Focus on Gasification in the Western U.S.

GTC
Workshop on Gasification Technologies
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Why is gasification important in the Western States?

How can gasification be used?

How does gasification compare to traditional pulverized coal plants for power generation?

What are other important considerations?
Figure 4.11  Coal Demonstrated Reserve Base, January 1, 2003

By Key State

By Region

West and East of the Mississippi

By Mining Method

By Rank

Note: Because vertical scales differ, graphs should not be compared.

Source: Table 4.11.
Unique Western States Gasification Issues

- **Low rank coals**
  - high moisture, lower heating value
  - higher reactivity
  - ash behavior

- **Environmental concerns**
  - Class I Air Shed visibility degradation
  - environmentally sensitive regions

- **Water is a scarce resource**

- **Altitude and climate considerations**
  - atmospheric pressure
  - relative humidity, annual temperature
Unique Western States Gasification Issues

- **Demographic considerations**
  - vessel fabrication and delivery
  - construction work force

- **Carbon management**
  - oil play
  - sequestration opportunities

- **Infrastructure limitations**
  - electrical power transmission grid
  - railroads at full capacity
  - gas and oil pipelines
  - CO₂ and coal slurry pipelines
The Opportunity for Gasification

Achieving balance between energy needs and environmental preservation
Western Fuels Properties Differ Markedly*

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Moisture wt%</td>
<td>-</td>
<td>1.1</td>
<td>5.2</td>
<td>13</td>
<td>2.4</td>
<td>30.2</td>
<td>33.5</td>
</tr>
<tr>
<td>C, wt%</td>
<td>85.3</td>
<td>90.8</td>
<td>73.8</td>
<td>59.8</td>
<td>68.5</td>
<td>48.2</td>
<td>39.6</td>
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<tr>
<td>H, wt%</td>
<td>10.8</td>
<td>3.2</td>
<td>4.9</td>
<td>4.1</td>
<td>5.6</td>
<td>3.3</td>
<td>2.6</td>
</tr>
<tr>
<td>S wt%</td>
<td>4.0</td>
<td>0.8</td>
<td>2.13</td>
<td>3.7</td>
<td>0.49</td>
<td>0.37</td>
<td>0.5</td>
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<tr>
<td>N wt%</td>
<td>0.3</td>
<td>0.8</td>
<td>1.4</td>
<td>1.1</td>
<td>1.4</td>
<td>0.70</td>
<td>0.7</td>
</tr>
<tr>
<td>O, wt%</td>
<td>0.2</td>
<td>2.1</td>
<td>1.9</td>
<td>7.6</td>
<td>13.5</td>
<td>11.9</td>
<td>9.7</td>
</tr>
<tr>
<td>Ash, wt%</td>
<td>0.15</td>
<td>1.2</td>
<td>5.0</td>
<td>10.7</td>
<td>8.3</td>
<td>5.3</td>
<td>15.9</td>
</tr>
<tr>
<td>HHV – AR (BTU/lb)</td>
<td>13,500</td>
<td>12,150</td>
<td>13,260</td>
<td>10,982</td>
<td>12,700</td>
<td>8,340</td>
<td>6,010</td>
</tr>
<tr>
<td>H:C Ratio</td>
<td>1.52</td>
<td>0.42</td>
<td>0.80</td>
<td>0.82</td>
<td>0.97</td>
<td>0.82</td>
<td>0.79</td>
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</tbody>
</table>

* Data Sources: Argonne Premium Coal Samples Bank, U.S. Bureau of Mines
Major Homogeneous & Heterogeneous Reactions

- Moisture and light volatiles
- Tight volatiles (pyrolysis)
- Char Gasification & CO Shift
- Ash Melting

