Underground Coal Gasification – Practical Experience with UCG Trials

Michael Green, UCG Engineering Ltd

Coal Research Forum Meeting on UCG 15th April 2015

ucg engineering ltd.

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.

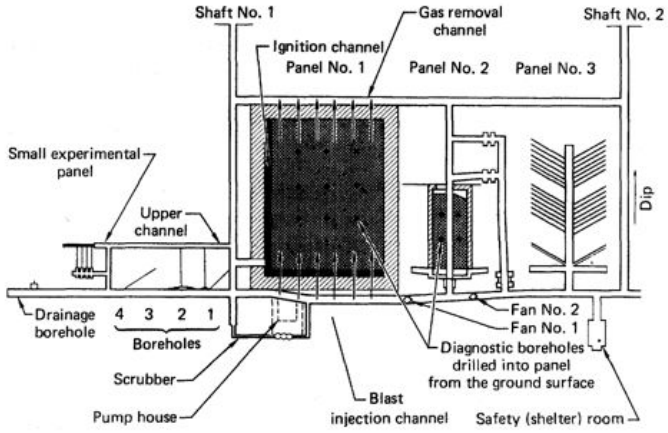


Table 1. Gas data from the first stream experiment in Lisichansk.

Time	p (atm)	CO_2	O_2	C_nH_m	CO	H_2	CH_4
2:40	2.8	17.6	0.2	-	27.2	-	-
3:20	2.6	12.7	0.9	0.15	51.6	28	0.3
3:40	3.5	13.1	0.4	0.1	53.5	31.3	0.3
5:00	7	12.8	0.6	0.1	55.8	23.6	0

ucg engineering ltd.

