REVIEW OF THE FEASIBILITY OF UNDERGROUND COAL GASIFICATION IN THE UK

CLEANER FOSSIL FUELS PROGRAMME

The DTI drives our ambition of 'prosperity for all' by working to create the best environment for business success in the UK. We help people and companies become more productive by promoting enterprise, innovation and creativity.

We champion UK business at home and abroad. We invest heavily in world-class science and technology. We protect the rights of working people and consumers. And we stand up for fair and open markets in the UK, Europe and the world.

- Successful business
- Fair Markets
- Science and Innovation

CONTENTS

Abstract

Underground coal gasification (UCG) involves the gasification of coal in the coal seam so that the gas can be utilised for power generation. The concept is simple, but the development of a controllable process proved difficult with the available technologies up to the early 1990s. Generally, UCG was restricted to shallow coal seams, which led to environmental concerns. However, its prospects have benefited from new underground exploration and production technologies, developed for oil and gas exploration, which now makes possible a reliable process that can be used in deep coal seams, of 600 metres or more.

A recent European field trial between 1992 and 1998 demonstrated that deep UCG could be undertaken successfully and in 1999 the Coal Authority initiated an investigation into UCG as a potential long-term energy exploitation option for the UK. This work was later taken up by the DTI. A series of studies were performed within this investigation covering the resource, technical, environmental, planning, public perception and economic aspects of the technology. It also looked at relevant work overseas and, more recently, the process and cost implications of CO_2 capture from UCG product gas.

This report concludes that UCG, in conjunction with carbon dioxide capture and storage (UCG-CCS) to reduce carbon dioxide emissions, has the potential to contribute to the UK's energy requirements. However, there are hurdles that need to be overcome: key are economic viability of this technology compared with other cleaner fossil fuel (CFF) technologies and the environmental concerns with implications for planning permission. For any project to be able to get started, these challenging issues will have to be tackled beforehand. Major concerns cover uncontrolled combustion, escape of pollutants, groundwater contamination and subsidence. Technical solutions do exist in these areas although they will need to be effectively demonstrated to satisfy the planning/consents regime.

The economic case for UCG-CCS based on the initial assessment in this report holds promise when compared with other CFF technologies. Furthermore, the available coal resource in the UK for UCG is significant and potential target areas with adjacent industrial sites for the processing and power plant have been identified. In particular, there are major coal seams beneath the southern sector of the North Sea that could only be exploited with a technology such as UCG in the longer term.

If planning and environmental issues can be dealt with, UCG, in conjunction with carbon capture and storage, increases diversity of supply and hence contributes to security within the context of a low carbon economy.

Executive Summary

Introduction and Background

Underground coal gasification (UCG) has a history of development around the world in countries as diverse as the United States, France, Belgium, the UK and, in particular, the former Soviet Union. However, as natural gas became abundant in the 1980s and evidence emerged in the USA that there could be environmental issues around UCG technology, in particular, the contamination of surface water by the gasification process, interest waned in the technology. Nevertheless, in Europe studies and an initial trial in Spain suggested that deep seam UCG, using new oil and gas technologies, appeared to offer an alternative to conventional mining.

The Spanish trial (1992-1998) confirmed that it was feasible to construct and operate wells in coal seams at depths of 550m and greater. The two key technologies to enable this were directional drilling and the use of moveable injection points along the borehole, providing control over the oxidants required for gasification. Meanwhile, renewed interest in UCG was developing in China, where 12 pilot trials have been undertaken, and in Queensland, Australia, which was the base for the Chinchilla UCG trial. These use simple vertical boreholes, shallow coal seams and an air-blown system (instead of oxygen) for gasification, which are rather different technologies to those required for deeper seam gasification.

In the light of the trials and the growing overseas interest in UCG, the UK embarked on an investigation to assess the long-term viability of UCG as a future method of coal exploitation. It examined the suitability of UK coal resources, the environmental risks and the economic viability of this technology compared to other energy sources. Further, given the Energy White Paper's emphasis on low to zero energy technologies, the gas from UCG could only be seen as a fuel compatible with a sustainable future if the carbon extracted with it was separated and sequestered. The Coal Authority, the DTI and, more recently, the Scottish Executive and a major power supplier sponsored the investigation. Specialist consultants carried out the studies feeding into this report.

Status of the Technology

Drilling and Borehole Technologies

UCG requires boreholes to access the coal, and three methods have been developed to connect between them, namely:

a. *Air pressurisation between vertical holes (Chinchilla, Australia, and the former Soviet Union (FSU) sites).*
b. *Man-built galleries in the coal (Chinese trials).*
c. *Directional drilling in the coal seam with controlled injection (US and the European field trial).*

The above methods have been demonstrated in single channel configurations but only method (a) has been operated at large scale (>200MWe). A recent pilot project (1999-2003) at Chinchilla was successful and an international company now offers it as a commercial process. Method (b), from China, is dismissed as being inappropriate for UK coal seams on commercial and technical grounds.

