The new Clean Coal Technology Centre and underground coal gasification in Poland

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Główny Instytut Górnictwa (Central Mining Institute)

4th European Coal Days, 13th November 2013
General goal

Improvement of competitiveness of the Polish economy through application of modern technology solutions rated among clean coal technologies (CCT), allowing assurance of national energy safety and limiting degradation of the environment

Objectives:

Founding a centre for clean coal technologies that will allow effective competition with modern European and world centres in performance of projects aimed at developing and elaborating new clean coal technologies
Clean Coal Technology Centre

The aim of the investment was to built the experimental area for research and development in the laboratory as well as semi-pilot and pilot (PDU) scale for efficient and Clean Coal Technologies

- Research Laboratories
- Technological installations
- Engineering group for process modelling
- Process Development Units
CCTC- Katowice
Katowice – research laboratories

Leading interdisciplinary works i.e. in the line of:

- Identifying the resources of coal and accompanying fossil fuels
- Analysing the basics of coal processing and of the properties of the products
- Preparing coal for various application technologies, and especially researching coal properties
- Process engineering and nanotechnology
- Identifying the CO$_2$ storage potential
- Minimising the environmental impact
- Environmental research and monitoring
Research on kinetics and thermodynamics of reaction

Examples of devices:

- Pressurized thermo-gravimetrics analyser connected with mass spectrometer
- Analyser TPR/TPO/TPD
- Analyser Autosorb iQ Quantachrome
- FTIR Spectrometer Nicolet iS50
- Micro-autoclaves
- Analyser for chlorine
- AXIO Microscope
- X-ray diffractometer D8 Discover Bruker
Automatic analyser for chlorine content determining
The AXIO Microscope for determination of the reflectance of vitrinite and macerals group composition
X-ray diffractometer D8 Discover Bruker
Static model of CO2 tank located in Dębowiec layers in the area of Upper Silesia Coal Basin
Mikołów Experimental mine Barbara – technological unit

Leading R&D works in laboratory, large laboratory and PDU scale i.e. on the following stands:

- Stand for research on ambient pressure and high pressure coal gasification applying reactors simulating the coal bed
- Stand for researching coal gasification in fixed and moving bed systems
- Stand for researching direct coal hydrogenation
- Stand for research on gas separation methods applying PSA and membranes
- Stand for testing gas combustion in turbines and gas engines
- Stand for analysing various aspects of UCG in real conditions in generators constructed in the coal bed
CCTC Mikołów - Technological hall
CCTC Mikołów - Technological hall
Installation for pressured simulation of ucg
Installation for pressurized simulation of ucg
Installation for pressure swing adsorption gas separation
An installation for ucg gas cleaning
An installation for ucg gas cleaning
Recent UCG projects in Poland

**HUGE**
2007 - 2010

Elaboration of coal gasification technology for a high efficiency production of fuels and electricity
2010 - 2015

**HUGE2**
2011 - 2014

**Funding sources:**
- EU Research Fund for Coal and Steel
- National Centre for Research and Development (NCBiR)
- EU 7th Framework Programme

**COGAR**
2013 - 2016

**TOPS**
2013 - 2016
UCG aspects under study

- Technical infrastructure for UCG
- Technological aspects
- Environment and safety
- Gas utilization
- Coupled UCG-CCS

HUGE (RFCS)

HUIGE2 (RFCS)

COGAR (RFCS)

TOPS (7th FP)

Elaboration of coal gasification... (NCBiR)
Projects HUGE & HUGE2

**Hydrogen Oriented Underground Coal Gasification for Europe**

**Aims:**
Theoretical and experimental exploration of the possibilities of in-situ production of *hydrogen-rich* gas through the *underground coal gasification (UCG)* technique

**HUGE 2** – Safety and Environmental Aspects
Ex-situ experimental installation

**Installation parameters**

- **Coal seam dimensions**: 2,5 x 0,8 x 0,8 m
- **Gasification agent**: Oxygen, air, steam
- **Gasification temperature**: up to 1600°C
- **Gasification pressure**: atmospheric

**Gas quality control**

**Temperature control**
Examples of large coal samples

0.5 m
Post-gasification studies
Field-scale UCG experiments at Experimental Mine „Barbara” in Mikołów
Scheme of the in-situ installation

1. Oxygen
2. Air
3. Water
4. Nitrogen
Georeactor’s input wall and inlet
Coal seam ignition
Operating conditions and general gasification results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasification agent</td>
<td>oxygen</td>
</tr>
<tr>
<td>Oxygen supply rate, Nm$^3$/h</td>
<td>10 - 40</td>
</tr>
<tr>
<td>Experiment duration, hours</td>
<td>355</td>
</tr>
<tr>
<td>Average gas production, Nm$^3$/h</td>
<td>202</td>
</tr>
<tr>
<td>Average gas composition, %:</td>
<td></td>
</tr>
<tr>
<td>CO$_2$</td>
<td>16.4</td>
</tr>
<tr>
<td>H$_2$</td>
<td>14.7</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>1.5</td>
</tr>
<tr>
<td>CO</td>
<td>13.4</td>
</tr>
<tr>
<td>N$_2$</td>
<td>52.9</td>
</tr>
<tr>
<td>Average gas heating value, MJ/Nm$^3$</td>
<td>3.75</td>
</tr>
<tr>
<td>Total coal consumption, kg</td>
<td>22 100</td>
</tr>
<tr>
<td>Process energy efficiency, %</td>
<td>56</td>
</tr>
</tbody>
</table>