USSR Developments in 1960 & 1970's

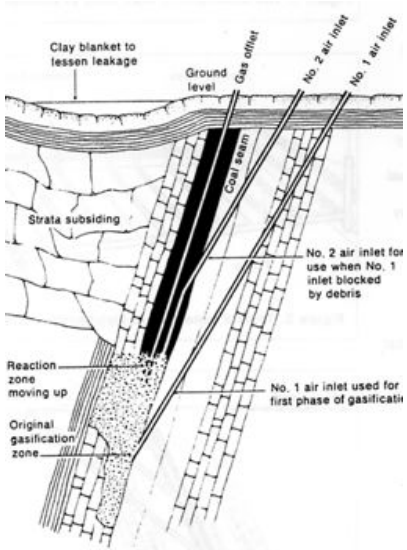


Figure 5. Use of two air inlet boreholes in a steeply sloping seam

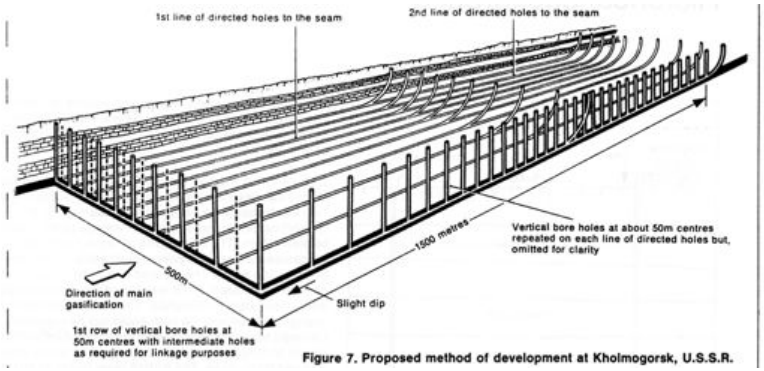
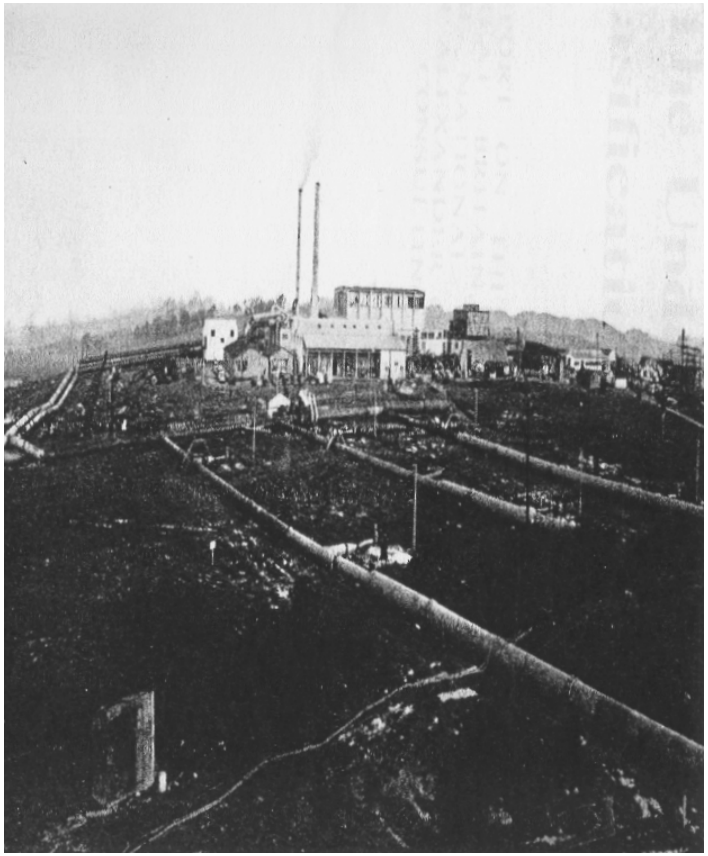


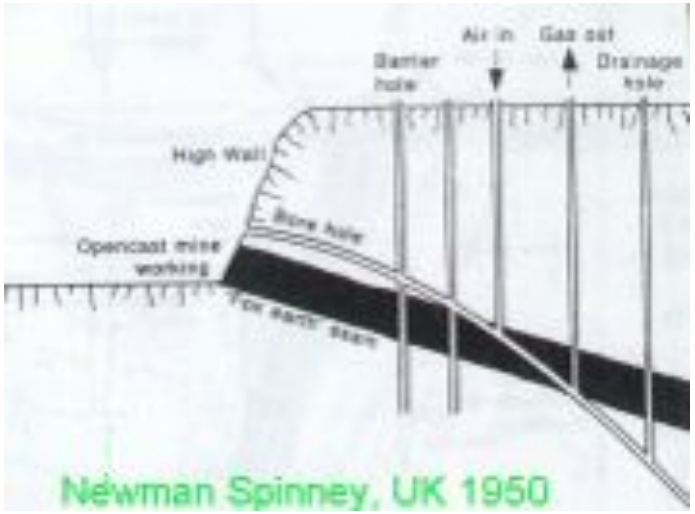
Figure 7. Proposed method of development at Kholmogorsk, U.S.S.R.

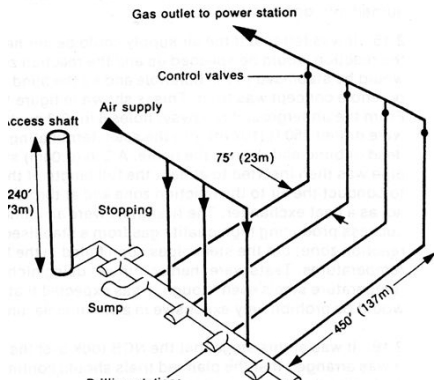
- Tested a variety of configurations in 6 or more sites, Ukraine, Russia, Uzbekistan
- Finally settled on linked vertical wells in shallow coal
- At least two commercial schemes, Siberia and Uzbekistan, probably still operating.

ucg engineering ltd.

