Powder River Basin Underground Coal Gasification

WY EORI CO$_2$ Conference
June 23-24, 2009

James R. Covell, RDS-EG&G Technical Services
Washington Division, URS
What is Underground Coal Gasification (UCG)?

- **In Situ Coal Gasifier**
  - Expanding Natural Reactor
  - Does Not Require Mining / Requires Wells and Well Connection (Horizontal Drilling or Reverse Combustion)
  - Uses Air or Steam / Oxygen Injection To React With Coal and Groundwater
  - Produces Syngas the Same as Surface Gasifiers
    - Major Gases: CO, H₂, CH₄, CO₂, and H₂O
    - Basic Building Blocks for SNG and Liquid Fuels Production
    - Syngas Can Directly Fuel Electric Generation
UCG Process

UCG Major Reactions

Coal + O₂ + H₂O > Ash + Gases + Tars + Heat  (General)
C + O₂ > CO₂ (Combustion)  C + H₂O > CO + H₂ (Steam-Char)
C + CO₂ > CO (Reduction)  CO + H₂O > CO₂ + H₂ (Shift)
UCG Process Schematic

From UK DTI, 2004
UCG Advantages

• Vast Resources for UCG – Targets Deep Coals
• Requires No Mining, Ash Handling, and Surface Gasifiers
  – Lower Capital Costs (Reduced 30%) and Overall Costs ($1.50 - $2.00/Million BTU)
  – Reduced Human Risks
• Environmentally Friendly
  – Contrary to Some Perceptions
  – Most Testing Conducted with No or Little Environmental Impacts
  – Small Footprint
UCG History and Reemergence

• Russians Began UCG Development in 1928 (2 Commercial Plants Still Operating)
• USA Testing and Development 1946-1996
  – 33 Trials
  – Most Successful Test, Rocky Mountain I
• Trials Also in Europe (1982-1999) and Australia (1999- Present)
• Global Reemergence of UCG
  – China, South Africa, and Australia Conducting Advanced Demonstrations or Commercial Development
  – USA Being Considered for Pre-Commercial and Commercial Development (3 Projects Planned in Wyoming, 2 in PRB)
Fossil Energy Reserves (2007)

- **Oil**: 17%
- **Natural Gas (NG)**: 16%
- **Economically Minable Coal**: 67%

Source: BP, 2007
2007 Fossil Energy {Reserves + Resources}

Source: AAPG and BP, 2007
World Coal Reserves/Resources

- Proven *world coal reserves* (economic) of 909 billion tons (BP, 2007). Cover Wyoming in 8 feet of coal.
- Estimated total *world coal resources* (identified, not necessarily economic) of up to 18 trillion tons (AAPG).
- Only 5% of resources are economically extractable as reserves.
- Most resources are simply too deep – known – but too deep.
- Underground Coal Gasification (UCG) Converts Coal Resources to Coal Reserves.

*From GasTech 2008 EORI Presentation*
Powder River Basin

From GasTech 2008
EORI Presentation
Powder River Basin Coal Resource

• 510 Billion tons coal in-place (USGS, 1999)
• Seams up to 250 feet thick
• Energy content equal to 20 times the world’s total annual energy consumption
• One ton of PRB coal has 300 times the energy content of the CBM gas in that same ton of coal
• 307 billion tons amenable to UCG (this study)
  – Seams >500 ft deep to top of seam
  – Seams > 30 feet thick

From GasTech 2008 EORI Presentation
### GasTech PRB UCG Data Base

Excerpt from database: 50 feet+ coal seams, 100 feet immediate mudstone overburden

<table>
<thead>
<tr>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>POINT ID</th>
<th>NW</th>
<th>SE</th>
<th>EXCLUSION RATIONALE</th>
<th>DATA SOURCE</th>
<th>LITHOLOGY</th>
<th>KINSS.1</th>
<th>KINSS.2</th>
<th>TH.1</th>
<th>PTH.1</th>
<th>NE.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.078</td>
<td>-105.474</td>
<td>RC0D138</td>
<td>47N</td>
<td>72W</td>
<td>UCG FRIENDLY</td>
<td>NO. 1-2 LYN</td>
<td>MUDSTONE</td>
<td>124</td>
<td>175</td>
<td>259</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.078</td>
<td>-105.474</td>
<td>RC0D138</td>
<td>47N</td>
<td>72W</td>
<td>UCG FRIENDLY</td>
<td>NO. 1-2 LYN</td>
<td>COAL</td>
<td>69</td>
<td>3</td>
<td>299</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.078</td>
<td>-105.474</td>
<td>RC0D141</td>
<td>47N</td>
<td>72W</td>
<td>UCG FRIENDLY</td>
<td>NO. 1-7 BREEN</td>
<td>MUDSTONE</td>
<td>141</td>
<td>237</td>
<td>348</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.078</td>
<td>-105.474</td>
<td>RC0D141</td>
<td>47N</td>
<td>72W</td>
<td>UCG FRIENDLY</td>
<td>NO. 1-7 BREEN</td>
<td>COAL</td>
<td>68</td>
<td>3</td>
<td>345</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.078</td>
<td>-105.474</td>
<td>RC0D141</td>
<td>47N</td>
<td>72W</td>
<td>UCG FRIENDLY</td>
<td>NO. 1-7 BREEN</td>
<td>MUDSTONE</td>
<td>136</td>
<td>298</td>
<td>394</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44.078</td>
<td>-105.474</td>
<td>RC0D141</td>
<td>47N</td>
<td>72W</td>
<td>UCG FRIENDLY</td>
<td>NO. 1-7 BREEN</td>
<td>MUDSTONE</td>
<td>74</td>
<td>3</td>
<td>394</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# National Energy Technology Laboratory
UCG Issues

