Underground Coal Gasification - An Expansion of the Coal Era?

FFF FBC Conference | 16 March 2010

In association with: TNO innovation for life

EcoMetrix Africa


?
NO MORE COAL

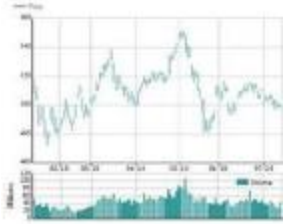
Cleaner coal

NOW

Table of Contents

EcoMetrix Africa is dedicated to deliver carbon financing and management services to Africa

- **Carbon Financing & Trading**
  - GHG emission reduction projects in various sectors e.g. power, heavy industry
  - project registration with appropriate carbon standards like the CDM
  - over the counter trading (e.g. CERs, VERs, gold standard)



- **Carbon Strategy and Management**
  - strategic advice on sustainability and management of emissions to air
  - determining carbon footprint and identification of emission reduction potential

- **New Energy Project Development**
  - Techno-economic assessment and introduction of new energy technologies e.g. Carbon Capture and Storage, biomass to energy, UCG
  - Monitoring and Verification of emissions from energy projects

TNO Organisation for Applied Scientific Research

- Head office in the Netherlands, satellite offices world wide
- Around 5000 FTE employees dedicated to applied research
- Bridging the gap between research and commercialisation
- Independent of private and public interests
- Covering seven market areas:

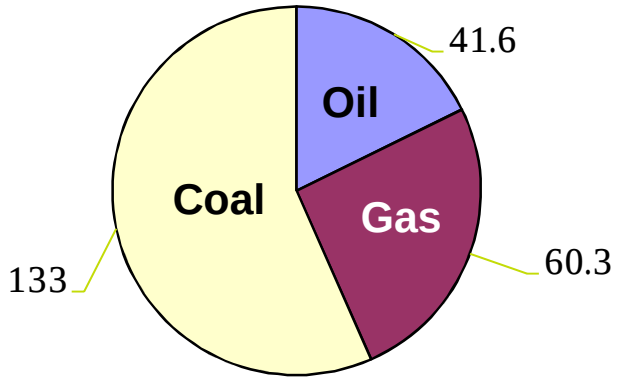
1. Healthy living
2. Industrial innovation
3. Defense, Safety and Security
4. **Energy**
5. Mobility
6. Built environment
7. Information society

Coal debate

- General view politicians and energy companies:

  Coal has great potential since it is
  - ü abundant and easily available
  - ü widely distributed
  - ü cheap

Reserves / Production ratio
Year of reference 2007



- Greenpeace (from '*Kolen op de schop')*
  - Ø numbers on reserves are old
  - Ø investing in infrastructure should have started long time ago
  - Ø growing consumption, production countries limit export

    à shortages in market within 25 years
  - Ø shortage will drive prices up (2007 70 -> 110, now around 120 USD/ton)

Challenge

- Are there technologies for environmental-friendly use of coal?
- This presentation highlights one of these technologies:
  - UCG (if combined with CCS)

Table 1: Estimated Available Coal Reserves (billion tonnes) & Corresponding Gas Reserve from UCG

	Estimated Available Coal Reserve for UCG (Bt)	Potential Gas Reserves from UCG (as Natural Gas) TCM*	Current Natural Gas Reserve 2006 TCM
USA	138.1	41.4	5.5
Europe (excl. Russia)	130.1	21.8	6.0
Russian Federation	87.9	26.3	47.8
China	64.1	19.2	2.4
India	51.8	15.5	1.1
South Africa	48.7	8.2	0.0
Australia	44.0	13.2	2.5
Total	**564.7**	**145.6**	**65.2**