Newman Spinney Trial UK 1950







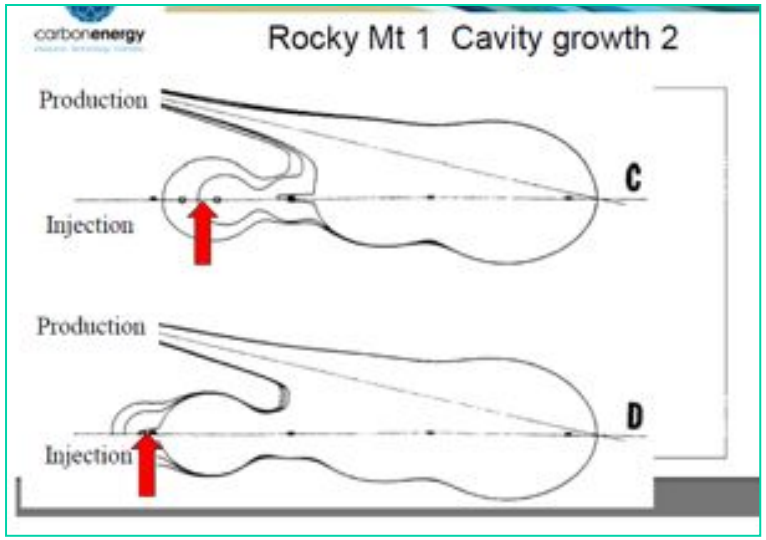
ucg engineering ltd.

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**

ucg engineering ltd.

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 NH_3 production designed – not constructed

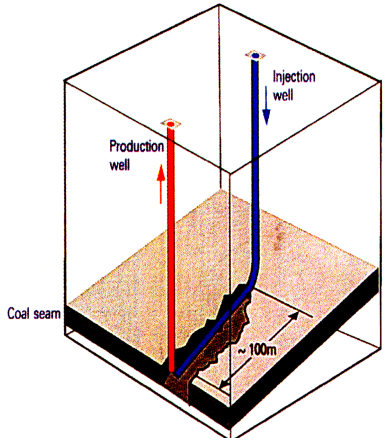
ucg engineering ltd.

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

ucg engineering ltd.

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.

ucg engineering ltd.

Key Results from European Trial

- Coal Affected 290 tons
- Product Gas 490 tons
- Peak Power 8MW
- Gas Composition (dry N_2 free)
  - Hydrogen 27%
  - Carbon Monoxide 14%
  - Methane 14%
  - Carbon Dioxide 45%
- Calorific value of product gas (LHV) 10.9MJ/m^3

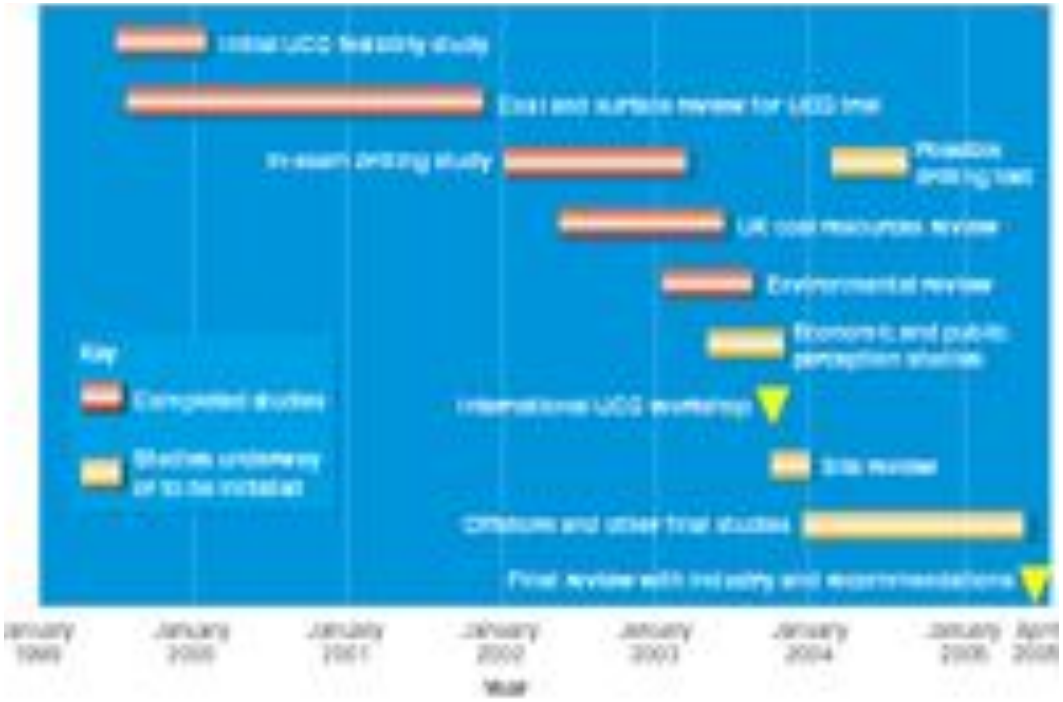
- Two successful ignitions, and seven manoeuvres of the coiled tubing
- Directional drilling for process well construction, but improvements required.
- Gasification at greater depth enhances methane formation and cavity growth .
- The process is controllable and highly responsive.
- Stopped because 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.

