Initial Investigations for In-situ Gasification of Lignite Seams – A Case Study of a Romanian Deposit

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General objectives of the project

Overall objective of the COAL2GAS Project:

to evaluate the feasibility of UCG in shallow lignite seams, geologically, technically and environmentally and to illustrate this for a selected deposit in Romania.

Tasks:

- Definition of site selection and **design criteria** to allow transfer to other potential targeted deposits;
- **Geological and hydrogeological research** and assessment of suitability;
- **Site selection** and design of drill and panel pattern to be adopted;
- Assessment of negative or positive **impact of former mine workings** and geological structure;
- Effect of **subsidence** in old mining areas and of remaining pillars prior to and after mine closure on UCG operations and vice versa;
- Design and field tests of **drainage and monitoring systems**;
- **Draft design** of utilization scheme and adaptation of UCG project design;
- Set-up of a monitoring database;
- Design of a **monitoring system** for operations and environmental protection;
- Final **risk analysis**;
- Establishment of appropriate techniques for **extinguishment, well closure and long term safekeeping**.
Structural Geology

Rabagia & Matenco (1999)
Basin Architecture

- Total of 22 lignite seams called “A” to ”D” and “I” – “XVIII”.
- A to VII correspond to “Dacian” stage (Pliocene), VIII to XII correspond to “Romanian” stage (Pliocene), XIII and younger to the Pleistocene
- Thickness variation common
- Deposited in a fluvial environment (Gilbert-Type Delta)
- At selected sites coal seams generally dip towards SE at shallow angles (3-4°)

**Diagram Description**: A diagram illustrating the basin architecture with reference to various lignite seams and geological stages. The seams are labeled as Lignite V and Lignite X, with reference boreholes marked. The diagram includes a reference to the Carpathian region, the Danube, and the Jiu river. The altitudes are indicated in meters.

Basin Architecture

### Structural Geology

- According to observations of CEO there is only low structural overprint.
- According to published literature there is “small scale local folding and thrusting” in the Pliocene.

Also minor offsets may affect coal combustion and panel design.

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Local Geology

Legend
- Exploration and Mining Licenses
- Quaternary / Holocene (qh)
- Quaternary - Pleistocene (qp)
- Romanian (ro)
- Dacian (dc)
- Pontian (po)
- Meotian (m)

Location
- Romania
- Bucharest

Suggested Project Sites - Oltenia
1: 150,000

Prepared for:
RFCS - Coal2Gas
Prepared by:
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45307 Essen, Germany
General stratigraphy

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Total Thickness of the coal (m)</th>
<th>Operational Depth (m)</th>
<th>Tectonics</th>
<th>Water Conditions Mc water / ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesteana Nord</td>
<td>12.83</td>
<td>80</td>
<td>simple</td>
<td>Difficult 9.50</td>
</tr>
<tr>
<td>Pesteana Sud</td>
<td>8.14</td>
<td>25</td>
<td>simple</td>
<td>Difficult 8.40</td>
</tr>
</tbody>
</table>

Clay, Sand, Lignite beds (III - XIII)

Mine operations and lithologic sequences
Several aquifers exist above and in between coal seams
The aquifers have variable thicknesses.
General groundwater flow direction is towards SE (some minor variations)
Confined aquifers are common
LargeDrawback (~90m) of confined aquifer below coal seam V due to coal mining
Fracturing as a consequence of underground coal exploitation has locally led to increased permeability in roof lithologies
Quick recovery of aquifer expected based on hydrogeological models
Groundwater geochemistry for several mine locations show values within the tolerated values

Regime of flow in the aquifer situated below the lignite bed I influenced by tappings or water (area E.M.Motru) [Scradeanu, D. & Palcu, M. (2003)]
Geologic and numerical model

- Set-up of 3D geologic model
- Numerical model to investigate thermal-hydro-mechanical-chemical impact of UCG operations on surrounding rocks
Panel and Well Design & Engineering

UCG Layout

- Linear-Controlled Retracting Point (L-CRIP) module recommended
  - comprises a deviated injection well drilled along the base of a coal seam and linked to a vertical production well.
  - The process wells are linked together by directional drilling.