*TCM: Trillion Cubic Metres

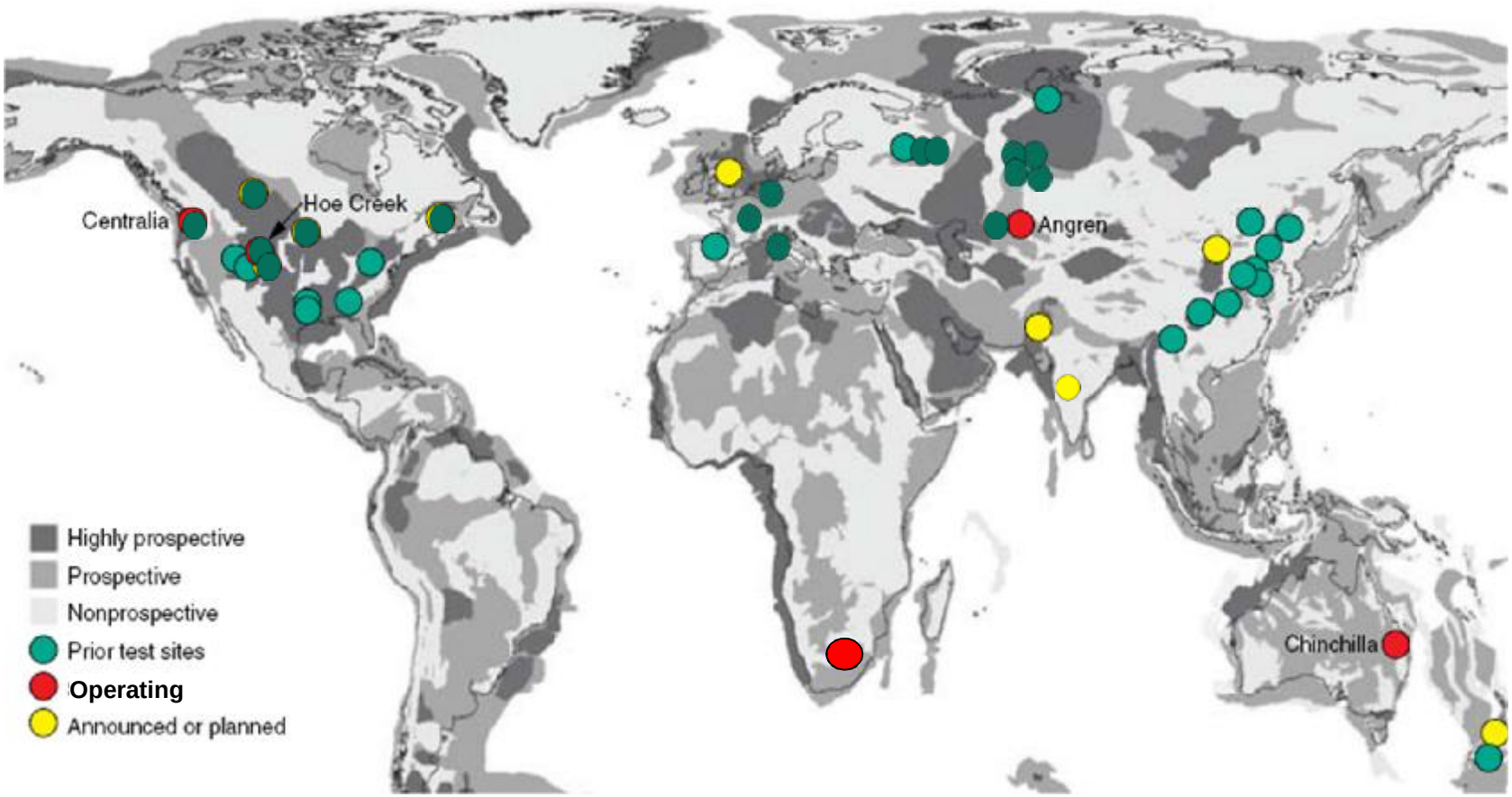
From Ecoal, October 2006

Underground Coal Gasification – Since 1868

- UCG is not a new invention, first suggested in 1868
  - Google: > 40,000 hits for “underground coal gasification”
  - Supply & engineering industry, e.g. UCG Engineering Ltd, Ergo Energy
  - UCG Partnership http://www.ucgp.com/
  - Several research initiatives (European, national, etc.)

- Numerous efforts since to develop commercial operation with varying success:
  - 1912 First test site Durham Coalfield UK
  - 1930’s Intensive development in Soviet Union
  - 1950 first European trial
  - 1964 first commercial site in Uzbekistan (still in operation)
  - 1970/80’s US program – few major trials
  - 1980/90’s European studies and trials (France, Belgium, Spain)
  - 1990’s China 16 trials
  - 2000 semi-commercial site in Australia (Chinchilla)
  - More (semi-)commercial sites, e.g. in Asia, USA and Africa

Field Operations



From Burton et al., 2007, updates Schmidt, Uhlig, 2008. See also: http://www.co2sinus.org/ucg_test_sites.html,

Field Operations in SA – Eskom's UCG Project

October 28, 2010 - Eskom's Majuba UCG project

Eskom's UCG demonstration plant commenced delivery of syngas to Majuba Power Station. This is a historic occasion, as it marks the first production of commercial electricity from UCG syngas outside of the former Soviet Union.

