Field experiment of CO$_2$-ECBM in the Upper Silesian Basin of Poland – update with MOVECBM results

Thursday 10 April 2008
Kaniow ECBM pilot

<table>
<thead>
<tr>
<th>Period</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transition Period</strong></td>
<td></td>
</tr>
<tr>
<td>Period 1</td>
<td>Abandonment MS-4 (prod. well)</td>
</tr>
<tr>
<td></td>
<td>Pressure fall-off</td>
</tr>
<tr>
<td></td>
<td>Modifications for gas release</td>
</tr>
<tr>
<td>Period 2</td>
<td>Gas release</td>
</tr>
<tr>
<td>Period 3</td>
<td>Modifications MS-3 to prod. well</td>
</tr>
<tr>
<td></td>
<td>Standstill/CO₂ soaking</td>
</tr>
<tr>
<td><strong>MOVECBM (EC-funded)</strong></td>
<td></td>
</tr>
<tr>
<td>Period 4</td>
<td>Gas production</td>
</tr>
<tr>
<td>Period 5</td>
<td>Permeability tests</td>
</tr>
<tr>
<td></td>
<td>Abandonment MS-3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coal-seq V
Outline of presentation

- Overview of ongoing activities in the MOVECBM project

- Overview of activities in the ECBM field pilot in Poland
  - RECOPOL project
  - Transition period between RECOPOL and MOVECBM
    - Partly presented on previous COAL-SEQ meetings
  - MOVECBM project
Overview of ongoing activities in the MOVECBM project
What is MOVECBM?

• Monitoring and Verification of CO$_2$ storage and ECBM in Poland - MOVECBM

• Start: 1 November 2006  End: 31 October 2008

• Budget: EURO 2,670,737  EC eligible: EURO 1,250,000

• Man months: 280

• Duration field experiment Kaniow: 10 months
• Small scale mine experiment Velenje: 18 months
Monitoring and verification of CO₂ storage and ECBM in Poland (MOVEECBM)

- Key objectives:
  - Better understanding adsorption, desorption and migration in coal
  - Determination of optimal storage and production regimes using coal seams (swelling & shrinkage)
  - Monitoring & verification methodology for coal seams, seal, wells and (near) surface
  - Optimal models by combining modelling, lab and field experiments
  - Derive monitoring and verification guidelines for site certification
  - Knowledge transfer: EU, China, Australia, USA
### MOVECBM partners

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands Organisation for Applied Scientific Research (TNO)</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Central Mining Institute Poland (CMI)</td>
<td>Poland</td>
</tr>
<tr>
<td>Shell International Exploration and Production (Shell)</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Etudes et Productions Schlumberger (EPS)</td>
<td>France</td>
</tr>
<tr>
<td>Universita di Roma “La Sapienza” (URLS)</td>
<td>Italy</td>
</tr>
<tr>
<td>Faculté Polytechnique de Mons, Wallonia-Brussels Academy (FPM)</td>
<td>Belgium</td>
</tr>
<tr>
<td>Universiteit Utrecht (UU)</td>
<td>Netherlands</td>
</tr>
<tr>
<td>State Key Laboratory of Coal Conversion (SKLCC)</td>
<td>P.R. China</td>
</tr>
<tr>
<td>Rheinisch-Westfälischen Technischen Hochschule (RWTH)</td>
<td>Germany</td>
</tr>
<tr>
<td>Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)</td>
<td>Italy</td>
</tr>
<tr>
<td>International Energy Agency-Green House Gas (IEA)</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Environmental Research &amp; Industrial Co-operation Institute (ERICO)</td>
<td>Slovenia</td>
</tr>
<tr>
<td>Advance Resources International (ARI)</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>Commonwealth Scientific and Industrial Research Organisation (CSIRO)</td>
<td>Australia</td>
</tr>
<tr>
<td>OXAND</td>
<td>France</td>
</tr>
<tr>
<td>Research Institute of Petroleum Exploration and Development, PetroChina (RIPED)</td>
<td>P.R. China</td>
</tr>
<tr>
<td>China United Coalbed Methane Company (CUCBM)</td>
<td>P.R. China</td>
</tr>
</tbody>
</table>
Work packages MOVECBM

- WP0: Coordination
  - TNO

- WP1: Improving storage understanding and performance
  - Shell, UU, FPM, TNO, CSIRO, EPS, ERICO, SKLCC, ARI

- WP2: Monitoring of gas migration in coal reservoirs and assessment of caprock integrity
  - CMI, TNO, OGS, RWTH

- WP3: Wellbore integrity
  - EPS, TNO, OXAND

- WP4: Environmental monitoring and risk assessment and safety (HSE)
  - URLS, CMI, TNO, RIPED

- WP5: Results and verification
  - TNO, CMI, Shell, EPS, URLS, ARI, RIPED, CUCBM, IEA
WP1: Improving storage understanding and storage

- Lab experiments (adsorption, desorption, migration, caprock)
  - Example of UU work

- Modelling and mine experiments (reservoir, well)
  - Mine experiment Slovenia
    - performed January-March 2008
WP2: MOVECBM Reservoir / process monitoring

- Field experiment in Poland  -> second part of presentation
- Seismic monitoring
  - Crosswell and VSP tested previously
  - In MOVECBM: surface seismics
    - Time-lapse
    - Combination with passive seismics
WP3: Well integrity monitoring

• In MOVECBM: several tools are repeated (CBL, p, T)
  • Time-lapse
  • Results will be combined with lab experiments

- Tubing material (injection tubing)
- HPT samples
  - FeCO₃ precipitation
  - Blisters; pitting
  - Reproducible
WP4: Environmental monitoring and risk assessment and safety

