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Review

Paul Younger's work on underground coal gasification with carbon capture and storage

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Supplementary Materials

UCG-CCS Introduction

At its simplest, UCG involves drilling a vertical borehole into a deep coal seam (which after lining and grouting will form a production well) and drilling another borehole (an injection borehole) nearby to carry an oxidant such as oxygen or air. Various approaches have been used since 1912 to create a linkage between the two wells by fracturing the coal in the seam, but most projects now use directional drilling (an oil industry technology) to bend an initially vertical hole until it follows the coal seam. The idea is to stop just short of the production well, insert an ignition device into the injection well, and feed an oxidant into the well until the coal ignites. The flow of oxidant is then reduced so that gasification (or partial oxidation) rather than full combustion occurs. The resulting gases contain hydrogen, carbon monoxide, methane and CO_2, and retain about 80% of the energy of the original coal. The oxidant injection unit is gradually retracted back through the injection well, gasifying the coal as it travels, and the cavity grows. This approach is referred to as CRIP (Controlled Retractable Injection Point).

The main chemical reactions involved in the gasification process are:

$$C + O_2 \rightarrow CO_2 \qquad \Delta H = -393.8\ kJ/mol$$

$$C + \tfrac{1}{2}O_2 \rightarrow CO \qquad \Delta H = -123.1\ kJ/mol$$

$$C + H_2O \leftrightarrow CO + H_2 \qquad \Delta H = 118.5\ kJ/mol$$

$$C + CO_2 \leftrightarrow 2\,CO \qquad \Delta H = 159.9\ kJ/mol$$

$$C + 2\,H_2 \leftrightarrow CH_4 \qquad \Delta H = -87.5\ kJ/mol$$

The schematic diagram below illustrates the concept in its simplest form:

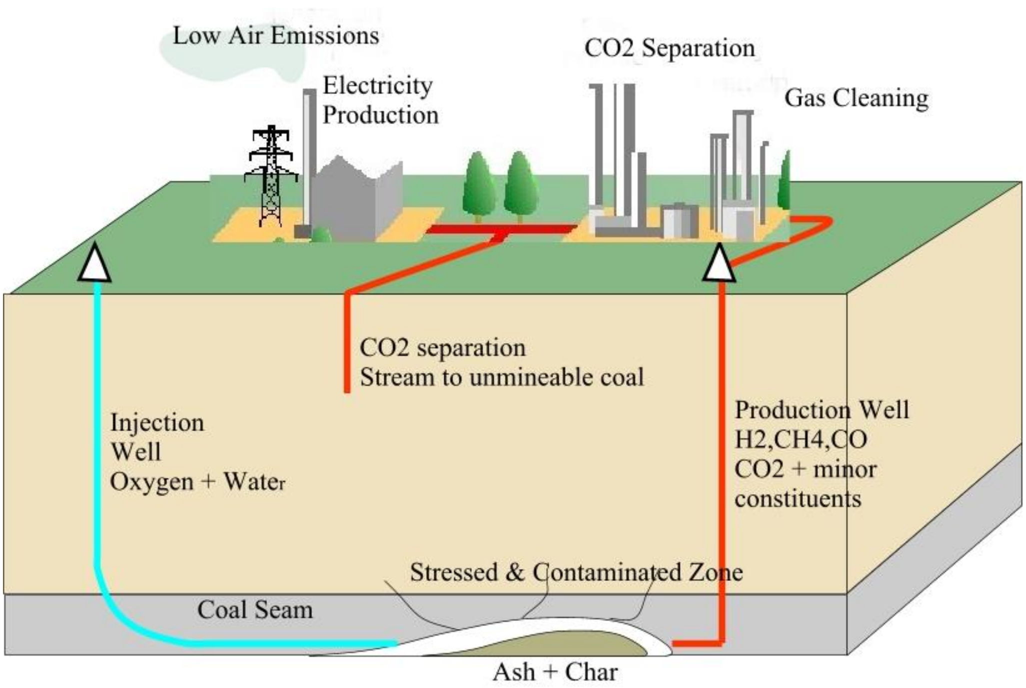

Figure S1. Illustration of UCG-CCS concept (Image courtesy of UCG Partnership).

In order to reach a commercially viable scale of operation, the idea is that a single production well would be fed by multiple injection wells within the same coal seam and possibly other injection wells in lower coal seams; and there should also be multiple production wells in order to cover an extensive coal field and produce gas at high rates.

The composition of the gas can be altered at the surface by converting methane into hydrogen and carbon monoxide in a process known as Steam Methane Reforming.

$$CH_4 + H_2O \leftrightarrow CO + 3\,H_2 \qquad \Delta H = 206\ kJ/mol$$

The hydrogen content of the original gas can be boosted via a Water Gas Shift reaction whereby carbon monoxide is converted into hydrogen and CO_2.

$$CO + H_2O \leftrightarrow H_2 + CO_2 \qquad \Delta H = -41\ kJ/mol$$

For some applications such as power generation, the preference is to maximise hydrogen production. For others (such as chemical synthesis) the preference is to produce a mixture of hydrogen and carbon monoxide. The term syngas is commonly used for the raw UCG gas but more properly applies only to a mixture of hydrogen and carbon monoxide.

In this paper the assumption is that the CO_2 will always be removed by capturing it using a chemical solvent or a physical solvent and then regenerating it as a CO_2 gas stream which can be compressed to supercritical conditions and then stored in a saline aquifer or in a UCG void. In the latter case, the concept is that a well-designed network of UCG cavities will undergo partial collapse over time after the gasification process has ceased, and then some of the overlying strata will deform and partially collapse in the same manner as happens with abandoned coal mines. This continues until a zone of net compression forms above the affected strata and forms a geological seal which is impervious to CO_2. The underlying material is known as “goaf” in the industry and is capable of storing large volumes of CO_2.

The reader is referred to Younger *et al.* [1] for further background on UCG-CCS and to Couch [2] for further detail on UCG.

References

1. Younger PL, Gluyas J, Cox M, Roddy DJ. Underground Coal Gasification. Ingenia. 2010;43:42-46.
2. Couch GR. Underground Coal Gasification. IEA Clean Coal Centre. 2009.