The Majuba UCG operation has been successfully **producing Syngas since 20 January 2007**. The project now surpasses the Australian Chinchilla trial in terms of both duration and coal extraction, making it the longest and largest UCG operation ever conducted in the western world. With syngas production expanded to **15,000 Nm3/hr**, the Majuba Project is unprecedented in its scale, geological complexity, and pioneering nature.

With the pipeline and commercial gas clean-up facility recently commissioned and necessary modifications made to the power station, first gas was delivered at 13:22 (SAST) on 28 October 2010. The **gas is being co-fired with coal and contributes 3MW** to the unit's current electricity production of approximately 650MW.

http://www.eskom.co.za/live/content.php?Item_ID=14077

http://www.ergoexergy.com/news/news_snippet_101028.htm

Field Operations in SA – Sasol's UCG Project

Sasol Completed To Develop Basic Engineering Design Coal Mining an Surface Gasification Plant in Secunda, April 5, 2009

Coal-to-liquids (CTL) giant Sasol has completed basic engineering designs for a demonstration-scale underground coal gasification plant to be built on an otherwise stranded deep coal seam near its CTL plant in Secunda. When commissioned, the plant will be expanding the currently envisaged UCG pilot project.

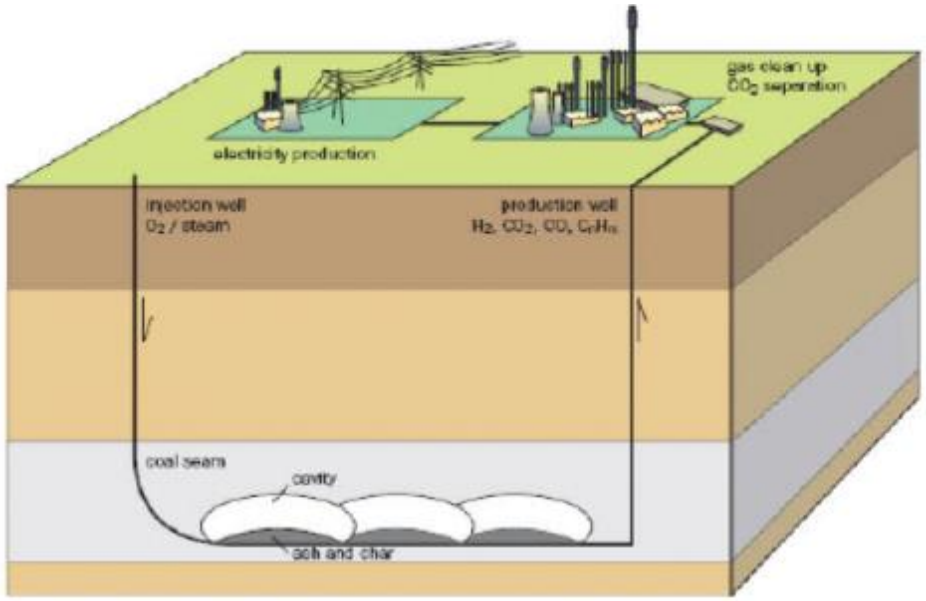
Sasol UCG business manager Johan Brand comments that UCG is generally **cheaper than conventional coal mining and surface gasification methods**, owing to the fact that the coal mining and gasification is carried out in one phase.

"By the time the gas is released from the well, the coal has already been beneficiated to such an extent that it can directly be used in a boiler without even treating the coal," he adds.
Also, the transportation of the gas in pipes is more efficient than by road, rail or conveyor.
UCG technology will extend the lifespan of the Secunda complex by using coal that is difficult to mine. **The technology proved a 95% coal extraction, exceeding that of conventional underground mining of deep seams, which has an extraction of 37%.**

http://paguntaka.org/2009/04/05/sasol-completed-to-develop-basic-engineering-design-coal-mining-an-surface-gasification-plant-in-secunda/

Overview of UCG Operations

- Injection of oxygen/steam mixture
- Underground gasification and cavity formation
- Recovery of produced syngas
  - Composition: H_2, CO, CO_2, CH_4 and little C_nH_m
- Gas cleanup (and CCS)



Use of produced syngas:

- ü **Electricity generation**
- ü **Hydrogen production**
- ü **Chemical manufacturing**
  - **liquid fuels, fertilizers, synthetic natural gas**
- ü **Etc.**

