THE POTENTIAL FOR UNDERGROUND COAL GASIFICATION IN INDIANA

Evgeny Shafirovich, * Arvind Varma
Purdue University, School of Chemical Engineering, West Lafayette, IN

Maria Mastalerz, Agnieszka Drobnia, John Rupp
Indiana Geological Survey, Bloomington, IN

*Current address: The University of Texas, El Paso, TX
The Concept of UCG

• Injection and production wells are **drilled and linked** together in a coal seam.
• Air or oxygen is injected and the coal is **ignited**.
• Water or steam is utilized.
• The gasification process produces primarily $\text{H}_2$, CO, CH$_4$ and CO$_2$.
• The produced gases flow to the surface where they are processed and utilized.

Advantages of UCG

• As compared with conventional underground mining and surface gasification, UCG has several important advantages:
  – Lower capital costs
  – No labor underground
  – Minimal underground technology
  – Simpler surface technologies
  – Increased coal resource utilization
  – No coal or solid wastes at the surface
  – No coal transportation costs
Feasibility assessment of UCG potential in Indiana

Purdue University and Indiana Geological Survey collaborated to complete:

- **Phase 1** (completed August 31, 2008)
  - Analysis of UCG current state of the science and technology (globally) and determination of criteria for selecting UCG locations in Indiana
  - Primary Responsibility: Purdue

- **Phase 2** (completed November 29, 2008)
  - Analysis of geospatial information and determination of potential UCG locations in Indiana
  - Primary Responsibility: IGS

- **Phase 3** (completed March 1, 2009)
  - Screening of the most promising UCG locations
  - Recommendations for future work
  - Primary Responsibility: Purdue and IGS
Analysis of Current Status of UCG

• Important milestones:
  – Development of UCG in the Former Soviet Union (five UCG plants in operation in 1960s)
  – UCG trials, modeling, and development of CRIP technique in the United States (1980s)
  – Trials and modeling in Western Europe (deep coals, 1990s)
  – Experiments in China (abandoned mines, 1980s - present)
  – Chinchilla experiment in Australia (ErgoExergy, 1999-2003)
  – Numerous current UCG activities throughout the world
Analysis of Current Status of UCG

• Analysis of the patent literature:
  – 1998-2008: Russia and China are the most active countries in UCG development

• The main challenge in UCG is related to the methods for linking injection and production wells:
  – Hydraulic fracturing and reverse combustion
  – Directional drilling and CRIP

• Selection of the best UCG technology is a complex process, and the properties of the UCG site must be taken into consideration.
Various factors such as

- Thickness of coal seam
- Depth of coal seam
- Coal rank and other properties
- Dip of coal seam
- Water availability
- Amount of coal
- Land-use restrictions

were analyzed and two were identified as the most important criteria for determining the possibility of using the UCG process in Indiana.
## Criterion #1: Thickness

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 2.0 m</td>
<td>high</td>
</tr>
<tr>
<td>1.5 – 2.0 m</td>
<td>medium</td>
</tr>
<tr>
<td>1.0 – 1.5 m</td>
<td>low</td>
</tr>
<tr>
<td>&lt; 1.0 m</td>
<td>unacceptable</td>
</tr>
</tbody>
</table>

- Of the **seven** major coal seams present in Indiana, the **Seelyville and Springfield Coals** have the largest quantity of sufficiently thick sites (>1.5 m).
## Criterion #2: Depth

<table>
<thead>
<tr>
<th>Depth</th>
<th>Suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 200 m</td>
<td>high</td>
</tr>
<tr>
<td>60 - 200 m</td>
<td>adequate</td>
</tr>
<tr>
<td>&lt; 60 m</td>
<td>unacceptable</td>
</tr>
</tbody>
</table>
Other Geospatial Information Used in the Feasibility Analysis

• Infrastructure proximity
  – Coal-burning power plants
  – Natural gas pipelines
  – Cities
  – Highways
  – Railroads

• Coal Availability (Surface and Underground)
  – Technical restrictions to mining
  – Cultural restrictions to mining

• Coal Properties
  – Heating value
  – Moisture content
Criteria: Thickness, Depth and Infrastructure