ucg engineering ltd.

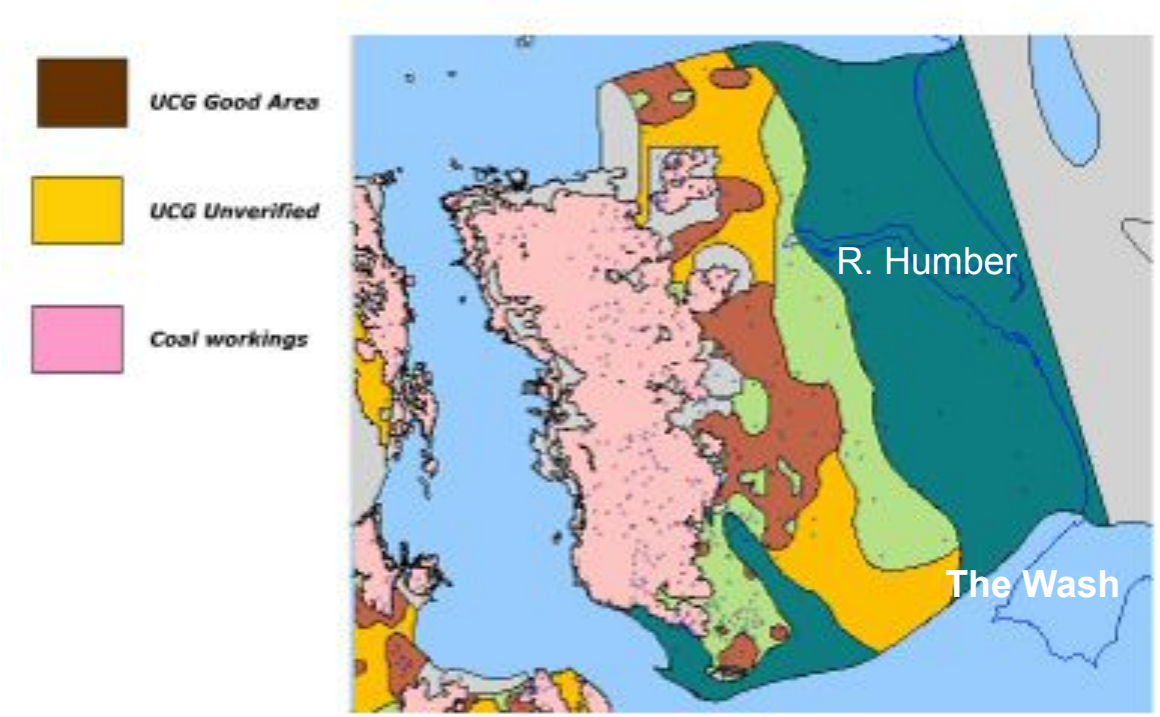
UK DTI Programme on UCG 1999-2005

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

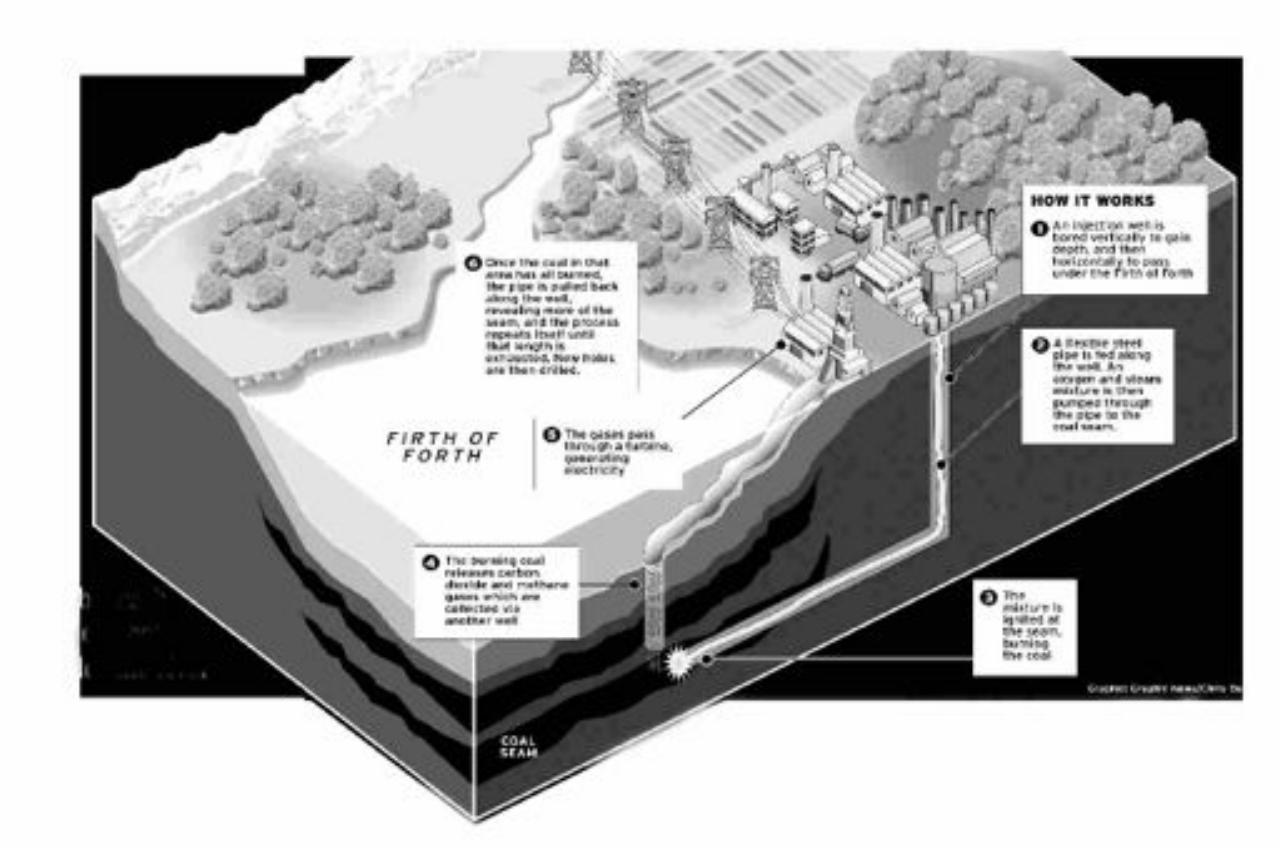


Area of UK	"Good" UCG Resource M-tonnes	UCG reserve as Nat Gas BCM
Eastern/NE England	6,824	681
Lancs/Dee	4,770	476
Midlands/Staffs	2,759	275
Warwick/Oxford	2,040	204
Wales	220	22
Scotland	171	17
TOTAL	16,784	1,676

1,676 BCM equals 11Billion Barrels of Oil equivalent

ucg engineering ltd.