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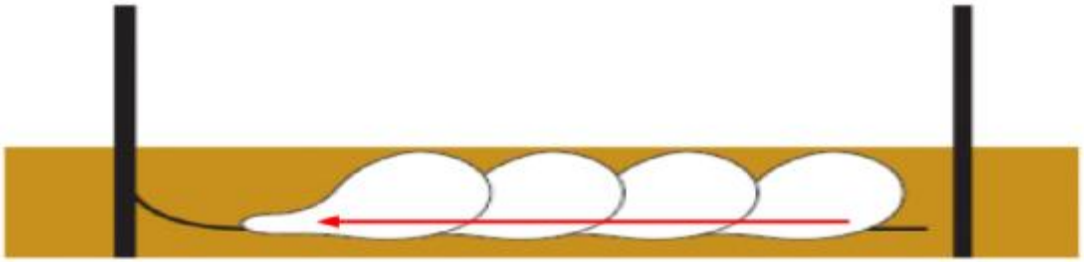
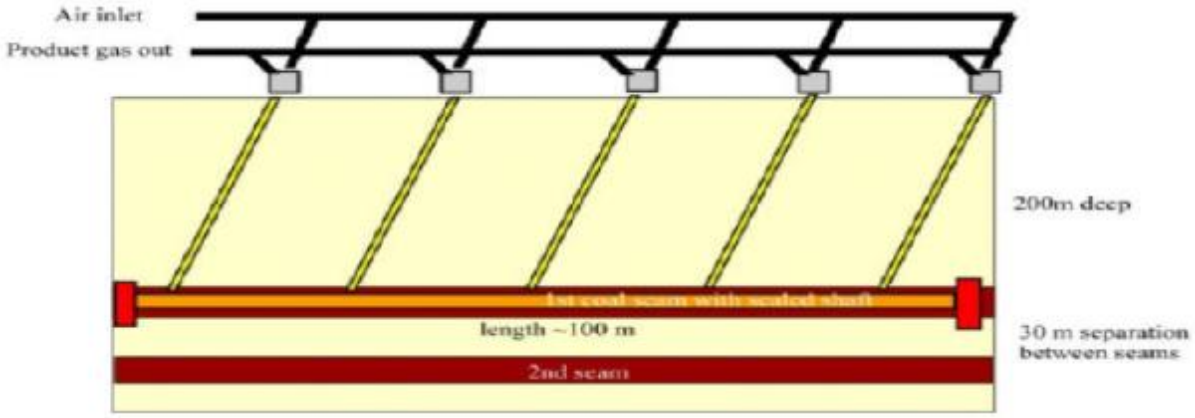
Different Methods of UCG

