Underground Coal Gasification

A clean, low cost, source of gas for power generation and chemical feedstock

Presented by
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Trustee, UCG Association
Underground Coal gasification

- The process of gasifying coal whilst in situ
- Best suited to deep, inaccessible coal, UCG has the potential to significantly increase global coal stocks and turn these into a high value synthetic gas, cleanly, safely, cheaply
- In recent years it has undergone a transformation due to technical advances, specific research, open exchange of knowledge and information.
- Much of the recent development and industry growth has been spearheaded by the UCG Association
- However, we did not envisage we would become responsible for the formation of a global industry and engaged with every aspect of taking a new technology to commercial viability
The UCG Association

• The professional body for the Underground Coal Gasification Industry
• Promotion and development of the highest standards of education and professional performance amongst all in UCG
• Engage with Governments, Decision makers, Environmental Groups and the Media - Work closely with Licensing, Regulatory Bodies
• Not for profit organisation
• Over 280 members, representing more than 70 organisations. 28 Countries represented : Argentina, Australia, Belgium, Botswana, Brazil, Bulgaria, Canada, China, Colombia, Germany, Hungary, India, Indonesia, Ireland, Italy, Japan, Kazakhstan, Netherlands, Norway, Poland, Russia, Slovakia, South Africa, Ukraine, UK, USA, Vietnam.
• As this industry has grown our already pivotal role has evolved
• UCGA is globally recognised as the centre of excellence and information for all
• www.ucgassociation.org
More of our Members
Basic UCG Technology

The UCG process takes place underground, generally below 1,200 feet (365 metres). The setting provides both the feedstock source as well as pressures comparable to that in an above-ground gasifier. Two wells are drilled on either side of an underground coal seam. One well is used to inject air or oxygen (and sometimes steam) into the coal seam to initiate the gasification reactions. The second well is used to collect the synthesis gas (syngas) that is formed from the gasification reactions and to pipe it to the surface for additional processing and use.
Basic UCG Technology

- A pair of wells can last 8-10 years. The resulting high quality Syngas can be processed to provide fuels for power generation, diesel fuels, jet fuels and hydrogen. Once a particular section of a coal seam is exhausted, new wells are drilled to initiate the gasification reaction in a different section of the coal seam.
The UCG Process

Key Variables:
1. The Coal – Nature, seam thickness, strata
2. Depth, - Hydrostatic Pressure
3. Oxidant – Oxygen content
Benefits of UCG

- As the gasification of coal takes place underground many of the advantages of UCG are obvious
- No coal is brought to the surface - No surface gasifier - No one underground - Lower fugitive dust - Noise - visual impact
- Syngas piped directly to end-user, reducing rail / road infrastructure
- The whole process affords opportunities to use coal more effectively
UCG – Lower emissions

- Particulates – 50% lower than surface equivalents and stay underground
- Mercury, Sulphur greatly reduced and easier to handle
- Reduced methane emissions - gas recovered, rather than lost in the atmosphere
- Leaves coal ash and other process wastes deep underground,
- Eliminating - costs/risks handling and disposing of surface ash
- Significant advantage for low rank, high ash coals such as India
UCG – Syngas production

- UCG – versatile, affordable synthetic gas (Syngas).
- Heating, power generation, liquid fuels such as diesel or methanol.
- Hydrogen accounts for nearly 50% total gas product.
- Automotive fuel or chemical feed-stock.
- But when we talk about the need to find more efficient technologies.

**UCG can operate at up to about 80% efficiency—**
the amount of the syngas recovered at the surface is about 80% of the original heating value of the coal feedstock.
Examples of UCG Syngas composition

Product gas, volume% (dry)

Gas calorific value, MJ/m³ (dry, STP)

Other
Carbon dioxide
Hydrogen
Carbon monoxide
Methane
Calorific value

with AIR

with OXYGEN

CO₂
H₂
CO
CH₄
UCG – Carbon Capture advantages

- UCG offers relatively simple, low-cost carbon removal, prior to use.
- Underground storage or transported for Enhanced Oil Recovery (EOR) or ECBM (Enhanced Coal bed Methane)
- Lower CO₂ emissions than a combined-cycle natural gas power plant - the cleanest of all fossil fuel plants.
UCG - Carbon Capture advantages

- Gasification Process - amenable to pre-combustion capture (CHEAPER CO₂ SEPARATION)
- Oxy-fuelled Process - burning gas produces only CO₂ and water (CHEAPER SEPARATION)
- H₂/methane mixtures can be produced - advantageous in gas turbines.
- The captured gases containing carbon dioxide **could** be safely stored underground in the cavities created by the UCG process.