Springfield Coal Member

Seelyville Coal Member

Natural gas pipelines
- Less than 10 in.
- 10 to 20 in.
- More than 20 in.
## Characteristics of Selected Zones

<table>
<thead>
<tr>
<th></th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 4</th>
<th>Zone 5</th>
<th>Zone 6</th>
<th>Zone 7</th>
<th>Zone 8</th>
<th>Zone 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mass</strong> [10^6 short tons]</td>
<td>27.7</td>
<td>103.2</td>
<td>53.1</td>
<td>32.4</td>
<td>35.8</td>
<td>75.5</td>
<td>46.2</td>
<td>23.6</td>
<td>182.9</td>
</tr>
<tr>
<td><strong>Thickness range [ft]</strong></td>
<td>6.6-7.9</td>
<td>6.6-8.6</td>
<td>6.6-10.3</td>
<td>6.6-7.9</td>
<td>6.6-9.4</td>
<td>6.6-9.2</td>
<td>6.6-11.4</td>
<td>6.6-9.4</td>
<td>6.6-11.3</td>
</tr>
<tr>
<td><strong>Moisture range [ar, %]</strong></td>
<td>5-10</td>
<td>5-10</td>
<td>5-7.5</td>
<td>7.5-12.5</td>
<td>&lt;7.5</td>
<td>5-7.5</td>
<td>5-7.5</td>
<td>7.5-10</td>
<td>7.5-10</td>
</tr>
<tr>
<td><strong>Ash range [dry, %]</strong></td>
<td>7.5-12.5</td>
<td>10-15</td>
<td>10-15</td>
<td>5-10</td>
<td>10-15</td>
<td>10-15</td>
<td>7.5-12.5</td>
<td>12.5-15</td>
<td>12.5-20</td>
</tr>
<tr>
<td><strong>Sulfur</strong> [total, dry, %]</td>
<td>3-4</td>
<td>2-4</td>
<td>3-5</td>
<td>1-3</td>
<td>3-5</td>
<td>2-4</td>
<td>3-4</td>
<td>3-4</td>
<td>2-4</td>
</tr>
<tr>
<td><strong>Heating value</strong> [dry, 10^3 Btu/lb]</td>
<td>12.5-13.0</td>
<td>12.0-13.0</td>
<td>11.5-12.5</td>
<td>13.0-14.0</td>
<td>11.5-12.0</td>
<td>11.5-12.0</td>
<td>11.5-12.0</td>
<td>11.5-12.0</td>
<td>11.5-12.0</td>
</tr>
<tr>
<td><strong>Distance to nearest power plant [miles]</strong></td>
<td>14</td>
<td>9.5</td>
<td>10</td>
<td>3</td>
<td>18</td>
<td>17</td>
<td>18</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td><strong>Distance to nearest pipeline [miles]</strong></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td><strong>Distance to nearest town [miles]</strong></td>
<td>3</td>
<td>0</td>
<td>6.7</td>
<td>5.5</td>
<td>3</td>
<td>2.5</td>
<td>2.2</td>
<td>1.6</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Project Summary

• Analysis of UCG current status shows that this technology has the potential to grow and replace/complement traditional methods for coal mining and gasification.

• Screening criteria for selecting areas where UCG could potentially function in Indiana have been formulated.

• Geospatial analysis of these data derived nine potential localities for potential UCG operations in southwestern Indiana.

• Detailed characterization (geological, chemical and engineering) of these localities must be undertaken to determine the most promising sites for UCG in Indiana.
Recommendations for Future Work

• Follow-up detailed characterization and evaluation of the selected localities, including:
  – Evaluation of the hydrology of the coals and surrounding rocks (both potable and non-potable aquifers).
  – Determination of the geomechanical properties of the overlying rock (risk of subsidence).
  – Studies on the influence of the petrophysical characteristics of the coals on the kinetics of the UCG process.
  – Site-specific modeling of the UCG process with a focus on the environmental aspects (groundwater contamination).
  – Investigation of the possibility to couple UCG operations with CO₂ capture and sequestration.
  – Economic analysis, including capital, operational and environmental costs.