- E.g. European/American methods: Controlled Retraction Injection Point



- E.g. Chinese gallery method

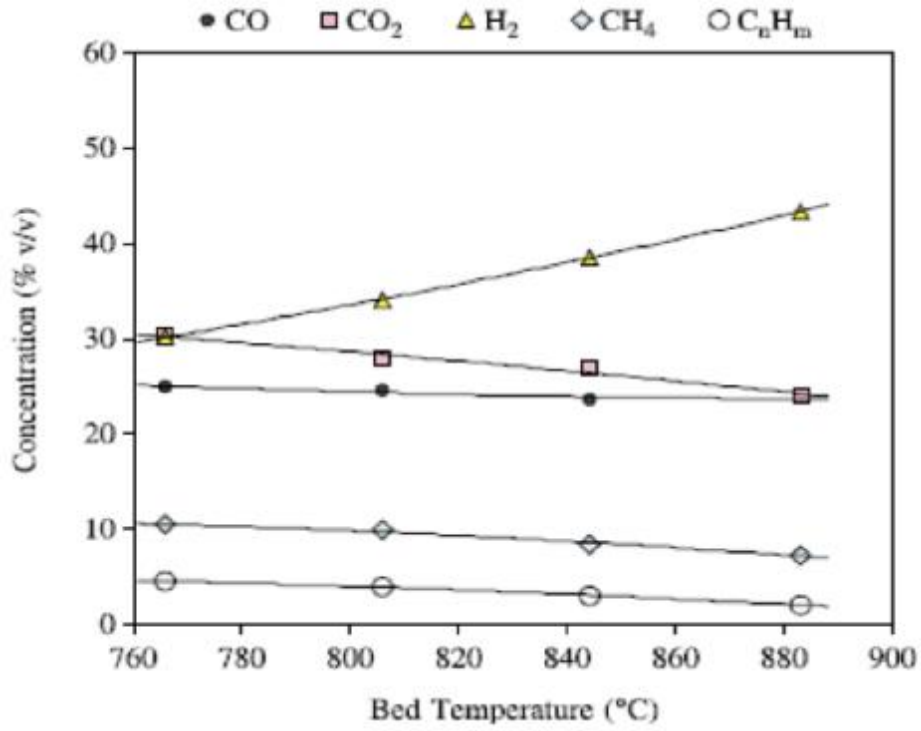


Advantages and Disadvantages of UCG

- **UCG is based on coal, which is**
  - Abundant, easily available and cheap
  - widely distributed also in politically stable countries
- **Advantages of underground** instead of surface gasification
  - no mining and transportation of coal
  - deep coal seams become available and no solid waste handling
  - CO_2 is easily separated due to high pressure
- **Disadvantage of underground** instead of surface gasification
  - surface gasification control is difficult, let alone underground
  - environmental impact: contamination of subsurface, water usage
- **UCG can be economically viable**
  - previous cost estimates indicate price CG clean gas at 30-40% of natural gas price **(Ecoal, October 2006)**

Hydrogen Production

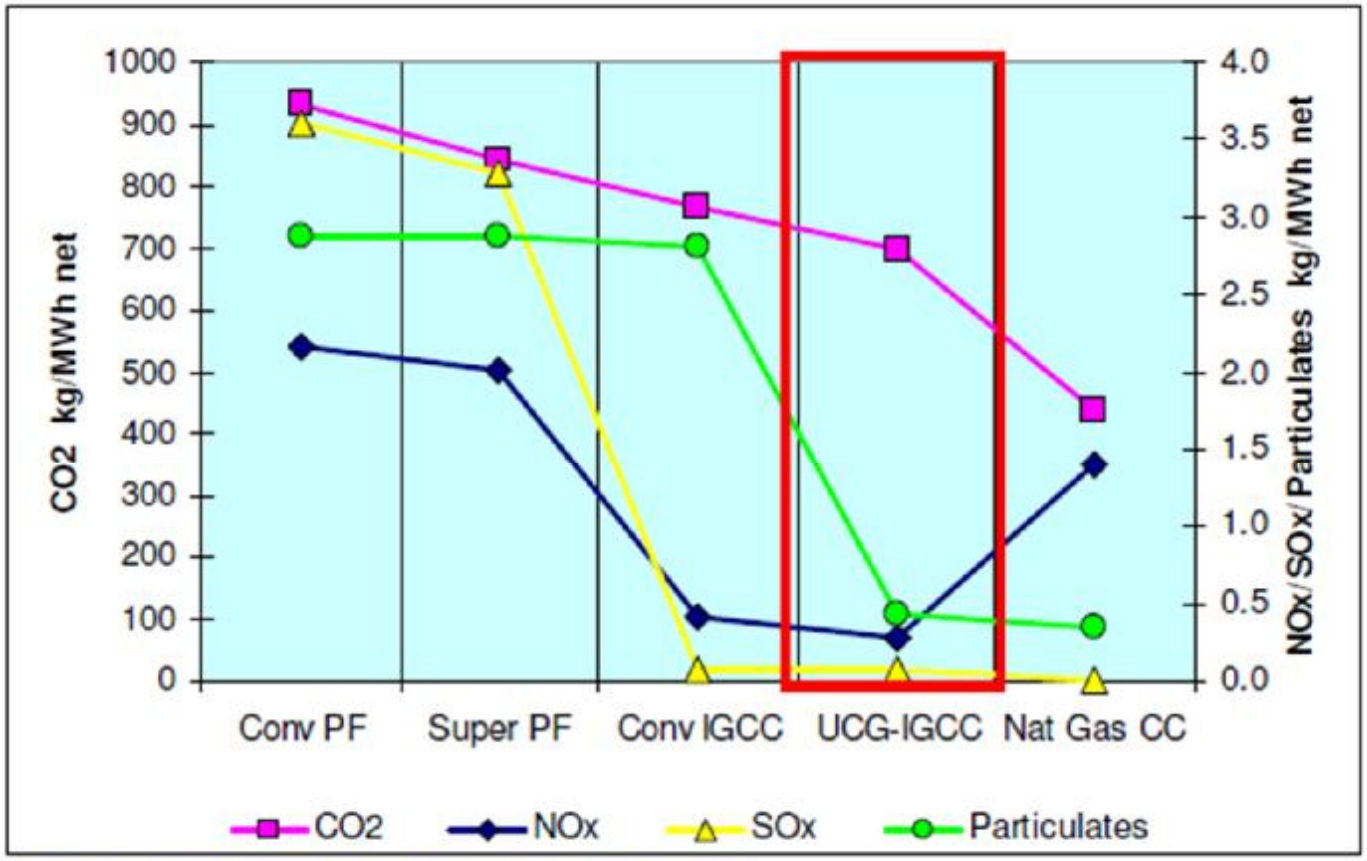
- UCG could become important in a future hydrogen based economy
- Field experiment in Woniushan Mine in China reports average content of H_2 over 50%, with maximum of 73% (Yang et al., 2008)
- Maximum concentration of H_2 in syngas through improved process control



