Experience with Gasification of Low Rank Coals

Workshop On Gasification Technologies
Bismarck, North Dakota
June 28, 2006

Phil Amick
Chairman
Gasification Technologies Council
U.S. Coal Resource Regions (Lower 48)

Source: Energy Information Administration
IMPACTS OF FUEL CHOICE ON GASIFICATION PLANTS

Environmental
- Generally independent of Fuel Choice
- Sulfur 0.5% to 8%, Sulfur Removal Technology changes but emissions can be constant
- Slag quality maintained

Oxygen
- Usage increases as ash and moisture increase
- Main Component of Auxiliary Power Consumption

Heating Value
- Throughput needs determine size and number of gasifiers
Gasifying Western Coals

Myths

- Gasification doesn’t work
- Technology Suppliers aren’t interested
- IGCC doesn’t work at high altitude
- Pulverized Coal is cleaner
- Carbon capture is in the future

“ Mythbusters” is a documentary show on the Discovery Channel
Gasifying Western Coals

Myths

– Gasification doesn’t work with PRB or Lignite
Modern Era Coal Gasification – Power & Industrial

Coal Used: 94% Lignite

Source: Gasification Technology Council
U.S. Coal-to-Power Gasification

Coal Used: 37% Sub-Bituminous - 63% Bituminous

- Lignite
- Sub-Bituminous
- Bituminous
- Petcoke/Blend

Millions of Tons Gasified

Through 1Q05

Source: Gasification Technology Council

www.gasification.org
Great Plains Synfuels Plant

Over 90% of All of the Coal Ever Gasified in the United States

- Lurgi Gasification Technology
- 54 BCF per year of Natural Gas produced
- 6 MM Tons of Lignite per Year Processed
- Commercial Operation since 1984
- Also produces fertilizer, solvents and CO2 commercially

Source: www.dakotagas.com
LGTI – Louisiana Gasification Technology, Inc

One Third of the Coal-to-Power Gasification in U.S.

- ConocoPhillips E-Gas™ Technology
- 3.7 MM Tons of PRB Coal
- 2400 tpd Sub Bituminous coal feed
- Commercial Operation 1987 – 1995
- Processed 3.7 MM tons
- Fueled (2) Siemens SGT6-3000E GTGs

Source: ConocoPhillips
Gasifying Western Coals

- **Myths**
  
  - Technology Suppliers and Developers aren’t interested
## Solid Fuel Gasification Experience

<table>
<thead>
<tr>
<th>High Ash Coals</th>
<th>Lignite</th>
<th>Sub-Bituminous</th>
<th>Bituminous Illinois Basin</th>
<th>Bituminous Appalachian</th>
<th>Anthracite &amp; Other Bitum</th>
<th>Petcoke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Allied Syngas BGL</td>
<td></td>
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<td>ConocoPhillips E-Gas</td>
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<td></td>
<td>General Electric</td>
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<td>KBR Transport</td>
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<td>Sasol – Lurgi</td>
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<td></td>
<td>Shell</td>
<td></td>
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<td></td>
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<td></td>
<td>Siemens Sustec</td>
<td></td>
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</tr>
</tbody>
</table>

*Tested
Demonstrated (500 TPD or more)
Million Tons Operation*

www.gasification.org

www.gasification.org
Mesaba Energy Project

Excelsior Energy is the Owner
Nominal 600 MW IGCC in Minnesota Iron Range
Fuel Flexible for Sub-Bituminous, Bituminous and Petcoke

Technology Selection May 2004
PUC Filings December 2005
Air Permit draft application filed May 2006; Final June 2006
Commercial Operation 2011
Orlando Gasification Project

“KBR Transport Gasifier”, Peter V. Smith, KBR, Gasification Technologies conference, October 2005, San Francisco, CA

www.gasification.org
Orlando Gasification Project

Southern Company and Orlando Utilities Commission are the Owners
Nominal 330 MW IGCC in central Florida
Sub-Bituminous coal from the Powder River Basin

Commenced Design October 2005
Construction Start December 2007
Commercial Operation 2010

“KBR Transport Gasifier”, Peter V. Smith, KBR, Gasification Technologies conference,
October 2005, San Francisco, CA
Pacific Mountain Energy Center

Pacific Mountain Energy Center

Located at the Port of Kalama near Kalama, WA.

Energy Northwest will develop, permit, construct, own, operate, and maintain the public-private development.