Ongoing: modelling the reactor and module performance of three study cases representative of the coal seam conditions expected at the Oltenia coalfield.

Schematic L-CRIP configuration

(Most Coal Engineering)

Controlled Retracting Injection Point concept

(Hill 1986)
Coiled Tubing:
- Small hole sizes
- Lower cost through efficiency including faster rig ups → rapid mobilization, high running speeds and build rates (higher ROP)
- Precise drilling through accurate monitoring, smoother wellbore → less risk of getting stuck, or requirement for subsequent operations
- Continuous circulation during tripping
- Telemetry independent of drilling fluid using wireline in coil
- Environment: smaller footprint, less pipe handling, fewer spills, less noise pollution
Well Design

Material selection

- Normal carbon steel will be sufficient for temperature up to 300°C, at higher temperatures strength will be reduced (20% at 400°C) and expansion factor will increase.
- Heat (Fire) resistant steel with additions of Cr, Mo, and others will be required for inner tubings of production wells.
- At 310°C, cement strength is decreased by 35% and porosity increased by 12 – 15%.
- Cement integrity has to be tested regularly, cement in contact will rather develop self healing processes.
- Proof of integrity; control of wells and cement required (e.g. CBL).
Outlook: Testing & Monitoring

Testing & Drilling:

- Logging of test drills for geologic and structural investigations:
  - Geotechnical core logging
  - High resolution 360° scanning of drill core
  - Borehole logging (deviation, gamma, optical, resistivity, evtl. density etc.)
- Sampling and testing (coal and water)
**Proposed downhole geophysical logging tools for exploration drillholes and hydrogeological monitoring wells**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caliper</td>
<td>Lithological correlation, detection of cavities</td>
</tr>
<tr>
<td>Conductivity / Temperature</td>
<td>Reference measurement, water inflow zones</td>
</tr>
<tr>
<td>Sampling device</td>
<td>Chemical groundwater composition</td>
</tr>
<tr>
<td>Natural Gamma</td>
<td>Lithological correlation</td>
</tr>
<tr>
<td>Flowmeter</td>
<td>Inflow areas</td>
</tr>
<tr>
<td>Full Wave Sonic</td>
<td>Lithological correlation, Determination of Vp and Vs</td>
</tr>
<tr>
<td>Optic and Acoustic Scanner</td>
<td>Lithological correlation, structural analysis</td>
</tr>
<tr>
<td>Resistivity Tool</td>
<td>Lithological correlation</td>
</tr>
<tr>
<td>Tracer Logging (without stimulation)</td>
<td>Vertical flow, In-/Outflow Rates</td>
</tr>
<tr>
<td>Tracer Logging (with stimulation)</td>
<td>Transmissivity, porosity</td>
</tr>
</tbody>
</table>
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Selection of monitoring techniques and design of monitoring plans:

- Establishing of action plans for monitoring the underground coal gasification combustion as well as for environmental parameters.
- Monitoring activities will include:
  - simulation studies regarding fracturing and ground subsidence, groundwater flow,
  - soil gas and flux survey
  - sampling of the water produced prior to, during and after the gasification and its chemical analysis.
Outlook: Set-up of action plans for demonstration project

The first action plan will consider the techniques needed to monitor the combustion processes, such as:
- Air flow in boreholes;
- Air pressure in boreholes;
- Combustion chamber temperature;
- Reactor development
- Quality of syngas obtained.

The second action plan will help monitoring the main environmental factors, such as:
- Roof fracturing and subsidence;
- Groundwater dynamics and quality in the mined area and future UCG panels;
- Groundwater and surface water quality (downstream of the selected area);
- Occurrence of combustion gases;
- Changes of air and water temperature;
- Heating of water from drainage drillings;
- On-site air quality;
- Effects of UCG on surface vegetation above the reactor and in its perimeter
- Soil quality
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