UCG is Proven Technology

- Angren site, Uzbekistan
  - Over 50 y commercial exploitation
- Chinchilla site, Australia
  - Demonstration on a commercial scale
  - Started December 1999
  - Successful gasification of 35,000 tonnes of coal in 30 month period
  - maximum production of 80,000m^3/hr or 675 tonnes/d of coal www.lincenergy.com.au
- Woniushan Mine, China
  - Gas output of 16,000 m^3/d, maximum of 46,000 m^3/d
    - Yang et al., 2007
- … and many other field pilots including **Eskom's Majuba UCG project** . . . .

UCG-IGCC results in Lower Carbon Emissions



Ref : Australian ACARP LCA study, Case Study B20, June 2002
http://www.iea.org/work/2007/neet/van_der_riet.pdf

The only cleaner coal-based technology is the proposed ultra-supercritical PF.

New SC 710 kg/MWh - IEA GHG (2001)

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Our View on the Main Barriers and Required Research

- Process control
  - Stabilization of syngas composition
  - Development of the cavity
  - Subsidence due to roof collapse
- Leakage of gasification products
  - Groundwater pollution
- Solid waste in the underground
  - Groundwater pollution
- Public perception
- Legal framework

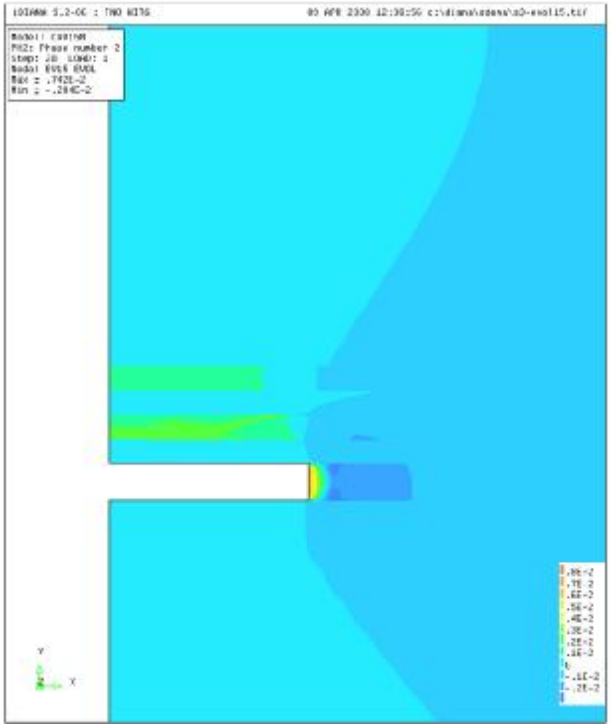
- *Commercial sites proved that barriers can be overcome*
  - *Site-specific*
- *Based on (disclosed) experience of these sites, other priorities may be set*