Image courtesy of Jade Technologies
UCG - the Future for UK Coal Production?

UCG is set to play a major role in meeting increased demand for secure, safe and indigenous energy - whilst meeting the carbon reductions required by Europe. This puts the UK back as one of the world leaders in UCG technology - development of UCG began in the UK. Projects will prove the technology is viable, safe, economic and plentiful, might herald a new era of UK coal production.
Areas of the UK Suitable for Commercial UCG

<table>
<thead>
<tr>
<th>Area of UK</th>
<th>&quot;Good&quot; UCG Resource M-tonnes</th>
<th>Power Output over 40 years MW</th>
<th>UCG as Nat Gas BCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern/N E England</td>
<td>6,824</td>
<td>11,900</td>
<td>681</td>
</tr>
<tr>
<td>Lancs/Dee</td>
<td>4,770</td>
<td>14,100</td>
<td>476</td>
</tr>
<tr>
<td>Wales</td>
<td>220</td>
<td>730</td>
<td>22</td>
</tr>
<tr>
<td>Scotland</td>
<td>171</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>TOTAL</td>
<td>16,784</td>
<td>26,730</td>
<td>1,76</td>
</tr>
</tbody>
</table>

Current Coal Power Capacity ~ 28,8550MW
UK Current Nat Gas Reserves 530BCM

BGS study of coal resources for UCG, supported by DTI
UCG License Areas in the UK

First UK UCG licence application - February 2009 - now 18
Thornton New Energy/BCG Energy
1 in the Firth of Forth
November 2009 - Clean Coal Limited
Five coastal areas of England and Wales
2010 - Riverside Energy
Six UCG Licences – 2 coastal areas of Scotland 4 England
Europa Oil and Gas – 2 coastal areas England
Five Quarters – 4 coastal North East England
All are conditional licenses – all are offshore
Riverside Energy 6 Licences, 2 FoF, 50% JV
Clean Coal (CCL) - UCG UK License Areas
## Clean Coal UCG – Coal Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Canonbie</th>
<th>Sunderland²</th>
<th>East Anglia</th>
<th>Humberside</th>
<th>Swansea Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average total coal seam thickness beneath Site (m)¹</td>
<td>Unconfirmed at site</td>
<td>Unconfirmed at site</td>
<td>Unconfirmed at site</td>
<td>Unconfirmed at site</td>
<td>Unconfirmed at site</td>
</tr>
<tr>
<td>Area of Site (km²)</td>
<td>41 km²</td>
<td>97 km²</td>
<td>100 km²</td>
<td>81 km²</td>
<td>77.5 km²</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>&gt;1,000 m</td>
<td>500-800 m</td>
<td>&gt;1,000 m</td>
<td>1,000-1,200 m</td>
<td>200-600 m</td>
</tr>
<tr>
<td>Resource² assuming 2m seam thickness (Mt)</td>
<td>103 Mt</td>
<td>252 Mt</td>
<td>252 Mt</td>
<td>204 Mt</td>
<td>206 Mt</td>
</tr>
<tr>
<td>Resource² assuming 4m thick seam (Mt)</td>
<td>207 Mt</td>
<td>504 Mt</td>
<td>504 Mt</td>
<td>408 Mt</td>
<td>412 Mt</td>
</tr>
<tr>
<td>Potential amount³ of coal recoverable by UCG: 2m seam (Mt)</td>
<td>54 Mt</td>
<td>131 Mt</td>
<td>131 Mt</td>
<td>106 Mt</td>
<td>107 Mt</td>
</tr>
<tr>
<td>Potential amount³ of coal recoverable by UCG: 4m seam (Mt)</td>
<td>107 Mt</td>
<td>262 Mt</td>
<td>262 Mt</td>
<td>212 Mt</td>
<td>214 Mt</td>
</tr>
</tbody>
</table>

¹ sites have been selected on the basis of high probability of coal seams being 2-4m at least.

² resource estimate will confirmed during feasibility studies and site exploration.

³ coal recoverable by UCG assumes a 52% UCG sweep efficiency and 100% resource availability.