• Concurrently, organize cooperative agreements with Lawrence Livermore National Laboratory (LLNL); Ergo Exergy and/or Linc Energy – for site characterization for a future pilot project.
Appendix

Detailed Springfield and Seelyville Coal Bed Maps for individual criteria, important for UCG operations
Coal Seam Extent

Springfield Coal Member

Seelyville Coal Member

Legend:
- Extent of Springfield coal
- Extent of Pennsylvanian System
- Active surface mines
- Active underground mines
- Mined out areas by surface mining
- Mined out areas by underground mining

Map scale:
- 0 10 miles
- 1:1,250,000
Criterion: Thickness

Springfield Coal Member

Seelyville Coal Member

Map scale
0 10 miles
1 : 1,000,000

Map scale
0 10 miles
1 : 1,250,000
Criterion: Depth

Springfield Coal Member

Seelyville Coal Member
Criterion: Moisture

Springfield Coal Member

Seelyville Coal Member
Criterion: Heating Value

Springfield Coal Member

Map of southwestern Indiana showing heating value [Btu/lb, dry] of the Springfield Coal Member.

- Less than 10,500
- 10,500 to 11,000
- 11,000 to 11,500
- 11,500 to 12,000
- 12,000 to 12,500
- 12,500 to 13,000
- 13,000 to 13,500
- Greater than 13,500

Seelyville Coal Member

Map of southwestern Indiana showing heating value [Btu/lb, dry] of the Seelyville Coal Member.

- Less than 10,500
- 10,500 to 11,000
- 11,000 to 11,500
- 11,500 to 12,000
- 12,000 to 12,500
- 12,500 to 13,000
- 13,000 to 13,500
- Greater than 13,500

Map scale
0 10 miles
1:1,000,000
Criterion: Restrictions for Surface Mining

Springfield Coal Member

Map of southwestern Indiana showing the areas where the Springfield Coal Member is available for surface mining and where surface mining is restricted (after Conolly and Zlotin, 1999).

Seelyville Coal Member

Map of southwestern Indiana showing the areas where the Seelyville Coal Member is available for surface mining and where surface mining is restricted (after Conolly, 2001).

Legend:
- Springfield coal available for surface mining
- Springfield coal mined out
- Depth to Springfield coal greater than 200 feet
- Surface mining restricted by technological factors
- Surface mining restricted by land-use features

Map scale
0 10 miles
1 : 1,000,000
Criterion: Restrictions for Underground Mining

Springfield Coal Member

Map of southwestern Indiana showing the areas where the Springfield Coal Member is available for underground mining and where underground mining is restricted (after Conolly and Zlotin, 1999).

Seelyville Coal Member

Map of southwestern Indiana showing the areas where the Seelyville Coal Member is available for underground mining and where underground mining is restricted (after Conolly, 2001).
Criteria: Thickness, Depth and Infrastructure

Springfield Coal Member

Seelyville Coal Member
Criteria: Thickness, Depth and Infrastructure

Springfield Coal Member

- Springfield Coal unavailable for underground gasification (depth less than 200 ft [-60m] or thickness less than 1m or coal mined out)
- Adequate depth and thickness from 1.0 to 2 m [3.28 to 6.56 ft]
- Adequate depth and thickness greater than 2m [greater than 6.56 ft]
- Depth greater than 200.0 m (> 656.17 feet)

Seelyville Coal Member

- Seelyville Coal unavailable for underground gasification (depth less than 200 ft [-60m] or thickness less than 1m or coal mined out)
- Adequate depth and thickness from 1 to 2 m [3.28 to 6.56 ft]
- Adequate depth and thickness greater than 2m [greater than 6.56 ft]
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Natural gas pipelines
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- More than 20 in.
Criteria: Thickness, Depth and Infrastructure

Springfield Coal Member

- Springfield Coal unavailable for underground gasification (depth less than 200 ft [-60m] or thickness less than 1m or coal mined out)
- Adequate depth and thickness from 1.5 to 2 m [4.92 to 6.56 ft]
- Adequate depth and thickness greater than 2m [greater than 6.56 ft]
- Depth greater than 200.0 m (> 656.17 feet)

Seelyville Coal Member

- Seelyville Coal unavailable for underground gasification (depth less than 200 ft [-60m] or thickness less than 1.5 m or coal mined out)
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