



## Water management issues in the underground gasification of coal and the subsequent use of resultant voids for long-term CO<sub>2</sub> Storage

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## Overview

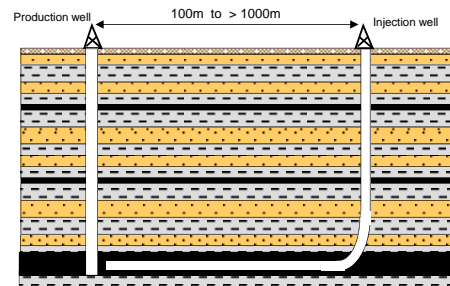
- The UCG process
- Coupling UCG directly to CCS
- Groundwater issues in UCG
- Risk assessment for CCS in UCG goaf



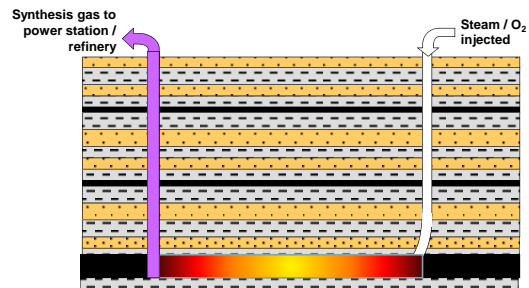
## Underground Coal Gasification UCG -CCS ... with carbon capture and storage



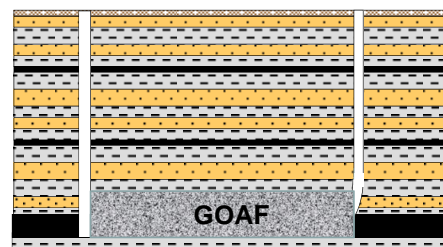
### The process: UCG



### The process: UCG



### After UCG - goaf formation





## Goaf



## UCG: history

- First UCG experiments were carried out in County Durham, UK, by Sir William Ramsay in 1912 - experiments halted by World War I
- Stalin then adopted UCG in the former Soviet Union, where it has been undertaken at industrial scale since the 1950s
- Interest in UCG in the West waned with the development of abundant oil and natural gas
- Significant pilot trials in China
- Currently operating commercially in Australia



## UCG to date ...



Image courtesy of



## Underground coal gasification in action



Diesel production from UCG in Australia, using the Fischer-Tropsch process



## Groundwater issues in UCG

- Water quantity issues:
  - Some water is good (saves on generating steam at surface)
  - Too much water is bad (hinders ignition and burn zone propagation)
- Pollution concerns:
  - Organics: phenols, benzene, PAHs, heterocyclics
  - Inorganics: salinity (Na-Cl), NH<sub>4</sub>, As, B, Zn, Se, U



## Managing groundwater issues in UCG

- Water quantity issues:
  - hydrologically intelligent selection of sites, seams and production scheduling in multiple seam sequences ("bottom-up" best)
- Pollution issues:
  - Use groundwater protection logic
  - Assess risk using the standard approach of: **Source → Pathway → Receptor**



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## CCS - the aspiration

Methods for storing CO<sub>2</sub> in deep underground geological formations

Overview of Geological Storage Options

1. Storage of oil and gas recovery
2. Use of CO<sub>2</sub> in enhanced oil and gas recovery
3. Deep saline formations – oil (often 80% recovery)
4. Use of CO<sub>2</sub> in enhanced coal bed methane recovery

Source: IPCC CCS Report

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## Underground gas storage: not a new technology

Underground Gas Storage: Worldwide Experiences and Future Development in the UK and Europe

Edited by D. I. Evans and R. A. Chubbuck

Geological Society  
Special Publication 343

TEES VALLEY Hydrogen Project

Infrastructure

- Underground storage capacity (1,000 t)
- Population centres and under the river
- Large hydrogen generation plants
- Deactivated by chemical industry

