Underground Coal Gasification – Practical Experience with UCG Trials

Michael Green, UCG Engineering Ltd
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Content of Presentation

• Early UCG Trials 1930-1990
• EU Trials and UK DTI Initiative 2000
• Main UCG Field Trials, Post 2000 Period, Australia, EU, Eskom, Wyoming, Poland
• Approaching Field Trials Status in 2015
UCG Experimental Mine in Lisichansk & Gorlovka, Ukraine 1934-5

- First combustible gas, 29th June 1934, when one of the boreholes was ignited and burned for 15 days.
- Calorific value of the gas 6.5MJ/m³ (typical composition: (6–12% CO, 7.8–20.6% H2 and 2.8–4.2% CH4)
- In August 1934 a syngas contained 25% CH4, 32% H2 and 7.5% CO, and a calorific value varying between up to 8MJ/m³ on oxygen, by Donetsk Institute of Coal Chemistry (DUKhI).
- The first pilot-style UCG operation was commenced in Gorlovka (Donetsk Basin) on February 8, 1935.
USSR Developments in 1960 & 1970’s

- Tested a variety of configurations in 6 or more sites, Ukraine, Russia, Uzbekistan
- Finally settled on linked vertical wells in shallow coal
- At least two commercial schemes, Siberia and Uzbekistan, probably still operating.
Newman Spinney Trial UK 1950
UCG Technology Changes
1960 - 1990

- Fixed Injection ➔ Retractable CRIP
- Reverse Combustion ➔ In-seam Drilling
- Air/Steam ➔ Oxygen/Water
- Shallow Depths ➔ Interim./Great Depth
- Hydrofracking ➔ Drilled Connection
- Experimental Trials ➔ Commercial Operations
US Trials 1970-1990

- 31 tests involving DOE, Gulf, Texas A&M, GRI, ARCO
- Two technologies developed
  - Steeply Dipping Beds
  - Moveable Injection CRIP
  - Rocky Mountain Trial, 14,000 tons of coal 93 days
- Oxygen Fired CV 9-11 MJ/m³
- Commercial scheme for NH₃ production designed – not constructed
Background to European UCG Trial up to 1990

- Developing Technology from U.S and oil & gas industry - CRIP, in seam drilling, use of oxygen
- Thulin Trial (1979-87) - 860m depth, high CV gas
- European Working Group Report (1989) – proposed trials at increasing depth in typical coal seams
El Tremedal, Spain, In-Seam Configuration and Project Plan

- **Preparatory stage**
  - Geology and coal evaluation.
  - Drilling, completion of boreholes,
  - Surface equipment.

- **Gasification activities**
  - Drying, pressurisation, ignition of the coal
  - Development of cavity by means of the CRIP manoeuvre.

- **Postburn activities**
  - Determine cavity shape by drilling
  - Validate gasification models used for process control.
  - Site restoration.
Key Results from European Trial

- Coal Affected: 290 tons
- Product Gas: 490 tons
- Peak Power: 8MW
- Gas Composition (dry N\textsubscript{2} free):
  - Hydrogen: 27%
  - Carbon Monoxide: 14%
  - Methane: 14%
  - Carbon Dioxide: 45%
- Calorific value of product gas (LHV): 10.9MJ/m\textsuperscript{3}

- Two successful ignitions, and seven manoeuvres of the coiled tubing
- Directional drilling for process well construction, but improvements required.
- Gasification at greater depth enhances methane formation and cavity growth.
- The process is controllable and highly responsive.
- Stopped because of a blockage in the supply tube to the burner. This led to a delayed ignition which created an underground explosion and damaged the injection well.
UK DTI Programme on UCG
1999-2005

Objectives
• Accuracy and consistency of in-seam drilling in typical UK seams (400m run)
• Environmental and public perception Study
• Evaluation of land reserves of coal for UCG
• Identification of potential trial and operational sites
• Economic scoping study
• Pre-feasibility of offshore UCG
• UCG as a low carbon option
# UK Coal Resources Study 2005

<table>
<thead>
<tr>
<th>Area of UK</th>
<th>&quot;Good&quot; UCG Resource M-tonnes</th>
<th>UCG reserve as Nat Gas BCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern/NE England</td>
<td>6,824</td>
<td>681</td>
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<tr>
<td>Lancs/Dee</td>
<td>4,770</td>
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<tr>
<td>Midlands/Staffs</td>
<td>2,759</td>
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<tr>
<td>Warwick/Oxford</td>
<td>2,040</td>
<td>204</td>
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<tr>
<td>Wales</td>
<td>220</td>
<td>22</td>
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<tr>
<td>Scotland</td>
<td>171</td>
<td>17</td>
</tr>
<tr>
<td>TOTAL</td>
<td>16,784</td>
<td>1,676</td>
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</tbody>
</table>

1,676 BCM equals 11Billion Barrels of Oil equivalent
Feasibility Study of UCG-CCS in the Firth of Forth 2004
Linc Energy Chinchilla UCG Facility

- 80 million Nm³ gas produced @ 4.5 - 5.7 MJ/Nm³ in five gasifiers.
- Maximum capacity of 80,000 Nm³/hr & 675 t/day
- Availability of gas production over 30 months
- Average depth of 130 m
- GTL pilot plant developed
Linc Energy - Yerostigas, Angren, Uzbekistan