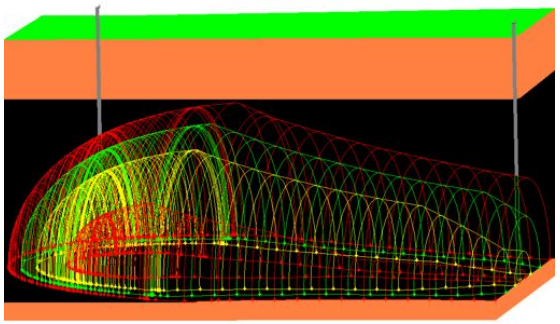
Feasibility Study of UCG-CCS in the Firth of Forth 2004

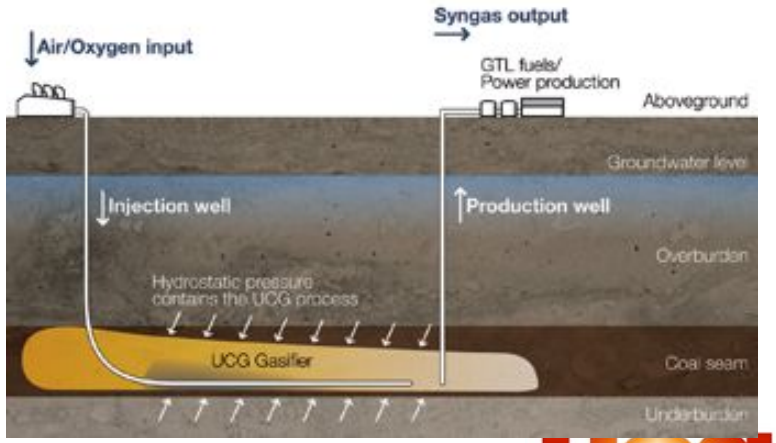


ucg engineering ltd.

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





ucg engineering ltd.

Linc Energy - Yerostigas, Angren Uzbekistan

Co-fired Power Station (1,200MW)
Operating since 1960's

ucg engineering ltd.

Carbon Energy, Parallel CRIP Bloodwood Creek, Queensland

Liquid Knock Out Module

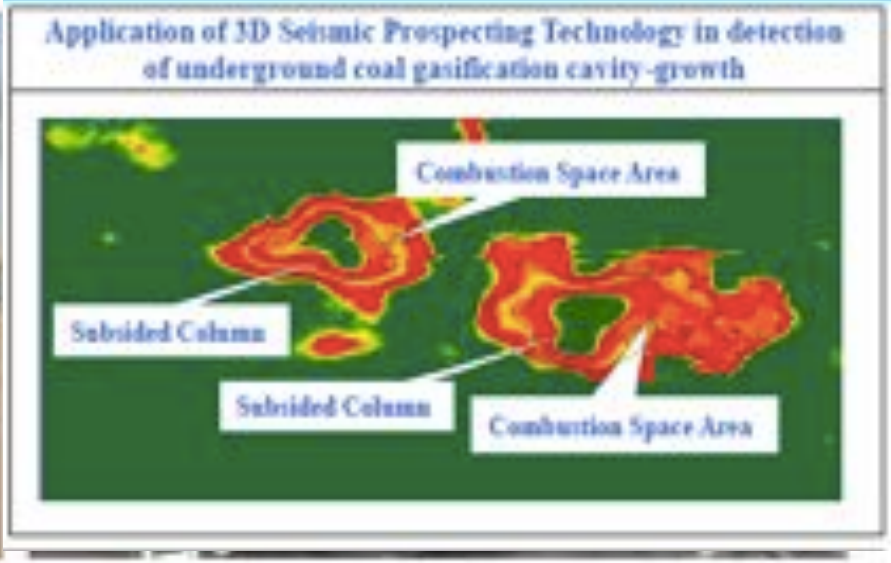
Carbon Energy has achieved Proof of Concept and has demonstrated:

- 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

ucg engineering ltd.