![Graph showing concentrations over time](image)

![Graph showing gas production rate over time](image)
Investigation of the post-gasification cavity

Char, semi-char
Bottom ash
Roof rock
Numerical modelling of UCG hydrogeology – E Mine

Groundwater flow model (2D)

Darcy’s law:

\[ u = -K \nabla H \]

\[ S \frac{\partial H}{\partial t} + \nabla \cdot [-K \nabla H] = Q_s \]

Contaminant transport model

Advevtive – dispersive transport:

\[ \frac{\partial C}{\partial t} + \nabla \cdot (-\theta D \nabla C + uC) - \lambda R \theta C = 0 \]
Contaminant transport in coal seam and selected rocks

<table>
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<tr>
<th>Shale 1</th>
<th>1 year</th>
<th>3 years</th>
<th>10 years</th>
<th>20 years</th>
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<th>3 years</th>
<th>10 years</th>
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<th>3 years</th>
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Normalized isolines of *naphtalene* (c/c₀)

dx₁, dx₂, dx₃
### Project TOPS

**Technology Options for Coupled Underground Coal Gasification and CO₂ Capture and Storage (TOPS)**

<table>
<thead>
<tr>
<th>Participant No</th>
<th>Participant Organisation Name</th>
<th>Country</th>
</tr>
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<tbody>
<tr>
<td>1 (Coordinator)</td>
<td>Imperial College of Science, Technology and Medicine (Imperial)</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>2</td>
<td>Seamwell International Ltd. (Seamwell)</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>3</td>
<td>Główny Instytut Górniczego (GIG)</td>
<td>Poland</td>
</tr>
<tr>
<td>4</td>
<td>Helmholtz-Zentrum Potsdam Deutsches GeoForschungszentrum (GFZ)</td>
<td>Germany</td>
</tr>
<tr>
<td>5</td>
<td>Technische Universiteit Delft (TUD)</td>
<td>Netherlands</td>
</tr>
<tr>
<td>6</td>
<td>University of Glasgow (UoG)</td>
<td>United Kingdom</td>
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<tr>
<td>7</td>
<td>Premogovnik Velenje, D.D. (CM-Velenje)</td>
<td>Slovenia</td>
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<tr>
<td>8</td>
<td>The Geological Survey of Denmark and Greenland (GEUS)</td>
<td>Denmark</td>
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<td>9</td>
<td>Katowicki Holding Węglowy S.A (KHW SA)</td>
<td>Poland</td>
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<td>10</td>
<td>Seamwell (Hong Kong) Ltd (Seamwell HK)</td>
<td>Hong Kong</td>
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<td>Golder Associates Africa (PTY) Ltd (GolderSA)</td>
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<td>12</td>
<td>Henan Polytechnic University (HPU)</td>
<td>China</td>
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<td>13</td>
<td>Commonwealth Scientific and Industrial Research Organisation (CSIRO)</td>
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<td>Monash University (Monash)</td>
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<td>Canada</td>
</tr>
<tr>
<td>16</td>
<td>The Trustees of Indiana University (IndianaU)</td>
<td>USA</td>
</tr>
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Workpackages and experimental stand

**WP2**
Experimental investigations in thermo-chemical processes involved in UCG – reagent and produced gas quality assessment/optimisation

**WP4**
Assessment of environmental impacts and risk

**WP5**
Storage options and coupling the UCG-CCS processes
Polish UCG project supported by The National Centre for Research and Development

Developing a technology of coal gasification for high efficient production of fuels and electric power
Pilot scale UCG experiment in one of the Upper-Silesian coal mines – KWK Wieczorek

Industrial UCG installation design

Partners: Central Mining Institute, Katowice Coal Holding, Academy of Mining and Metallurgy, Kraków
Cost: 20 mln euro
The aim of the project

• Accessibility of coal seam of proper localisation and thickness
• Gasification of coal in pilot scale
• Demonstration an ability of save ignition, gasification and cooling of the process
• Demonstration an ability of using the product of gasification (designing burner, using engine)
• Collection of data for technological project scaled up to demonstration size
Technical assumptions

Coal consumption: 15 ton / day
Duration of trial: 2-3 months, a F/M of 2014
Gasification agent: air (oxygen for starting)
Coal seam thickness: 5,5 m
Depths of coal layer: 500 m
Accessibility from galleries
Infrastructure requirements – Potential to integrate with existing coal mining infrastructure
Woda z sieci -> Woda z sieci

Powietrze

Cyclone

Chłodnia Wentylatorowa

Wybudź gazu do atmosfery

Adrosbery związków H₂S

Woda

Zbiornik ścieków

Zbiornik ścieków

Woda z sieci

Wentylator

Wymienik gaz/powietrze

Wymienik gaz/woda

Separator wirowy

Zbiornik ścieków

Pochodnia

UKŁAD SILNIKA

Woda
Main technical and formal problems

• Choosing the proper place for gasification (Silesia mining area)
• Preparation the trial in working mine
• Getting special permission for the UCG trial
• Fulfilling the regulations of Mining Authorities
Expected results

1. Mathematical model of georeactor
2. Procedures for accessibility of coal seams for UCG
3. Technological project of UCG demonstration installation
4. Feasibility study of UCG demonstration installation
5. Development of optimal system of UCG gas utilisation
Thank you very much for your attention