⁴ part of the Sunderland area is contains abandoned sub-seafloor with coal mines and so resources are likely overestimated.
Awarded two licences by the UK Coal Authority to investigate underground coal gasification of virgin coals along the eastern coast of England. These licences are situated in areas with deep coal measures with little structural complexity and a proximity to existing gas and utility infrastructure. With only 30% utilisation rate for the coals, the estimated potential UCG energy resource in these two licence areas is 36EJ or 6 billion barrels of oil equivalent.
Five Quarters

- A consortium of business men and senior professors from Newcastle University including Prof. Paul Younger, Prof, Dermot Roddy
- Newcastle University, many years of UCG Research, Sir Joseph Swann Institute
- 4 conditional UCG licenses - all located off shore in North East England
- Lynemouth, Blyth, Tynemouth, Loughton
- This is a region that once thrived on coal and has a great deal of knowledge and information on coal strata.
- Has a lot of local support, including local government
Five Quarters UCG sites

Lynemouth

Longhoughton

Blyth

Tynemouth
Underground Coal Gasification

Energy Institute E.Midlands
27th September 2011

Efficiency and Capital Cost of Various Coal Combustion Technologies

- **£1150/kW**
- **£1200/kW**
- **£1300/kW**

**CAPEX without CCS**

- **Sub-critical**
- **Supercritical**
- **Ultra-SC**
- **IGCC**

CO2 Emission gram/kWh

- **1500**
- **1000**
- **500**

Proposed limit of 500g/kWh

20-25% energy cost for 90% post-combustion capture

- **£1700 - 1800/kW**
- **£1150/kW**
- **£1600/kW**
- **£800/kW**
- **£1300/kW**

10% energy cost for 100% pre-combustion capture

150 MW UCG + CCGT

150 MW UCG + Fuel Cells

Average Europe

Net efficiency (LHV) %

- 30%
- 35%
- 40%
- 45%
- 50%
- 55%

Courtesy of BCG Energy
UCG - Costs for Power Generation

UCG also offers lower Capex and Opex – lower plant and operational costs

Cost of UCG for Power Generation – UCGA 2010
UCG – sustainable development

- Applying UCG technology to stranded, low-grade coal seams vastly increases the amount of exploitable global reserves.
- Estimates suggest UCG could increase recoverable coal reserves by 300%-400%.
- Coal when applied to UCG becomes the largest sustainable resource base in the world.

- World Resource: 5-8000BT
- Proven Reserve (2005): 909BT
- Est. UCG addition: 600BT

*Accelerating Development of Underground Coal Gasification, Dr. S Julio Friedmann, Lawrence Livermore National Laboratory, 2007.*
UCG – ENVIRONMENTAL CONCERNS

Subsidence and Groundwater Contamination

Both are easily managed by Careful Site Selection, Project Design and Project Monitoring.

- Site selection criteria the same; geomechanical and hydrogeological, since the two are intimately linked.
- Operating conditions involve never allowing the cavity pressure to exceed the hydrostatic pressure.
UCG – ENVIRONMENTAL CONCERNS

Subsidence - surface and subsurface.

The key factors affecting subsidence are:
- Seam thickness and amount of coal gasified
- Seam Depth (overburden thickness).
- Geomechanical properties of the overburden (stiffness, yield strength).
- Fracture density and orientation.

- Risks can be minimized or even eliminated with proper site selection, reactor zone pressure and temperature management
- Spacing of UCG reactors - walls and pillars between production zones
- Identification and avoidance of structural weaknesses - pre-existing faults

UCG operations cause less subsidence than underground mining
UCG –ENVIRONMENTAL CONCERNS

Likewise, the risk of groundwater contamination can be virtually eliminated by selecting a site well below the fresh-water aquifer and with the proper type of impermeable overburden strata.

Process chamber pressure - carefully managed
Kept below the hydrostatic pressure in the coal seam,
Keep water in flux and pollutants in the process cavity.
UCG – ENVIRONMENTAL CONCERNS

- Dry overlying rocks will not provide a seal to the UCG reactor.
- Saturated rocks will, because water fills the pore spaces.
- The greater the hydrostatic pressure, the greater the pressure maintained in the reactor.
- Too much reactor pressure can lead to gas escape and potential groundwater contamination.
- Maintain groundwater levels to ensure process efficiency & a seal around the reactor.
- Local and regional groundwater modelling required.
How fast is the industry growing?