Up to 1000 tonnes of H<sub>2</sub> stored in solution mining caverns in salt in densely populated urban area – has operated safely for > 60 years

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## The vision: CCS in UCG goaf & overburden

CO<sub>2</sub> store

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## CCS in UCG goaf and overburden

- UCG likely to be undertaken closer to large static CO<sub>2</sub> sources than many spent oil and gas reservoirs (especially in N Sea region): saving on transit costs
- Typical permeabilities of goaf (1 to > 20 d) far greater than those of deep saline aquifers (i.e. 0.01 to 1 d)
  - Thus it will be up to 2000 times easier to inject CO<sub>2</sub> into UCG goaf than into deep saline aquifers
- However, CO<sub>2</sub> occupies 3 - 5 times the volume of original coal: access to pore space in fractured overburden (above goaf) will also be required
- Hydrogeological experience from longwall mining gives abundant grounds for optimism over the development of CO<sub>2</sub> storage zones in goaf & fractured overburden

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## Strata deformation and permeability development above collapsing mine voids

Possible surface cracks due to subsidence

Subsidence trough

Zone I: H=15m, Zone of net extension: fracturing raises K to around 0.1 - 1 mD

Zone II: D=15m to 30m above seam, Zone of net compression: pre-existing joints have apertures reduced, giving K in range 0.001 - 0.1 mD

Zone III: H=30 to 58m, Zone of net extension: fracturing and sagging of strata, with bed separation and joint opening, gives high K in the range 1 - 20 mD. The lower part of this zone gradually collapses to partly backfill the underlying void, forming goaf.

Shear Failure zone (enhanced K in vertical draw) (Ellsworth & Liu 1995)

Carved zone (goaf) K = 60-80% unmined value (Singh & Adkins 1982)

Seam Thickness = t

width = W

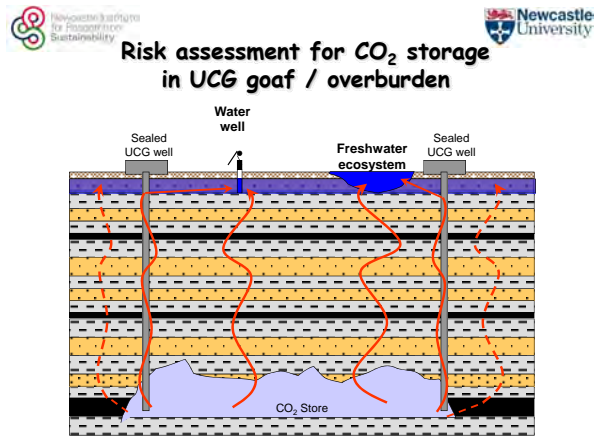
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## Risk assessment for CCS in UCG goaf

- Most of the contaminants produced during UCG are not very soluble in water
- However, super-critical CO<sub>2</sub> is one of the most powerful solvents known; it will dissolve them, so if CO<sub>2</sub> migrates, the contaminants will certainly migrate with it
- Hence for risk assessment of CCS in UCG goaf the only important task is to evaluate the risk of CO<sub>2</sub> migration

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**Project Ramsay: assessing the UCG-CCS opportunity in North East England**

- Multidisciplinary team of specialists led by Newcastle University assessed potential reserves, drilling and processing technologies, surface engineering issues, and financial scenarios
- Identified more than 5 billion tonnes of coal in workable seams at depths suitable for CCS in goaf and overburden
- Company now being established to pursue the opportunity commercially

**Conclusions**

- UCG has great potential to support the transition to a renewable energy future without further damage to the atmosphere
- Application of hydrogeological lessons learned during longwall coal mining suggests significant scope for CO<sub>2</sub> storage in and above goaf formed by collapse of UCG voids
- Groundwater issues can be managed using the same principles used in conventional mine water management situations

Thank you *◇ Merci beaucoup ◇*  
 Tapadh leibh *◇ O'wela'lin ◇*

"Jowl the top an' keep thi timmer in"

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