THE POTENTIAL FOR UNDERGROUND COAL GASIFICATION IN INDIANA

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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**.
- Groundwater is utilized.
- The gasification process produces primarily $\text{H}_2$, CO, $\text{CH}_4$ and $\text{CO}_2$.
- The produced gases flow to the surface through the production well and cleaned.

Advantages of UCG

- As compared with conventional mining and surface gasification, UCG has several important advantages:
  - Lower capital costs
  - No human labor underground
  - Lower surface disruption
  - Increased coal resource availability
  - No handling of coal and solid wastes at the surface
  - Direct use of groundwater
  - Cavities formed as a result of UCG can be used for CO$_2$ sequestration
CCTR Project on UCG

Participants: Purdue University – Chemical Engineering
Indiana Geological Survey (sub-contractor)

• **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
  – Responsibility: Purdue

• **Phase 2** (completed November 29, 2008)
  – Determination of suitable UCG locations in Indiana
  – Responsibility: IGS

• **Phase 3** (by January 15, 2009)
  – Selection of the most promising UCG locations
  – Recommendations for future work
  – Responsibility: Purdue and IGS
Analysis of UCG Current Status

- **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 UCG Current Status

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

• The main controversy 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
  – Groundwater
  – Amount of coal
  – Land-use restrictions

were analyzed and some were identified as the most important criteria for selecting UCG locations in Indiana.
### Criterion #1: Seam 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, only the **Seelyville and Springfield Coals** have a significant quantity of sufficiently thick sites (>1.5 m).
- The selection process focuses on these two coal beds.
## 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 Criteria Used in the Present Analysis

• Infrastructure
  – Coal-burning power plants
  – Natural gas pipelines
  – Cities
  – Highways
  – Active railroads
• Moisture
• Heating value
• Restrictions for surface mining
• Restrictions for underground mining
Coal Seam Extent

Springfield Coal Member

Seelyville Coal Member
Criterion: Thickness

Springfield Coal Member

Seelyville Coal Member
Criterion: Depth

Springfield Coal Member

Seelyville Coal Member
Criteria: Thickness and Depth

Springfield Coal Member

Seelyville Coal Member

Springfield Coal unavailable for underground gasification (depth less than 200 m or thickness less than 2 m or active mining or coal mined out)

Thickness greater than 2m (greater than 6.56 ft)
Depth greater than 200.0 m (> 656.17 feet)

Seelyville Coal unavailable for underground gasification (depth less than 200 m or thickness less than 2 m or active mining or coal mined out)

Thickness greater than 2m (greater than 6.56 ft)
Depth greater than 200.0 m (> 656.17 feet)
Criteria: Thickness and Depth

Springfield Coal Member

Seelyville Coal Member
Criteria: Thickness and Depth

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 1.5 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)
- 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)
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 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)
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Seelyville Coal Member

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- Adequate depth and thickness greater than 2m [greater than 6.56 ft]
- Depth greater than 200.0 m (~656.17 feet)

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]
- Depth greater than 200.0 m (~656.17 feet)

Natural gas pipelines:
- Less than 10 in.
- 10 to 20 in.
- More than 20 in.
Criterion: Moisture

Springfield Coal Member

Seelyville Coal Member

Map of southwestern Indiana showing moisture content [%] of the Springfield Coal Member.

Map of southwestern Indiana showing moisture content [%] of the Seelyville Coal Member.

Less than 5
5 to 7.5
7.5 to 10
10 to 12.5
12.5 to 15
15 to 20
Greater than 20

Map scale
0   10 miles
1 : 1,000,000
Criterion: Heating Value

Springfield Coal Member

Seelyville Coal Member

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

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

Legend:
- 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).

Legend:
- Springfield coal available for underground mining
- Springfield coal mined out
- Depth to Springfield coal less than 100 feet
- Underground mining restricted by technological factors
- Underground mining restricted by land-use features

Map scale
0 10 miles
1:1,000,000
Summary of the Project Phases 1 and 2

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

• The criteria for selecting UCG sites in Indiana have been formulated.

• Using these criteria, the maps that show suitable locations for UCG have been generated for the Springfield and Seelyville coal beds.
The next step (Phase 3) will analyze the maps generated in Phase 2 showing geologically-related parameters and infrastructure in the most promising areas to select the best locations for potential UCG operations.

In particular, product transportation issues will be considered, such as transportation of the produced syngas to the available power plants and construction of power and chemical plants near selected UCG locations.

Special attention will be paid to environmental aspects, including the risks of groundwater pollution and uncontrolled combustion.

The Final Report, including the list and characteristics of the most promising UCG locations, will be submitted by Jan. 15, 2009.
Future Work, cont’d

- As part of the Final Report, recommendations for follow-up **detailed characterization** of the sites that have met the screening criteria will be itemized. These should include:
  - evaluation of the volumes and geometries of the coals in selected areas
  - the character of the surrounding or enclosing rock
  - the hydrology of the coals
  - the details of the petrophysical characteristics of the coals as they control the kinetics of the combustion process

- Specific investigations related to gasification **kinetics** of the selected Indiana coals, and **modeling** of the UCG process, will also be described for the follow-up studies.