on net power generation.
• Compare water usage requirements for different gasifiers and levels of $\text{CO}_2$ recovery.
• Strategies for reducing water requirements.
Procedures

• Several IGCC models have been constructed using Aspen Plus software.
  
  — Slurry fed gasifier
  
  — Dry fed gasifiers
    • Conventional and mechanical feed.
    • Models completed thus far are:
      
      — 0%, 70% and 90% CO₂ capture for each gasifier.
  
  — Air vs. evaporative cooling for 90% CO₂ capture.

• Models based upon components supplied by Idaho National Laboratory (INL).
Plant Descriptions

• All plants have equal coal consumption (6,900 tons/day).

• All are mine-mouth plants located in Wyoming (elevation 5,000 ft.).

• Carbon dioxide sequestration for enhanced oil recovery.
IGCC – Dry Fed
IGCC – Slurry Fed
Results
Power Generation vs. CO₂ Capture

% CO₂ Recovery

- 0% CO₂
- 70% CO₂
- 90% CO₂

- Dry
- "Dry" Slurry
- Slurry
- Mech Fed

MW

0
50
100
150
200
250
300
350
400
450
500

409.5
400.7
460.9
490.2
338.4
343.9
372.8
413.5
349.8
357.1
392.9
421.7
Process Water Consumption vs. CO₂ Capture
(w/o Cooling)

Gallons / Minute vs. % CO₂ Capture

- Dry
- "Dry" Slurry
- Slurry
- Mech Fed

Bar Chart:
- 0 % CO₂: 75, -41, -216
- 70 % CO₂: 359, 365, 241, 301
- 90 % CO₂: 392, 488, 404, 412
Total Water Consumption (with Evaporative Cooling) vs. CO₂ Capture

- Mech Fed
- Slurry
- "Dry" Slurry
- Dry

<table>
<thead>
<tr>
<th>% CO₂ Capture</th>
<th>0 % CO₂</th>
<th>70 % CO₂</th>
<th>90 % CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons/minute</td>
<td>2444</td>
<td>2997</td>
<td>2952</td>
</tr>
<tr>
<td>75</td>
<td>359</td>
<td>392</td>
<td>392</td>
</tr>
<tr>
<td>2519</td>
<td>2875</td>
<td>3184</td>
<td>3184</td>
</tr>
<tr>
<td>-41</td>
<td>-166</td>
<td>-216</td>
<td>-216</td>
</tr>
<tr>
<td>2463</td>
<td>2997</td>
<td>3184</td>
<td>3184</td>
</tr>
<tr>
<td>3400</td>
<td>2875</td>
<td>3184</td>
<td>3184</td>
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<tr>
<td>3081</td>
<td>2638</td>
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<td>2849</td>
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<td>2997</td>
<td>3381</td>
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<tr>
<td>241</td>
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<td>241</td>
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</tbody>
</table>
Water Vapor Vented to Atmosphere (w/o Cooling)

- 0 % CO2: Gallons/minute, Dry = 855, Slurry = 458, Mech Fed = 467
- 70 % CO2: Gallons/minute, Dry = 1142, Slurry = 919, Mech Fed = 976
- 90 % CO2: Gallons/minute, Dry = 1175, Slurry = 969, Mech Fed = 969
Evaporative vs. Air Cooling
(Net Power Production)

Gasifier/Feed Type

<table>
<thead>
<tr>
<th>Type</th>
<th>Evaporative Cooling</th>
<th>Air Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>349.8</td>
<td>347.6</td>
</tr>
<tr>
<td>&quot;Dry&quot; Slurry</td>
<td>357.1</td>
<td>352.2</td>
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<tr>
<td>Slurry</td>
<td>392.9</td>
<td>386.3</td>
</tr>
<tr>
<td>Mech Fed</td>
<td>421.7</td>
<td>419.8</td>
</tr>
</tbody>
</table>

MW
CO₂ Vented to Atmosphere

- **Dry**
- "Dry" Slurry
- Slurry
- Mech Fed

<table>
<thead>
<tr>
<th>% CO₂ Capture</th>
<th>Tons/hr</th>
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</thead>
<tbody>
<tr>
<td>0% CO₂</td>
<td>375.5</td>
</tr>
<tr>
<td></td>
<td>368.8</td>
</tr>
<tr>
<td></td>
<td>484.1</td>
</tr>
<tr>
<td></td>
<td>485.1</td>
</tr>
<tr>
<td>70% CO₂</td>
<td>109.5</td>
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<tr>
<td></td>
<td>109.5</td>
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<tr>
<td></td>
<td>142.4</td>
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<td></td>
<td>145.7</td>
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<tr>
<td>90% CO₂</td>
<td>36.6</td>
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<td></td>
<td>35.5</td>
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<tr>
<td></td>
<td>46.2</td>
</tr>
<tr>
<td></td>
<td>46.4</td>
</tr>
</tbody>
</table>
Conclusions

• Carbon capture and sequestration results in a significant reduction in net power production.

• Carbon capture and sequestration also results in a significant increase in water requirements.

• A large reduction in water usage could be obtained through the use of air cooling.

• It may be possible to satisfy a substantial portion of the remaining water requirements through water recovery from flue gas and coal drying exhaust.
Conclusions (cont.)

- There is sufficient inherent moisture available in PRB coal for gasification when fed without drying.

- The elimination of drying and slurry feeding results in a significant increase in net power production.
What’s Left?

• Continue to refine current models to improve accuracy.

• Develop economics in conjunction with INL and Tom Foulke (University of Wyoming).

• Evaluate economics of different gasifier/feed scenarios.

• Evaluate economic costs / benefits of minimum water use cases.
What’s Left (cont.)

• Supply appropriate models to Wyoming Business Council to aid in the promotion of the use of Wyoming coal resources within Wyoming.

• Modification of models for coal / biomass blends?
  – Biomass preparation for blending.
  – Data collection on blend gasification and combustion.
  – Model adaptation and analysis.
Acknowledgements

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• Wyoming Business Council

• Idaho National Laboratory
  – Dr. Richard Boardman, Rick Wood
Thank you for your attention.