UK:
- 13 UCG licences awarded (BCG Energy, CCL, Riverside, Europa Oil & Gas, B9 Coal and others) promoting a demonstration UCG-GGS project offshore and 500MW power station.

Ireland:
- 1 UCG licence awarded in Dublin Bay - VP Power.

Belgium:
- EU trial at Thulin.

Canada:
- UCG Projects announced in Alberta, Nova Scotia, Swan Hills, CCL & Laurus.

USA:
- Major trials in the 1950s. Substantial interest & new project activity planned in Wyoming, Montana, North Dakota, Cook Inlet, Alaska & other states. Linc, CCL & Laurus.

Spain:
- EU trial at El Tremedal.

Colombia:
- UCG project planned.

Chile:
- UCG project announced by Carbon Energy.

Brazil:
- Demonstration project planned.

Slovenia:
- UCG under review.

Czech Republic:
- UCG under review.

Slovak Republic:
- MOU signed by CCL.

Hungary:
- White Coal & Wildhorse Energy project.

Romania:
- UCG activity under review.

Bulgaria:
- 2 projects under review.

Turkey:
- CCL project in Amsara with Hema.

Kazakhstan:
- UCG trial site identified.

Russia:

Japan:
- Research activity.

China:
- History of Pilots. Academic training of many UCG PhDs. New projects planned - Cougar & CCL. The Ulanchap, Inner Mongolia project is in its 3rd year. Other projects in this region in planning stage with other operators including CGE, Cougar & Gulfside.

Bangladesh:
- UCG activity planned.

Vietnam:
- 2 projects Red River Delta in planning stage - Linc & CCL.

Indonesia:
- MOU signed by CCL.

Australia:

New Zealand:
- Solid Energy UCG project.

India:
- Substantial activity planned with 13 companies bidding for leases.

South Africa:
- Eskom in 2nd stage of UCG project. Others reviewing.

Uzbekistan:
- Oldest UCG plant in the World (50yrs) in Angren.

Pakistan:
- Substantial activity planned in Synth Province.

Map Courtesy of Clean Coal Ltd.
Global UCG Development

- **Australia** - Bloodwood Creek, Carbon Energy
- Chinchilla, Linc, western Australia, 3 sites
- New announcement for Pekira Basin,
- **Bulgaria** – EU funded research project – Overgas, Aachen University, Leeds University, UCG Engineering
- **Canada**, Swan Hills Synfuels, deepest ever, 1,400 meters, Laurus Energy Project
  others Liberty Resources, Linc, Canada working on legislation
- **China** – recent announcement of Inner Mongolia Project, joint UK/China initiative, ENN syngas from pilot project in Walanchabi City, Inner Mongolia, 26 months, gasifying more than 100,000 tons of coal.
- **Chile** - Carbon Energy
- **Hungary**, WildHorse, Mecsek Hills project, plus two other sites earmarked
- **Turkey** – Carbon Energy
Global UCG Development

- **India** – announcement soon of UCG projects
- **New Zealand** – Solid Energy project at Huntley
- **South Africa** – Eskom, Majuba
- **UK** - 18 licenses to explore UCG off shore
- **USA**, Wyoming, Montana, Alaska – Linc, Carbon,
- State level - Montana, Colorado, Indiana,
  University of Utah, grant DoE, for UCG research
- Countries with green credentials - New Zealand and Canada are actively engaged in UCG
- Linc Energy ahead – 9 offices, 3 continents and 400 staff
- UCG is **now** being recognised globally as a viable and economic method for accessing deep otherwise unrecoverable coal reserves, **on and offshore**
Summary - UCG has so much to offer

- Lower Emissions
- Options for carbon capture,
- Higher yield - at lower cost
- Vastly increases global coal resources, on and off shore
- In the UK there are 18 licenses to explore UCG off shore
- Countries with green credentials - New Zealand and Canada, are actively engaged in UCG
- Site Selection is vital - not all coal is suitable
- UCG is certainly entering a new and exciting phase of development – worldwide
- Commercial-scale operations within five to seven years
- Sharing knowledge - vital for UCG to be accepted
The UCG Association
At the forefront of the developing UCG Industry

7th UCGA International Conference & Workshop
London, 2nd - 3rd May 2012

www.ucgassociation.org