Public power will purchase power from one 300 MW CT, and private companies will purchase power from the other 300 MW CT.

Sub-bituminous coal and/or petroleum coke for feedstock

Conceptual Engineering completed in 2005

Qualifications RFP 2Q06

Commercial operation in 2012

Pacific Mountain Energy Center

Emissions Comparisons of Coal, Natural Gas, and IGCC Power Plants Using Modern Pollution Control Technology

[Graph showing emissions comparisons of different power plants]


Other Coal Projects in the West

- IGCC projects under development in Arizona and Idaho
- IGCC evaluations announced by utilities in Colorado and Texas
- CTL Project announcements in Arizona, Montana, North Dakota and Wyoming
- Four of the Twelve Proposed FutureGen Sites are in western states
Technology Suppliers

- ConocoPhillips, Shell, Allied Syngas, KBR all pursuing U.S. Low Rank Fuel Projects
- Siemens Technology announced in European Brown Coal Project
- Shell Technology announced in Australian Brown Coal Project
- GE announced Low Rank Gasification Initiative; ConocoPhillips developing advanced gasifier for lignite and PRB coals.
Gasifying Western Coals

Myths

– Pulverized Coal is cleaner
## Coal Plant Main Stack Permit Targets

<table>
<thead>
<tr>
<th>Permit Targets</th>
<th>IGCC Amine Based</th>
<th>IGCC Selexol with SCR</th>
<th>SCPC(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO(_2) Emission Rate (lb/MMBtu of coal feed)</td>
<td>0.03</td>
<td>0.01</td>
<td>0.16</td>
</tr>
<tr>
<td>NO(_x) Emission Rate (lb/MMBtu of coal feed)</td>
<td>0.06</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Total NO(_x) &amp; SO(_2) TPY (based on 630MW Plant –IL6)</td>
<td>1,640</td>
<td>500</td>
<td>4,500</td>
</tr>
</tbody>
</table>

1) Wisconsin Electric Power SCPC information from April 2003 Draft Environmental Impact Statement, Elm Road Generating Station, Volume 1, Public Service Commission of Wisconsin & Department of Natural Resources, Table 7-11, p. 155 (Pittsburgh No. 8 coal)
# Criteria Pollutant Comparisons

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>IGCC Bituminous</th>
<th>Subcritical PC Bituminous</th>
<th>Subcritical PC Subbituminous</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0.049</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>SO₂</td>
<td>0.043</td>
<td>0.086</td>
<td>0.065</td>
</tr>
<tr>
<td>PM/PM₁₀</td>
<td>0.007</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td>VOC</td>
<td>0.0017</td>
<td>0.0024</td>
<td>0.0027</td>
</tr>
<tr>
<td>CO</td>
<td>0.03</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

All emissions in lb/MMBtu. IGCC NOx based on 15 ppmvd/15% O₂ and with no SCR. An SO2 removal of 87% reflects a very low coal sulfur content (0.22%).

Source: S. Khan, U.S. EPA
## Water Use and Solid Waste Comparisons

<table>
<thead>
<tr>
<th>Parameter*</th>
<th>PC Plant</th>
<th>IGCC Plant</th>
<th>% less for IGCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid waste, bituminous coal, tpd</td>
<td>1,090</td>
<td>430</td>
<td>60</td>
</tr>
<tr>
<td>Solid waste, subbituminous coal, tpd</td>
<td>480</td>
<td>280</td>
<td>42</td>
</tr>
<tr>
<td>Solid waste, lignite, tpd</td>
<td>2,080</td>
<td>1,600</td>
<td>23</td>
</tr>
<tr>
<td>Plant makeup water, gpm</td>
<td>9,340</td>
<td>6,030</td>
<td>35</td>
</tr>
<tr>
<td>Wastewater discharge, gpm</td>
<td>2,910</td>
<td>1,960</td>
<td>33</td>
</tr>
</tbody>
</table>

Note: gasification slag included in solid waste; only recovered sulfur considered non waste.

