Underground Coal Gasification

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Conclusions regarding UCG

Advanced technology to produce syngas
Distinct cost and environmental advantages
Environmental hazards readily managed
Commercial-scale demos possible

*Best Practices in Underground Coal Gasification: Pending DOE-FE Report*
Underground coal gasification produces syngas with low capital and low operating cost

Gasification occurs in situ. The technology is well tested >40 years

Environmental benefits
• No mining
• Much less pollution (no $\text{SO}_x$, $\text{NO}_x$; less mercury, particulates)
• Low-cost $\text{H}_2$ production

Economic benefits
• No gasifier purchase, operation
• No coal purchase or transport
• Low-cost power generation

Carbon Management
• Lower cost $\text{CO}_2$ separation
• Good coincidence between UCG and sequestration sites

Courtesy ErgoExergy

Britten & Thorsness, 1978
There has been a dramatic increase in commercial UCG interest world-wide.

Over 33 US, 66 FSU projects, and 20 other international pilots.
New projects proceeding rapidly with aims for a variety of different products

Linc Energy, Australia (Chinchilla)
- First gas, 1999; continuous for 2.5 years
- 35,000 tons brown coal evacuated
- Current plans for CTL plant

Eskom, S. Africa (Majuba)
- Ignition Jan. 2007; electric power
- Bituminous coal
- Planning 1000 MW IGCC step out this year

GAIL, India
- Scheduled production, 2009
- Lignite coal, planned electric power

XinAo, China
- Pilot ignition, Aug. 2007
- Sub-bituminous; planned methanol plant

Other companies planning or operating hydrogen, synthetic natural gas, F-T, and power with CCS
Prior test sites
Announced/planned
Sites of note
US UCG projects
UCG has substantial economic benefits

- No coal mining; no coal purchase or transport; no ash management
- No gasifier or boiler purchase
- UCG syngas tested with off-the-shelf turbines
- Great flexibility in products (power; synthetic NG, liquids),
- Very low cost H₂ production ($0.60/mcf; $2-3/MBTU)

These aspects have increased interest in developing countries (India, China) with high sulfur & high ash coals.
UCG has substantial environmental benefits

- No coal mining; no coal purchase or transport; no ash management
- Smaller surface footprint
- No NO\(_x\)
- 50% volume of particulates, mercury, arsenic, sulfur, tar
- No SO\(_x\); sulfur management straightforward
- Synergies with carbon management

These aspects have increased interest in developing countries (India, China) with high sulfur & high ash coals.
UCG has real engineering and environmental issues

Engineering issues
- Cannot control all aspects of gasification
- Volume and composition of syngas fluctuate; still difficult to predict
- Must design surface facilities to handle tar, H₂S

Environmental issues
- Like long-wall mining, must manage subsidence
- Concerns over groundwater contamination hazard and risks

<table>
<thead>
<tr>
<th>Component</th>
<th>UCG model predictions (percent)</th>
<th>Field measurements (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>27.2</td>
<td>27.3</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>13.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>19.4</td>
<td>27.2</td>
</tr>
<tr>
<td>Methane</td>
<td>7.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Water</td>
<td>33.0</td>
<td>33.0</td>
</tr>
</tbody>
</table>

These issues can be managed readily by careful site selection and operation

Courtesy ErgoExergy
LLNL Focus: Criteria for site selection & planning

- **Geological Assessments**
  - Structural
  - Stratigraphic
  - Hydrologic

- **Contaminant Transport Prediction**
  - Potential contaminant types from coal and rock mineral compositions
  - Contaminant behavior under UCG burn and post-burn conditions

<table>
<thead>
<tr>
<th>Stratigraphic category</th>
<th>Lateral Isolation</th>
<th>Overlying Unit Character</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>Sand-prone</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>Shale-prone</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>Shale-prone</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Moderate</td>
<td>Shale-prone</td>
<td>Moderate</td>
</tr>
<tr>
<td>5</td>
<td>Moderate</td>
<td>Sand-prone</td>
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</tr>
</tbody>
</table>
UCG can and should always proceed in a way to manage and reduce groundwater risks

Pressure management
- Operate below hydrostatic pressure
- No flow of VOC out of cavity
- Validated at Chinchilla

Site selection
- Deeper sites (>200m; >500m preferred)
- More characterization of overburden
- Risk characterization

Regular monitoring
- Water chemistry, pressure
- Passive geophysics (ERT, microseismic)

Like all subsurface operations, hazards are real but can be readily managed
There are synergies between UCG and CBM development and production

- Production elements at roughly same depths
- Detailed characterization of seam (drilling, production information)
- Production dewatering could lead to more process control
- Possibility to use existing wells as both injection and syngas production wells
- Land-use, management, regulatory issues convergent

Courtesy GasTech, Inc.
Carbon dioxide can be stored in geological targets, usually as a supercritical phase.

Carbon capture & storage (CCS) has emerged as a new field for reducing greenhouse gas emissions, chiefly CO₂, through geological sequestration.

Saline Aquifers
Depleted Oil & Gas fields (w/ or w/o EOR and EGR)
Unmineable Coal Seams (w/ or w/o ECBM)

These formations are likely to be found near coal seams chosen for UCG.

Carbon capture economics and coincidence of storage targets make an attractive carbon management package.
Possible synergies between UCG and CCS

- Deeper sites = higher pressures
  - Lower capture costs
- Low risk UCG sites are low-risk CCS sites
- Potential to double monitoring arrays
  - Reduce operating costs
- Co-location of sites and facilities for conventional CCS
  - Smaller footprint
- Potential for use of cavity as storage location
  - This requires much more S&T

Both UCG and CCS are emerging technologies. S&T development can help to enable and accelerate both.
Technology gaps in UCG can be readily addressed through focused R&D initiatives

Simulation
- Integration of platforms (CFD, hydrologic, chemistry, surface facilities)
- Improved process models for syngas generation & production
- Improved process models for subsidence, env. fate and transport

Field pilots and demonstrations
- Application of a broad monitoring suite
- Validation of predictions; model improvements
- Economic characterizations with real facilities
- Ultimately, combined UCG + CCS

This RD&D agenda is fairly simple, and could be readily addressed through collaborative research programs
Conclusions regarding UCG

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DOE & LLNL have been active in UCG for over three decades

- Invented the CRIP (controlled retractable injection point) process (1974-1985)
- Conducted a number of field tests (Hoe Creek, Hanna, Centralia)
- Developed cavity growth models (Thorseness and Britten, 1989)
- Developed a CFD-based model of the UCG process and integrated it with Aspen Plus (Wallman 2004)
- Currently expanding the CFD model to include additional phenomenology
- Developed a large suite of tools for environmental assessment
- Developed methodologies for process control monitoring
- Applied carbon management and CO₂ sequestration expertise to UCG (Blinderman & Friedmann, 2006)