Temperature

Coal animation drawing from Smoot and Smith (BYU)
# Gasification Reactions

<table>
<thead>
<tr>
<th>Reaction Type</th>
<th>Equation</th>
<th>Energy Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO Oxidation</td>
<td>CO + ½ O₂ → CO₂</td>
<td>-283 MJ/kmol</td>
</tr>
<tr>
<td>Partial Oxid.</td>
<td>CnHm + n/2 O₂ → n CO + m/2 H₂</td>
<td>slight exothermic</td>
</tr>
<tr>
<td>Methane Ref.</td>
<td>CH₄ + H₂O ↔ CO + 3H₂</td>
<td>+2-6 MJ/kmol</td>
</tr>
<tr>
<td>CO Shift</td>
<td>CO + H₂O → CO₂ + H₂</td>
<td>-41 MJ/kmol</td>
</tr>
<tr>
<td>Full Oxid.</td>
<td>C + O₂ → CO₂</td>
<td>-394 MJ/kmol</td>
</tr>
<tr>
<td>Partial Oxid.</td>
<td>C + ½ O₂ → CO</td>
<td>-111 MJ/kmol</td>
</tr>
<tr>
<td>Water Gas</td>
<td>C + H₂O → CO + H₂</td>
<td>+131 MJ/kmol</td>
</tr>
<tr>
<td>Boudouard</td>
<td>C + CO₂ → 2 CO</td>
<td>+172 MJ/kmol</td>
</tr>
<tr>
<td>Methanation</td>
<td>C + 2H₂ → CH₄</td>
<td>-75 MJ/kmol</td>
</tr>
</tbody>
</table>

Relative Char Reaction Rate: \( \text{O}_2 \gg \text{H}_2\text{O} \gg \text{CO}_2 \gg \text{H}_2 \)

Char Reactivity (Rates):

Lignite Char > Sub-B. char > Bit. Char > Pet. Coke
INL IGCC Process Modeling*

*INL modeling activities initiated by Bechtel-B&W Idaho(2002)
## Comparison of Coal Rank for IGCC

<table>
<thead>
<tr>
<th>Coal Type</th>
<th>Coal Feed Rate (t/d)</th>
<th>Coal HHV (Btu/lb)</th>
<th>Coal Moisture Content (%)</th>
<th>Slurry Solids Conc. (%)</th>
<th>Net Power Output (MW)</th>
<th>Overall Conversion Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent. #9</td>
<td>2563</td>
<td>11,510</td>
<td>13.2</td>
<td>64</td>
<td>260</td>
<td>36.1</td>
</tr>
<tr>
<td>Illinois #6</td>
<td>2759</td>
<td>10,934</td>
<td>13.7</td>
<td>64</td>
<td>263</td>
<td>35.7</td>
</tr>
<tr>
<td>Wyodak</td>
<td>2759</td>
<td>8,425</td>
<td>28.1</td>
<td>60</td>
<td>197</td>
<td>33.2</td>
</tr>
</tbody>
</table>

- Excess moisture in sub-bit. coal derates slurry-fed gasifier and yields greater waste water
- Gas turbine derate of 10% due to air compression design capacity
- Reference plant tuned to Polk facility operating conditions
  Actual efficiencies may be higher for new designs
Emissions for PRB Coal Gasification

- PC with FGD (sulfur), SCR (NOx), carbon injection (Hg)
- IGCC with Purisol™ (sulfur), SCR (NOx), carbon bed (Hg)

- PM – IGCC about 2x less
- CO and VOC’s - IGCC 3x less
- NOx - IGCC 2x less
- SO₂ - IGCC 4 to 10x less
- Hg - about the same, but 50-100x less carbon used for IGCC

- CO₂ - opportunities for EOR, CBM recovery, sequestration
- FutureGen - approaching zero emissions
Water Consumption

- IGCC, Slurry-Feed:
  - about 30% less than PC boiler

- IGCC, Dry-Feed:
  - about 35% less than PC boiler
  - when recovering and using coal moisture
Carbon Control

• PC Boilers:
  – MDEA or ammonia (wet) scrubbers
  – “oxy fuel” combustion (ASU with CO₂ FGR)
  – chemical looping combustion (staged “redox”)

• IGCC:
  – MDEA, Purisol™, Selexol™, Rectisol™
    or other scrubbing
  – PSA, cryogenic, membranes
Economics & Efficiency

• Reference IGCC plant needed for specific western states sites and applications
• Operating and capital costs
  – PRB coal currently $8-12/ton near mine mouth

• IGCC cost reduction considerations:
  – need US fabrication capability
  – construction experience
  – turbine designs for altitude (size, air pre-compressors)
  – use surplus syngas to dry coal and/or “duct-fire” HRSG
  – air-blown, low pressure gasifiers
  – design gasifiers to match ASU and gas turbines
Fabrication and Delivery of High Pressure Reactor Vessels

Heavy wall plate rolling  Stress relieve oven

Photos courtesy of High Country Fabrication, Inc.
Casper, Wyoming
Fabrication and Delivery of High Pressure Reactor Vessels

High Country Fabrication, Inc.

Photo courtesy of High Country Fabrication, Inc.
Casper, Wyoming