Method (c) using directional drilling is more costly to construct but has the advantage that the basic drilling and completion technology is available from the oil and gas industry, and the adaptations for drilling in coal have been tested in the European UCG trial. Furthermore, directional drilling in coal has advanced considerably since these trial wells were drilled, and it appears very likely that UCG process wells can be constructed successfully in UK coal seams.

The issue of shallow versus deep UCG will be determined by the environmental, economic and utilisation issues summarised below. If deeper UCG is required to satisfy UK environmental regulations, then method (c), based on directional drilling, is likely to be the way forward. This, however, does not rule out shallow UCG for specific sites in the UK, where the appropriate hydrogeological conditions prevail.

The key unknowns for method (c) are sustainable gasification over long inseam wells (>200m in length), the branch drilling of borehole networks for commercial-scale operations, and the control of a large gasification process, using moveable injection in simultaneous channels (see CRIP, Appendix 1). At least one pilot trial, extending to semi-commercial operation, would be required to obtain the necessary operational and environmental data before a full-scale project could be considered for construction. Test work to date indicates that the technical and engineering risks of failure from scaling-up the underground process are relatively small.

Coal seam characteristics to a resolution of at least coal seam thickness are a pre-requisite of the design and construction of UCG process wells. A detailed seismic survey and the drilling of exploratory boreholes would need to be undertaken. It is also important to have good knowledge of the adjacent strata to ensure well bore and environmental integrity, and provide the necessary information for the environmental impact assessment (EIA) which would be mandatory for a UK planning application. Site evaluation will be a significant part of the initial costs, and sites may fail as a result of detailed investigation.

UK Coal Resources

UK coal resources suitable for deep seam UCG on land are estimated at 17 billion tonnes (300 years' supply at current consumption) and this excludes at least a similar tonnage where the coal is unverifiable for UCG. The largest areas are in Yorkshire, Lincolnshire, the Dee area and Warwickshire, with smaller deposits in Central Scotland and South Wales. Most of the coal seams with potential for UCG are located in rural areas, but important and useful exceptions exist under rivers and brownfield areas. Opportunities are likely to occur in the Firth of Forth, the Dee Estuary and around the River Humber.

Environmental Issues

Groundwater, Surface Water and Subsidence Issues

The gasification cavity is a source of both gaseous and liquid pollutants and can pose an environmental risk to groundwater in adjacent strata, depending on whether the contaminants can migrate beyond the immediate reactor zone. US tests in shallow coal seams produced significant groundwater contamination, but the deeper European trial showed no detectable effect on groundwater concentrations in surrounding boreholes.

A UCG project site with the appropriate operational controls should present a very low risk to groundwater, but a robust assessment will be required. The UK Groundwater Regulations are likely to be met when the target coal seam lies in an area of 'permanently unsuitable' water without communication to existing aquifers. This would have to be proven through environmental investigation. A full analysis of the groundwater risks, hydrogeological modelling of the site, a network for monitoring groundwater during and after operations, and a suitable mitigation response to pollution breakout will be required.
The surface plant will have a significant requirement for temporary storage of various process and contaminated water streams. Control of spillages and the use of best practice in the processing of effluent waters will be an important part of site management.

Surface subsidence will have to be evaluated as part of the EIA. The gasifier would be designed to minimise any adverse effects of subsidence. Significant subsidence will be unlikely as cavities will be narrow, compared with longwall mining, and separated by pillars of coal.

Air Emissions and CO_2 capture

The traditional emissions of concern are the oxides of sulphur and nitrogen, particulates and heavy metals such as mercury. Air emission controls are already stringent for these materials and the technology of mitigation is well developed. UCG should have no special difficulties in meeting current and future regulations.

The framework for approval of a UCG project is a permit under the Integrated Pollution Prevention and Control (IPPC) Regulations. The utilisation of UCG product gas at surface will have to conform to the Large Combustion Plant Directive (LCPD), the UK air quality requirements and any future further conditions that might be imposed on gasification plant through European IPPC guidance notes (known as BREF and currently in draft form).

A UCG power plant produces CO_2 post-combustion emissions, comparable with the surface gasification of coal (~0.8tonnes/MWe). An Australian study has shown that the emissions are lower, on a life-cycle basis, than power generation using supercritical pulverised fuel.

Capture and sequestration of all the CO_2 from the UCG process will be required for UCG with carbon dioxide capture and storage (CCS) and the options considered were:

1. *Shifting and reforming of the carbon-containing gases (CO and methane) in the UCG product gas to hydrogen and CO_2 and capture by physical absorption (Selexol).*
2. *Post-combustion capture after power generation using a chemical separation process (amine-based).*
3. *Oxy-firing of the product gas in a boiler or gas turbine producing only CO_2 and water in the flue gas.*

The study suggests that the most likely and cost-effective option in the near term, is total pre-combustion capture using method 1, which has the additional advantage that the product is mostly hydrogen which could be distributed for transport or used in large stationary fuel cells.