Co-fired Power Station (1,200MW)
Operating since 1960’s
Coal Research Forum AGM 15th April 2015 Leeds

Carbon Energy, Parallel CRIP Bloodwood Creek, Queensland

Carbon Energy has achieved Proof of Concept and has demonstrated:
- Drilling and construction
- Ignition and commissioning
- Over 5 years of in-field trials
- Over 20 months continuous production
- Consistent production of high quality syngas
- Operation of 1.5 MW Power Station
- Connected, synchronised Power Station to the local grid
- Validation of gasification prediction models
- Sound environmental management
- Independently verified Proof of Concept
- Completed an independent electro-seismic survey
3. ENN’s UCG Progress (site progress)

- New gasifier run for 26 months; 100 kton coal gasified
- Air blown gas: 350,000m³/d, 900Kcal/m³
- Enriched-oxygen gas: 250,000m³/d, 2000Kcal/m³
- Power generation: 5MW capacity, 22 month continuously run

Application of 3D Seismic Prospecting Technology in detection of underground coal gasification cavity-growth
Huntly, Waikoto, NZ & Swan Hills, Alberta UCG  2010-2012

- Sub-bituminous and volatile bituminous Coals at 350m & 1,400m depth.
- Trials of 1 year each, State Supported.
- Air and O2 fired.
- Vertical linked & In-line CRIP
ESKOM UCG PROJECT STATUS

• The Eskom pilot plant was commissioned in January 2007 and has run continuously ever since.
• The gas cleaning plant and condensate separation plant for a 15,000Nm3/hr co-firing demonstration have been commissioned.
• Mine production can be ramped up to provide the necessary gas flow for a co-firing demonstration in Unit 4 at Majuba Power Station.
• Initial co-firing at Majuba power station was achieved in October 2010.
• The design phase for a 100-140 MWE open cycle gas turbine demonstration plant using UCG gas is currently underway.
€3.2M EU Study HUGE - Hydrogen Underground Gasification Europe

Location of HUGE HUGE2 Gasifiers at Barbra Mine
€8M Polish National UCG Project “Wieczorek mine”

- In-situ coal and in mine test at 350m depth. Initially flared, but long term the gas will be utilised for power.
- June 2014, over two months, around 250 tonnes of coal and around 900,000 m³ of gas produced.
- Calorific value between 3.0 to 4.5 MJ/m³ was produced. The process yielded syngas at around 600-800 m³/hour.
- Gas temperature at the outlet of the georeactor was measured as 470-520°C.
- Oxidants were air/oxygen, different volumes of water and the part supply of CO₂ as the reagent to produce carbon monoxide.
Options for coupled UCG & CCS EU RFCS Projects, Bulgaria & TOPS

- **Bulgaria** – Evaluated potential of deep coal seams for UCG and storage of CO2 in the affected area (2010-2013).
  - 20% can be stored in cavity,
  - Bulgaria site suitable for tests
  - UCG-CCS costs at €70-80/MWh

- **TOPS Project** led by Imperial College to investigate UCG-CCS wider options, risk & environment (2014 ongoing)
  - High pressure Ex-situ Gasifier tests and Pilot plant in Poland. Site selection process for matching UCG and CCS potential.
  - Generic Environmental Risk Assessment Framework (GERAF) & Life cycle inventory models with and without CCS
THEUNISSEN AFRICARY Project

• Exploration complete
• Entered in S African DOE Competition for IPP 50MW
• BHP Bilton coal field and support 350-500m
• Polygeneration for power and fertilisers
SinoCoking Ltd

- Coking company with already developed markets for syngas to local industry (Shemna Industries) and in-house power generation.
  - $11m UCG project started in Aug14 and has apparently already achieved 15,000 m3/h syngas with 25,000 m3/h in 2015
  - 95m depth and 8m thick coking coal seams (Chinese Technology)
  - O2 enriched for NG production + 3MW Power unit, and H2 for Fuel Cells and refuelling planned.
Firth of Forth Licensing Areas - April 2015

UCG License Areas in FoF  Apr 2015
### Conclusions - Leading UCG Trials 2015

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<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>End Product</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two UK Companies, CNR &amp; 5Q</td>
<td>Offshore, UK</td>
<td>Demonstrator for Industrial and Power Generation</td>
<td>40MW</td>
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<tr>
<td>Linc Energy</td>
<td>US, Tanzania, Poland &amp; Uzbekistan</td>
<td>Feasibility of UCG to Diesel Fuel and power generation</td>
<td>20k bbl/d &amp; 1 GW</td>
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<tr>
<td>Carbon Energy</td>
<td>Queensland, Australia</td>
<td>Blue Gum SNG</td>
<td>720PJ</td>
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<td>Sinocoking</td>
<td>Hebei Prov, China</td>
<td>Power Generation</td>
<td>400MW</td>
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<td>Katowicki Holding Węglowy (KHW)</td>
<td>Wieczorek”, Mine, Poland</td>
<td>Heating, Power generation</td>
<td>40MW</td>
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<tr>
<td>Eskom</td>
<td>Majuba, S Africa</td>
<td>Power Generation</td>
<td>400MW</td>
</tr>
<tr>
<td>ENN, Xinao Group</td>
<td>China</td>
<td>Methanol</td>
<td>20kt/y</td>
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