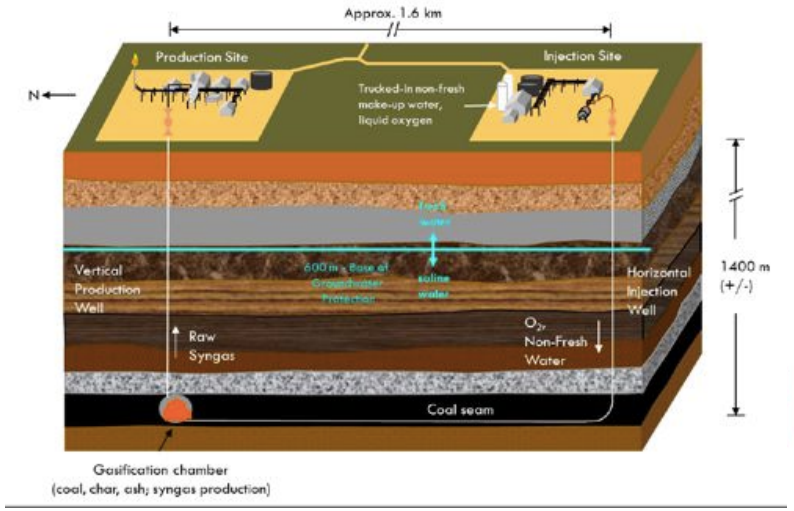
3、ENN's UCG Progress (site progress)

- 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



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

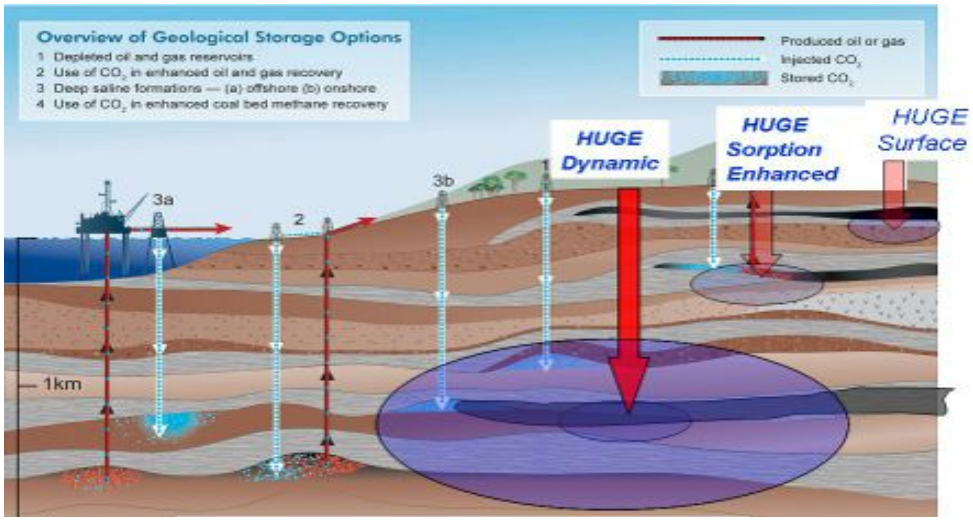


ESKOM UCG PROJECT STATUS

- 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.

ucg engineering ltd.

€3.2M EU Study HUGE - Hydrogen Underground Gasification Europe

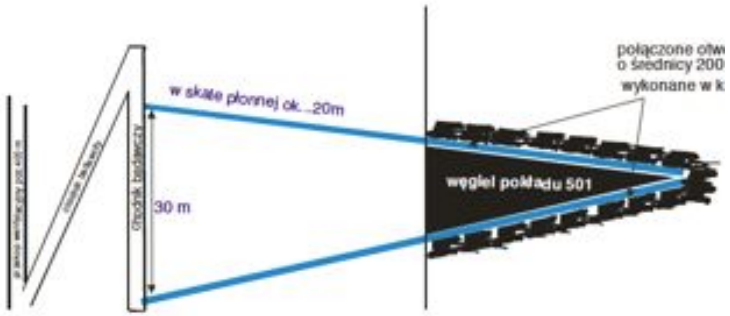


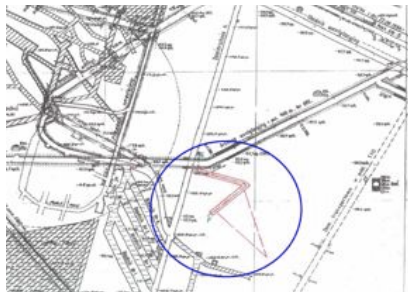
Location of HUGE HUGE2 Gasifiers at Barbra Mine

ucg engineering ltd.

