Substitute Natural Gas (SNG)
Scrubbing the Carbon in Coal and Petcoke

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Outline

1. SNG Drivers
2. Plant Design and Study Basis
3. Results
Domestic Natural Gas Production Falling Short of Demand

The US is short on Natural Gas

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Delineation of U.S. Coal Resources and Reserves
(In Billions of Tons)

250 year supply at current consumption

US is long on Coal

Source: EIA Coal Reserves Data, 1997
“Illinois coal resources hold more BTUs than all of Saudi Arabia's and Kuwait's oil reserves combined.” - ISGS
US Drivers for Substitute Natural Gas

✓ USA is short on natural gas and very long on coal

✓ Gasification technology can augment North American natural gas supplies and LNG imports

✓ Adds value to US coal reserves

✓ Increased energy diversity

✓ National energy security implications

✓ Method to reduce carbon penalty associated with coal
SNG Process Scrubs Carbon from Coal

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Carbon capture for enhanced oil recovery
- Reasonable proximity to oil fields required
- Improves project economics
- Increases life of existing oil fields
- Scrubs approximately 65% of the carbon from the feedstock
- Increases environmental attractiveness

Carbon Balance

Coal or Petcoke Feed
100 C Units

Gasifier + Carbon Scrubber (Rectisol®)

Carbon in SNG
34 Carbon Units

Slag+Aux Boiler
1 Carbon Unit

CO₂ for EOR
65 Carbon Units

65% of carbon in feedstock can be captured with SNG
E-Gas™ Gasification & SNG Process

- Coal
- Slurry
- Milling, Heating & Feeding
- Gasification
- High Temp. Heat Recovery
- Particulate Removal
- Gasification Technology Battery Limit (TBL)
- Char
- Slag Handling
- Steam
- BFW
- Air Separation Unit
- Nitrogen
- Oxygen
- Air
- Rectisol® & Methanation
- Methanation & Compression
- Product SNG
- Rectisol® AGR
- Sweet Syngas
- Acid Gas
- Sulfur Product
- Sulfur Recovery Unit
- Cool Sour Syngas
- LTHR, Chloride Scrubbing, Sour Shift & Hg removal
- Sour Water
- Discharge Water
- Water Treatment
- Recycle Slurry Water
- Quench Water
- Slag Slurry
- Slag Product
- Power Block and BoP
- Power Block and BoP
SNG Design Basis

Fixed gasifier size for all cases
3 x 50% gasification train plant
12 hours of LOX storage
High reliability
High purity oxygen (99.5%)
CO shift
Hg removal
Rectisol® acid gas recovery
Claus sulfur recovery unit
Commercial methanation
SNG delivery pressure 900 psi
CO₂ compression to 2000 psi

<table>
<thead>
<tr>
<th>Case</th>
<th>Feedstock</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Petcoke</td>
<td>Gulf Coast</td>
</tr>
<tr>
<td>2</td>
<td>IL#6 Coal</td>
<td>Midwest</td>
</tr>
<tr>
<td>3</td>
<td>PRB</td>
<td>Wyoming</td>
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</tbody>
</table>

CO₂ capture option evaluated
# Feedstock Parameters

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Petcoke</th>
<th>IL #6</th>
<th>PRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Gulf Coast</td>
<td>Midwest Minemouth</td>
<td>Wyoming Minemouth</td>
</tr>
<tr>
<td>HHV, Btu/lb (As Rec’d)</td>
<td>13,699</td>
<td>11,053</td>
<td>8,800</td>
</tr>
<tr>
<td>Composition:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon (dry basis), wt%</td>
<td>87.3</td>
<td>70.1</td>
<td>70.2</td>
</tr>
<tr>
<td>Hydrogen (dry basis), wt%</td>
<td>3.7</td>
<td>4.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Sulfur (dry basis), wt%</td>
<td>6.3</td>
<td>2.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Nitrogen (dry basis), wt%</td>
<td>1.3</td>
<td>0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Ash (As Rec’d), wt%</td>
<td>0.63</td>
<td>11.08</td>
<td>6.8</td>
</tr>
<tr>
<td>Moisture (As Rec’d), wt%</td>
<td>9.9</td>
<td>13.7</td>
<td>26.9</td>
</tr>
</tbody>
</table>
## Expected Performance Results

<table>
<thead>
<tr>
<th></th>
<th>Pet coke</th>
<th>IL#6</th>
<th>PRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedrate (TPD)</td>
<td>6,300</td>
<td>7,000</td>
<td>8,300</td>
</tr>
<tr>
<td>Gross Power</td>
<td>160</td>
<td>155</td>
<td>165</td>
</tr>
<tr>
<td>Net Power* (MW)</td>
<td>20</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>SNG Product (MMSCFD)</td>
<td>115</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Product Yield (MCF/ton)</td>
<td>18</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>CO₂ product (MMSCFD)</td>
<td>190</td>
<td>160</td>
<td>170</td>
</tr>
</tbody>
</table>

* Net power reduced by approximately 15MW in CO₂ capture case
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Capital Cost Comparison

- CO₂ capture adds ~45MM to EPC cost
- Gulf Coast location results in ~10% CapX advantage
Capital Cost Breakdown by Major Process Area

Gasification is less than $\frac{1}{3}$rd of total capital cost
### Financial and Economic Assumptions in Base Case

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<table>
<thead>
<tr>
<th>Key Assumptions</th>
<th>Value</th>
<th>Other Factors Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNG base price ($/mmbtu)</td>
<td>$6.00</td>
<td>• O&amp;M</td>
</tr>
<tr>
<td>Interest on debt</td>
<td>6.0%</td>
<td>• Owners Cost</td>
</tr>
<tr>
<td>Debt/Equity</td>
<td>70/30</td>
<td>• Financing Fees</td>
</tr>
<tr>
<td>Feedstock ($/ton)</td>
<td>$28</td>
<td>• Working Capital</td>
</tr>
<tr>
<td>CO₂ Product Price ($/ton)</td>
<td>$20</td>
<td>• Capital Spares</td>
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<tr>
<td>Project Life</td>
<td>20 years</td>
<td>• Escalation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Insurance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Taxes</td>
</tr>
</tbody>
</table>
Cost of Gas

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CO₂ sales reduces SNG price by ~$0.20/MMBtu

Analysis based on 15% leveraged ROI
Sensitivity Analysis – Impact to ROI

Basis: Ill#6 without CO₂ Capture

- SNG Price
  ($5 / $8)

- Capital Cost
  (+25% / -25%)

- Feedstock Cost
  (+25% / -25%)

- Interest Rate on Debt
  (+25% / -25%)

- O&M Cost
  (+25% / -25%)

CO₂ capture improves
ROI ~1.5%
Enablers for Successful Projects

- Favorable forward gas price
- Location, location, location
  - Construction cost (labor, rail and deep water access)
  - Feedstock pricing
  - Market for CO₂
  - Other product markets (Liquid air products, sulfuric acid, etc.)
- Innovative financing to minimize interest payments
- Governmental supports (both state and federal)
- Reduction in capital cost – all technologies
  - ASU, Rectisol®, methanation and gasification
Summary

- SNG integrates proven technologies
- SNG has favorable economics in certain applications
- Scrubbing carbon from coal – puts coal on an comparable footing with natural gas
- Deployment of SNG augments North American supplies
  - Broadens energy diversity
  - Reduces foreign dependence on natural gas
  - Significant deployment requires governmental supports
E-Gas Technology for Gasification

“Common Sense For Energy And The Environment”