• Groundwater Contamination
• Subsidence
• Resolution of Conflicting Resources or Resource Extraction
  – Coal Mining
  – Coal Bed Methane
  – UCG
• Carbon Dioxide Management
  – Enhanced Oil Recovery
  – Carbon Capture Sequestration (CCS)
UCG Groundwater Contamination

• **Issue - Challenge**
  – Perceived as “Dirty Technology”
    • Groundwater Contamination
    • Based on Hoe Creek

• **Actual US Experience**
  – Relatively Clean Technology
    • Most U.S. UCG Operations Resulted in Limited or No Groundwater Contamination
    • Groundwater Contamination Caused by Gas Losses (Human Error)
    • Dynamic Process-Consumes Deposited Contamination Sources

• **Mitigation**
  – Site Selection
  – Operation Constraints
  – Clean-Cavity Concept
UCG Subsidence

- **Serious Issue**
  - Gas Losses
  - Interconnection of Water Bearing Units
  - Surface Disruption
  - Water Influx

- **Mitigation**
  - Site Selection
  - Depth
  - Module Design
  - Planned Subsidence
Conflicting Recovery Technologies
Coal Mining, CBM, and UCG

- **No Definitive Regulations - Evolving**
  - Conflict in PRB of Wyoming Between Mining and CBM
  - BLM Addressing Issue
    - CBM New Technology After Mining Leases Issued
    - Lease Seniority (Oil-Gas Senior to Mining Leases)
    - Advantage to New technologies
    - Incentives to Recover CBM Near Coal Mines to Free Mine leases
    - First Approach is Negotiations Between Lease Holders
    - Prompted BLM to Issue HR 2952, the Powder River Basin Development Act of 2001
    - Additional Guidance Issued in May 2006

![Wyoming CBM Clearinghouse](wyoming-cbm-clearinghouse.png)

![Wyoming CBM Clearinghouse](wyoming-cbm-clearinghouse.png)

![Rocky Mountain 1 UCG Site](rocky-mountain-1-ucg-site.png)
Conflicting Recovery Technologies
Coal Mining, CBM, and UCG (Continued)

• See Following for Details of Conflict Resolutions

• UCG Conflicts with Coal Mining and CBM
  – Has Not Been Addressed - UCG not Commercial
  – Similar Lease Position as Coal Mine Lease
  – UCG Development in PRB Will Likely Be in CBM Depleted Areas
    • Not Much of a Problem Because of the Maturity of CBM Development and the Time Lag for Commercial UCG Development
  – UCG Conflicts More Likely with CBM Than Coal Mining
    • UCG Resources Deeper Than Coal Mining Resources
UCG and EOR in the PRB

- 200 Mwe UCG-IGCC power plant will produce 1 million tons (Mt) CO$_2$/yr
- UCG syngas is 15% CO$_2$ (air blown) to 30% CO$_2$ (O$_2$ blown)
- Rocky Mountain Area Transmission Study (2006) predicts 700 Mwe new generating capacity from coal in the PRB; if UCG, produces 3.5 Mt CO$_2$/yr
- PRB demand for CO$_2$ for 168 reservoirs is 236 to 354 Mt (Wo, 2007)
- UCG is viable source of CO$_2$ for EOR
- Energy Penalty for CO$_2$ Removal: 6-9% (LLNL 2007)
Carbon Capture Sequestration (CCS)

- If CCS desired, use oxygen-blown system
- CCS in the PRB
  - Tertiary oil recovery, as Salt Creek, Hartzog Draw
  - “Extinct” UCG cavities as dense phase
  - Deep marine formations; PRB has numerous candidates for receiver formations: Mesa Verde, Sussex, Shannon, Frontier, Muddy, Morrison, Tensleep
- Possible carbon credits
- Energy penalty economically acceptable
CCS in Powder River Coals

- PRB Coal Seams too Shallow for Super Critical Storage (Depths > 2,500 feet)
- Dense Phase (Gas) CO$_2$ Storage Possible in Exhausted UCG Cavities
- PRB Coals May React Different than Other Coals for CCS
  - Coals Lose Permeability with CO$_2$ Injection
  - PRB Coals Reported to Gain Permeability (McLendon, NETL 2009)
- CO$_2$ Injection May Mobilize Contaminants in Coal Groundwater
Permeability Decrease in Coal Seams From CO$_2$ Injections (N. Dakota Lignite)

NETL, UWV, UND Report 2008
UCG in the PRB
Conclusions

• UCG is a Viable, Cost-Effective, and Environment-Friendly Technology for Electrical Generation and Synthetic Fuels Production

• Coal Gasification Provides the Basic Building Blocks for SNG, Transportation Fuels, and Other Products (e.g. Fertilizers)

• UCG Development in the PRB is Coming
  – Spearheaded by GasTech and Others
  – Significant Global Interest

• UCG Would Provide an Economical Source of CO₂ for EOR in the PRB and Surrounding Basins

• CCS in the PRB May Be Feasible in Marine Formations; May Be Feasible in Coal Seams as Dense Gas Phase