Source: S. Khan, U.S. EPA
Comparative Cost of Hg Removal

Cost per pound of mercury removed

Source: U.S. DOE from industry data
Gasifying Western Coals

- IGCC doesn’t work at high altitude
Case Study on PRB Coal

- Minemouth Location
  - 5000 feet
  - 45°F average ambient

- Midwestern Location
  - 500 feet, 50°F average ambient
600 MW Sub Bituminous IGCC Design Template

FEATURES:

• No coal prep required
• 2 Gasification Trains
• 2 Stage Gasification (FSQ)
• 3 Col Selexol™ AGR
• SCR to 3 ppm NOx
• 90% Hg removal
• 2x1 CC w/ SGT6-5000F GTGs
• Spare Gasif. Train (optional)
• ZLD (optional)
• Dry Cooling (optional)

3D Rendering Provided by Fluor/Siemens/ConocoPhillips
# 600 MW Sub Bituminous IGCC Case Description

<table>
<thead>
<tr>
<th></th>
<th>Midwest</th>
<th>Mine Mouth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site Conditions</strong></td>
<td>500 ft, 50 F avg. amb.</td>
<td>5,000 ft, 45 F avg. amb.</td>
</tr>
<tr>
<td>Q Coal (AR, HHV), Btu/lb</td>
<td>8,340</td>
<td></td>
</tr>
<tr>
<td>Carbon (dry basis), wt%</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>Sulfur (dry basis), wt%</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Ash (AR), wt%</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Moisture (AR), wt%</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td><strong>Acid Gas Removal</strong></td>
<td>3 Col. Selexol™</td>
<td></td>
</tr>
<tr>
<td><strong>Steam Conditions psig/F</strong></td>
<td>1800/1050/1050</td>
<td></td>
</tr>
<tr>
<td><strong>Heat Rejection</strong></td>
<td>Cooling Tower</td>
<td>Air Cooled</td>
</tr>
<tr>
<td><strong>GTG Emissions Control</strong></td>
<td>15 ppm NOx (diluent) plus SCR</td>
<td></td>
</tr>
<tr>
<td><strong>Process Wastewater</strong></td>
<td>SW recycle via R.O.</td>
<td>SW recycle + ZLD</td>
</tr>
</tbody>
</table>

Source: ConocoPhillips

www.gasification.org
## 600 MW Sub Bituminous IGCC Estimated Plant Performance

<table>
<thead>
<tr>
<th></th>
<th>Midwest</th>
<th>Mine Mouth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Rate, tpd (AR)</td>
<td>8,300</td>
<td>7,300</td>
</tr>
<tr>
<td>Oxygen, tpd (95% vol)</td>
<td>4,700</td>
<td>4,100</td>
</tr>
<tr>
<td>Gross Power, MW</td>
<td>780</td>
<td>670</td>
</tr>
<tr>
<td>Aux. Power, MW</td>
<td>130</td>
<td>120</td>
</tr>
<tr>
<td>Net Power, MW</td>
<td>640</td>
<td>560</td>
</tr>
<tr>
<td>Net H.R., Btu/kWh (HHV)</td>
<td>9000</td>
<td>9,100</td>
</tr>
<tr>
<td>Emissions [1]:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;, lb/MMBtu</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>SO&lt;sub&gt;2&lt;/sub&gt;, lb/MMBtu</td>
<td></td>
<td>0.01</td>
</tr>
</tbody>
</table>

Notes:
[1] Target permit levels

Source: ConocoPhillips
COE vs. Fuel Cost ($2010)

Source: ConocoPhillips
Gasifying Western Coals

Myths

- Carbon capture is in the future
Projects Implementing Carbon Capture

- Great Plains Synfuels is providing CO2 to the Weyburn oilfield
- Pernis Refinery gasification facility supplies CO2 to greenhouses in the Netherlands
- At least 2 of the expected EPACT tax credit applicants are planning carbon capture for enhanced oil recovery
## Comparative Cost Impact of CO$_2$ Capture and Sequestration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IGCC Plant</th>
<th>PC Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$ capture, %</td>
<td>91</td>
<td>90</td>
</tr>
<tr>
<td>Unit output derating, %</td>
<td>14</td>
<td>29</td>
</tr>
<tr>
<td>Heat rate increase, %</td>
<td>16.5</td>
<td>40</td>
</tr>
<tr>
<td>Capital cost increase, %</td>
<td>47</td>
<td>73</td>
</tr>
<tr>
<td>COE increase, %</td>
<td>38</td>
<td>66</td>
</tr>
</tbody>
</table>

Source: S. Khan, U.S. EPA
WASHINGTON, D.C.

www.gasification.org

Gasification – The Enabling Technology

Save the Dates
OCTOBER 1–4
JW MARRIOTT HOTEL

Gasification Technologies 2006

CONFERENCE