€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

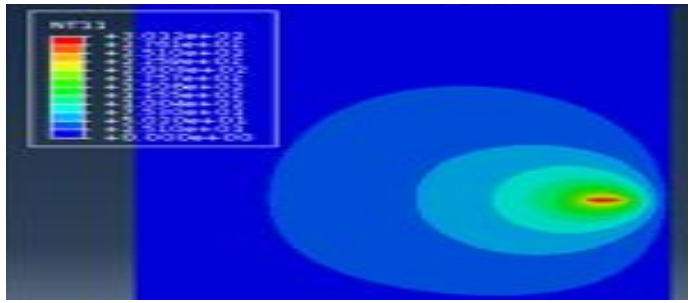




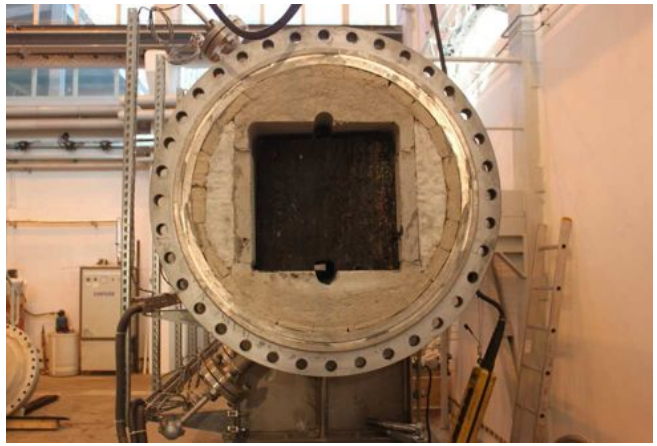
ucg engineering ltd.

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.
  - UCG models using thermo-& hydro-thermo-mechanical modelling.
  - Generic Environmental Risk Assessment Framework (GERAF) & Life cycle inventory models with and without CCS



Thermo-Mechanicl Modelling fpr Dobroudzha Coal Deposit



Energy Procedia 63 (2014) 5827 – 5835

ucg engineering ltd.

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

ucg engineering ltd.

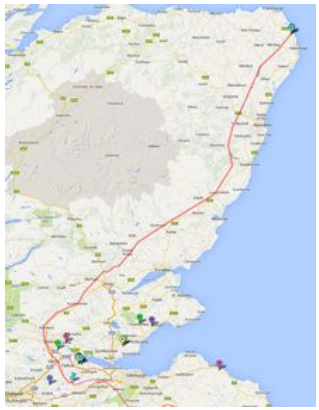
SinoCoking Ltd

- 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.

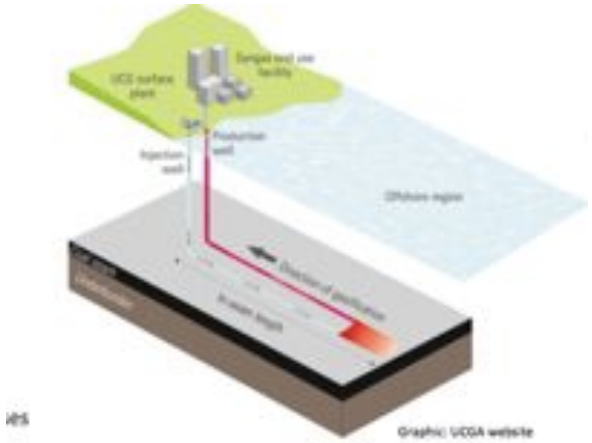
ucg engineering ltd.

Firth of Forth Licensing Areas - April 2015

UCG License Areas in FoF Apr 2015



CO2 pipeline
Avonbridge to Petershead



Parallel CRIP from Shore

ucg engineering ltd.

Conclusions - Leading UCG Trials 2015

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

ucg engineering ltd.