Planning and Licensing Regulations

A UCG project in the UK would require approval under the planning and environmental laws and a licence from the Coal Authority would be needed to access the coal. Development of a UCG trial or production facility would be considered as a mining operation, but any associated electricity generation facilities above 50MWe would be viewed as industrial development requiring the consent of the Secretary of State for Trade and Industry.

Under Town and Country Planning provisions, there is a presumption in favour of permitting applications for mineral projects, but UCG, initially, will represent a departure from the Mineral Development Plan and may require special approval. It is reasonable to assume that the first UCG commercial project would be subjected to review under the appeal procedures.

Public Perception

A study of public perceptions indicates that concerns would be raised about uncontrolled combustion, escape of pollutants, groundwater contamination and subsidence. Planning and public perception could impose significant restraints on the exploitation of UCG in rural areas. UCG under estuaries and in near-shore waters, with the power and processing island located on a brownfield onshore site, is seen as the best prospect for early project entry in the UK.

Economic Issues and Commercialisation of UCG

Economic Evaluation

The main findings of an initial economic assessment were:

- Large-scale UCG with power generation (300MWe) undertaken remote from the gasification site has a generation cost comparable to, and possibly less than, Integrated Gasification Combined Cycle (IGCC) technologies. However, small-scale developments (~50MWe) are not likely to be economically viable as stand-alone projects.
- UCG with CCS has a power generation and capture cost which lies between the two estimates for IGCC with CCS and is comparable with gas turbine combined cycle (GTCC) with CCS.
- The above assessment assumes post-gasification capture and has not examined the case of pre-combustion methane reforming and CO shifting prior to CO_2 capture. This would yield similar abatement levels to the post-combustion separation of Case 3 but may have advantages regarding energy efficiency and costs.

Onshore and Offshore Opportunities

A preliminary exercise based on conservative assumptions for power plant location and coal seam access suggests that large UCG power projects could be located in at least five brownfield areas around the UK. If these sites had access to temporary satellite UCG stations within 25km of the generating plant, they could service an estimated 27GWe of installed power generation capacity for at least 20 years. This is greater than the current generating capacity from coal in the UK.

The offshore coalfields in the lower North Sea hold considerable promise for large-scale UCG. Potentially redundant offshore platforms could be used for the production of UCG gas, which would be brought ashore, possibly in existing pipelines, for processing and power production. Potential CO_2 storage sites, such as aquifers, EOR opportunities and unmineable coal, could be in close proximity.

Overseas Potential for UCG

UCG feasibility studies are underway in Australia, Asia (Japan, and India), Europe (UK, Poland, Portugal and Slovenia) and there is some interest in UCG for hydrogen production in the USA. There are growing opportunities for international collaboration.

In the technologies of UCG, UK has a lead in the underground process, the geological selection of sites, environmental issues and the processing of UCG product gas. Offshore UCG, if successfully developed, would use much of the expertise in platform design and servicing that already exists in the UK to support the oil and gas industry. The market potential for offshore technology would be very significant; for example, Japan has large offshore coal deposits. A co-ordinated policy on the export of UCG technology could result in a demand for UK equipment and services.

Conclusions and Recommendations

This report has established that UCG-CCS is a potential future technology for the exploitation of UK coal resources, particularly for coal resources under river estuaries, and near-shore and, eventually, offshore coal. Concerns remain about the environmental impact of UCG, with approval under the Groundwater Regulations and public perception issues being key factors. In addition, the economics of UCG-CCS need refinement and offshore UCG (from platforms) requires further investigation. In short, UCG-CCS is a promising technology for the UK, although it has to be a commercial decision whether to deploy it, taking into account the planning hurdles that would need to be overcome before any project can go ahead.

The feasibility study for the Firth of Forth has the potential to become a 'lighthouse' project for taking this technology forward and, by investigating a specific site area, the study has the potential to clarify and potentially resolve many of the outstanding environmental, planning and hydrogeological issues identified in this report.

UCG-CCS has reached a stage where, ideally, an industry consortium should lead the future development of the technology, and there is probably a range of service providers (drilling, process design, mineral and hydrocarbon extraction) and equipment manufacturers (plant, power generation) which would benefit from the successful development of UCG. The Firth of Forth study is currently the leading opportunity to develop a UCG demonstrator in the UK.

Other important aspects of UCG-CCS are its potential for hydrogen production for transportation or stationary fuel cells, its flexibility for load following as a complement to renewable energy and its export potential for UK industry. If planning and environmental issues can be resolved, UCG-CCS increases diversity of supply and could add to the security of energy supply in a low carbon economy.

The DTI is currently developing a Carbon Abatement Technologies Strategy that will consider all forms of sustainable uses of fossil fuels for power generation. In this Strategy, UCG will be considered alongside other fossil fuel technologies, such as IGCC, but ultimately it has to be commercial viability that determines which technologies prevail in a sustainable world.