Identification of unlikely leakage of injected CO₂ to the surface:

- Monitoring in nearby mine
  - Gas composition and isotopic value of CO₂

- Surface monitoring (concentration and flux)
  - Isotopes
  - Trends (spatial, time)

[Diagram of CO₂ monitoring and leakage pathways]
WP5: Results and verification

- Integration and reporting of project results
- International knowledge transfer
  - Special focus on cooperation with China
- Dissemination of project results
Overview of activities in the ECBM field pilot in Poland
RECOPOLE Period

- May 2004 (start production MS-4) - 28 June 2005 (last injection)
RECOPOL Period

**CO₂ injection**

- Cumulative injected CO₂ [t]
- 1 August: start of injection in coal seams
- Increase in injection rate
- Injection problems due to reduced permeability
- End of continuous injection
- 28 June: last injection

**CH₄ production**

- Cumulative production [m³]
- Start of second fall-off period and subsequent injectivity problems after mini-frac
- Start of continuous injection

- Methane production with CO₂ injection
- Estimated methane production without CO₂ injection

- Pipeline connection pump to wellhead
- CO₂ tanks
- Pump SKID
- Wellhead
Lessons learned in RECOPOL

• Injection in coal seams is not trivial!
  • Coal is swelling, thereby reducing the permeability

Build-up times decreased and fall-off times increased

• Although gas production is enhanced, gas production rates are lower than expected
  • Diffusion plays a major role in the gas production
  • Type of reaction between coal and CO₂ might be more complex than initially envisaged
Overview of activities in the periods following RECOPOL
Period 1

- 29 June 2005-10 January 2006
  - Abandonment production well MS-4
  - Pressure fall-off
    - Permeability ~1 mD
  - Modifications for gas release without pump
Period 2

- 11 January 2006 – 19 March 2006
  - Gas release with associated water level rise in the well (no water prod.)
    - Declining gas rates, approaching zero at the end of period
    - Reservoir P back to hydrostatic
  - Well occasionally shut-in for observation of P build-up
  - Gas composition (~60% CO2, 40% CH4)
Period 3

- 20 March 2006 – 20 March 2007
- (1 November 2006, start MOVECBM)
  - Modifications injector well MS-3 to prod. well
  - Standstill/CO₂ soaking
Period 4 – production MS-3

• 21 March 2007 – 18 September 2007
  • Production from MS-3 well
  • Very low water production, declining gas production rates
  • Water level continuously below lowest perforations
  • Gas composition (~40% CO₂, 60% CH₄)
Period 4

**Wellbore zone**
~3-5 m³ water filled pore space
(rel.) low pH, High HCO₃⁻
(rel.) low salinity
possible corrosion products (Ni)
(rel.) high CO₂ conc (60%)

**Reservoir zone**
Small volume of water filled pore space
(rel.) high pH, low HCO₃⁻
(rel.) high salinity
(rel.) high CH₄ conc (60%)

N.B: 2nd frac job used fresh water
Period 5

• 18 September 2007 – October 2007
  • Permeability tests
    • Water test
    • DST test
  • Abandonment

• Permeability tests in Period 5 showed that the perforations are open
Main questions

- Where is the water?
  - Water production in MS-4 well already low
  - Water can dissolve into CO₂ phase – effectively drying out the coal
- Where is the gas?
  - CH₄
    - Gas production in MS-4 well already low – indicating very slow matrix diffusion (confirmed by canister tests)
  - CO₂
    - Ca. 692 t CO₂ stored in the reservoir, only 8 t (1%) produced back
      - Leakage to the overburden – possible, but unlikely given monitoring results
      - Higher CO₂ production in MS-4 than registered – possible, but unlikely to account for all “missing” CO₂
      - Dissolution in water – volume not enough
        - Mainly in the wellbore zone, not in reservoir zone
        - Storage in coal seams – not in accordance with slow matrix diffusion
- What is the exchange process?
  - More complicated than envisaged (2:1)
Concluding remarks

- Interaction between CO₂ and coal under reservoir conditions is still a research issue
  - Understanding matrix diffusion and strain development is crucial in planning and operational phase of any ECBM project
  - Adjustment and calibration of numerical models required

- Significant progress made since project start

- ECBM is a niche option in Europe
  - probably not the best option for CO₂ storage if other options are available
  - In some countries alternatives not readily available …
Acknowledgements

• The RECOPOL project and MOVECBM are a team effort, with contributions from all partners of the international consortium
  • All are acknowledged for their contributions and financial support
    RECOPOL: Central Mining institute, Delft University of Technology, Aachen University of Technology, Air Liquide, DBI-GUT, Gaz de France, IFP, IEA Greenhouse Gas R&D Programme, CSIRO, GAZONOR, ARI, TNO
    MOVECBM: Central Mining institute, Aachen University of Technology, Shell, Univ. Roma, Univ. Mons, Utrecht Univ., SKLCC, OGS, ERICO, OXAND, RIPED, EPS, CUCBM, IEA Greenhouse Gas R&D Programme, CSIRO, ARI, TNO

• The European Commission is thanked for funding and support of the RECOPOL and MOVECBM projects

• Shell International, JCoal, the Federal Region of Wallonie (through the Faculté Polytechnique de Mons) and the Polish and Dutch governments (via Novem) are thanked for their support to RECOPOL

• Shell International, Schlumberger, Central Mining Institute and TNO are acknowledged for funding and supporting the transition period
WP5: website

- Website [www.movecbm.eu](http://www.movecbm.eu)