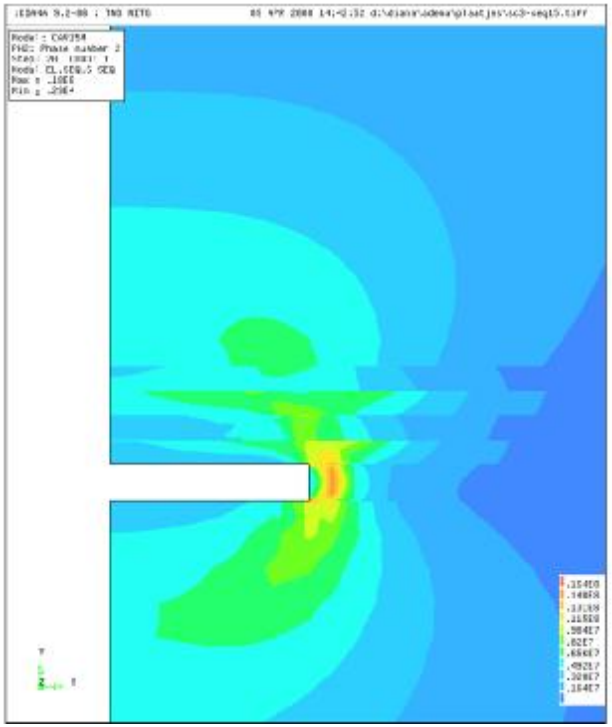
Process Control

- **Stabilization of syngas composition**
  - Composition is controlled by temperature in the cavity
  - Temperature regulated by oxygen/steam ratio of injection gas
  - Closed loop operation envisaged:
    - measured T directly controls oxygen/steam ratio of injection gas
      - T measurement through probe or “proxy”, e.g. isotopic composition of gas
- **Development of cavity**
  - Use of 4D (passive) seismics

Subsidence – Strain may induce increased Porosity

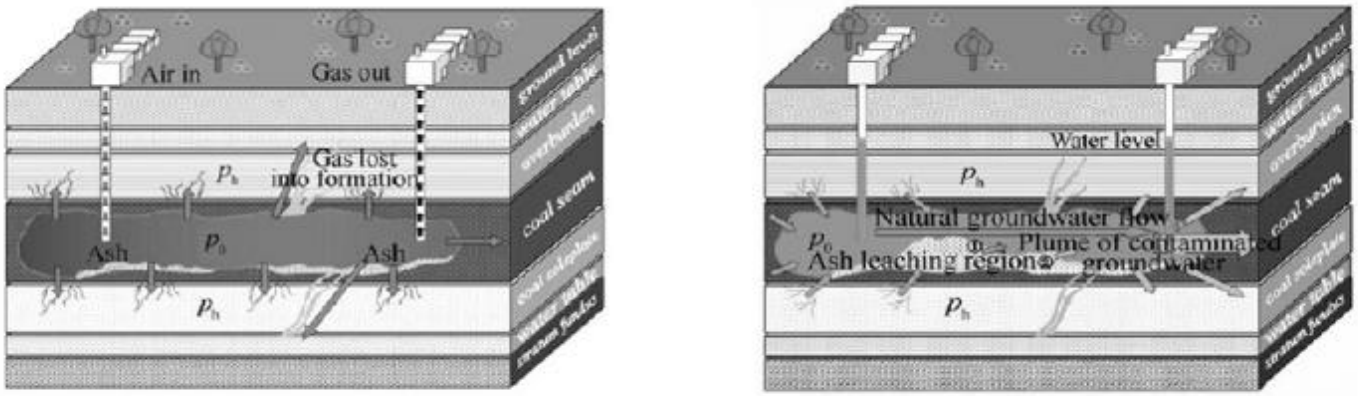
- Numerical modelling for strain around cavity
- Strain indicates increased porosity and occurrence of fractures





Groundwater Pollution

- Risk to groundwater pollution due to
  - gas dispersion to surrounding strata under high pressures (during operations)
  - leaching of residue by natural groundwater flow (after operations)



(a) During UCG (b) After UCG

Fig. 1 Groundwater pollution

- Contaminants decrease over time and with the distance from cavity
- Groundwater pollution can be controlled (e.g. through pressure mitigation)
  - *Liu et al., 2007*

Public Perception

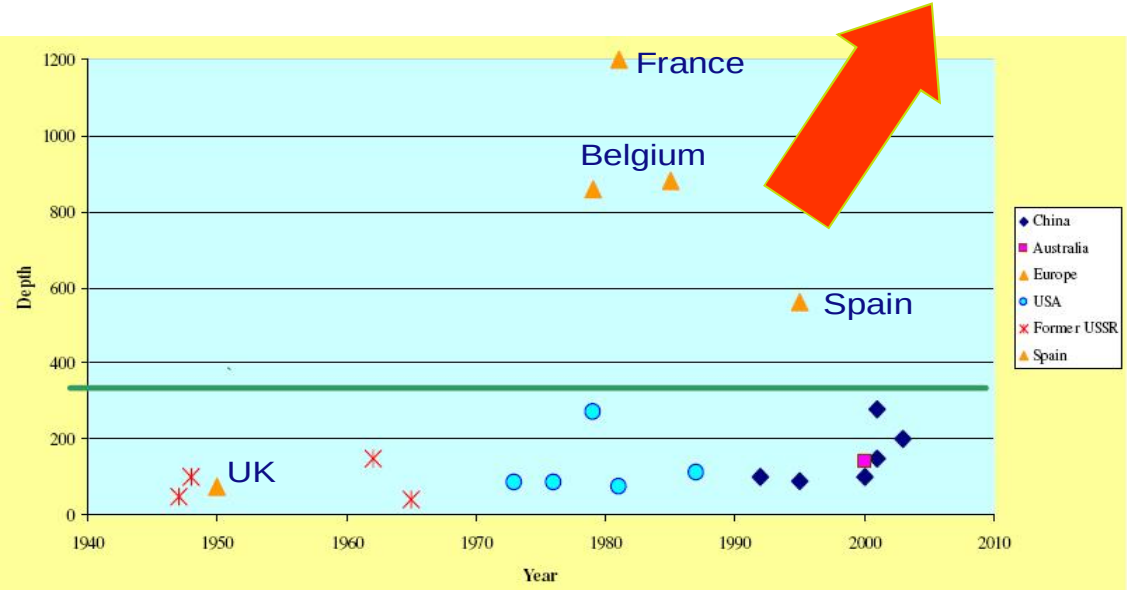
- Study in the UK on the basis of a failed proposal for a UCG drill site
- Condition: safe to humans and the environment and cost-effective
- Issues to address:
  - potential benefits to the local community
  - potential risks
  - the role of CCS
  - links to the hydrogen economy

- Recommendations of focus group
  - open, transparent and consultative process of decision-making and operation by developer, operator and regulator
  - UCG should be developed at a remote site, preferably on land, before applying it in coal seams close to populated areas.

(Shackley et al., 2006)

Site Selection (1)

- Overcoming barriers by site selection through detailed exploration work
  - Major upfront costs of UCG (Ecoal, October 2006)
    - risk of site rejection / redesign of commercial scheme as more data becomes available
- Geological characterization and criteria required
  - Seam thickness (>2m), coal properties (rank, ash content etc.), depth, low dip of coal seam, impermeable roof (no faults), (far) distance from potable water aquifers, etc.
- Major challenge in deep (1500-5000m) exploration



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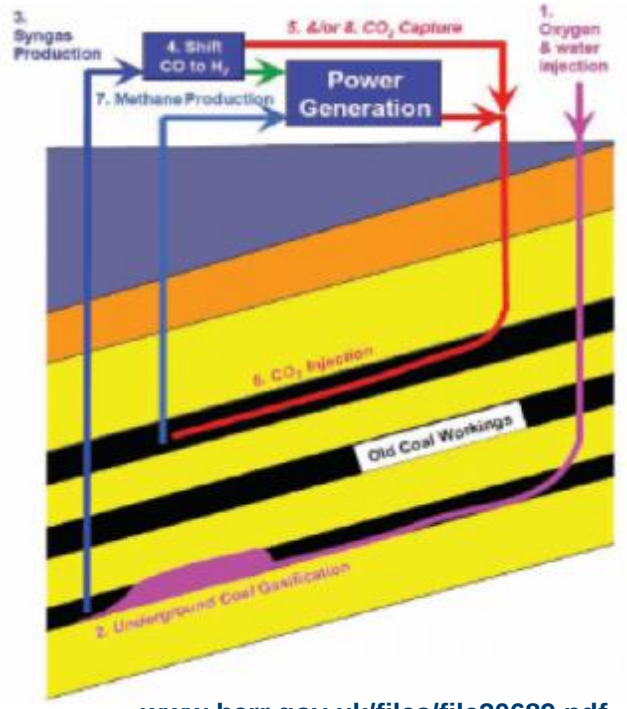
Site Selection (2)

- Major challenge in offshore exploitation
  - Ø New drilling technologies (deviated/horizontal)
  - Ø Limits surface risks

http://www.pet.hw.ac.uk/research/ucg/images/schematic_large.jpg



www.berr.gov.uk/files/file30689.pdf

- Major challenge in full integration of CCS in site selection

Summary and Conclusions

- Application of UCG would increase availability of energy from coal
- UCG is relatively clean if combined with CCS
- UCG is prospective but still faces a lot of barriers before large-scale implementation
  - Recent technological advancements and reported success merit new investigations
    - drilling techniques
    - seismic imaging
    - process control
- Need for scientific proof of the transferability of experience from commercial sites to other locations of the world

Thank you for your attention

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