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Worldwide Developments in UCG and Indian Initiative

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Abstract

Concept of converting coal in-situ into gas has existed for many years. Basically it involves drilling a pair of wells into a coal seam and injecting gasifying agent like oxygen or air and steam through the Injector and after ignition and gasification of coal, the gas is brought to the surface through the other hole (Producer) and used as fuel or chemical feedstock. The first experimental work can be traced back to 1912 when William Ramsey began work in Durham, U.K. Intensive coal gasification work began in the then USSR in 1930s at a shallower depth. This led to industrial scale projects in several parts particularly in Russia and Uzbekistan. One project of Uzbekistan is still operational. These trials established the basic technology of UCG. There was a renewed interest in UCG in Western Europe in view of energy shortage in 1944-1959. Borehole method was tested in Newmann Spinney and Bayton in U.K. This could not be sustained for long as during 1960s, low cost fuel was available in plenty and therefore there was a period of lull on the progress of UCG in Europe. Oil/gas price and supply have dictated the pace of progress in UCG. After the first oil crisis, USA again embarked on the development of UCG in 1972 and continued in 1980s, involving in the process a number of institutes and agencies. This led to considerable technological development. There were concerns on environmental pollution which the trial raised. It was thought appropriate to test the application of technological developments that had taken placed in oil and gas industry in UCG. In 1990s deviation and in seam drilling was tried in “Al Tremidal” in Spain. The trial was successful and it proved the viability of directional drilling and benefits of CRIP technology (Controlled Retractable and Injection Point). As a result of Spanish trial, Department of Trade and Industry Technology (DTI), U.K., emphasized growing importance of UCG as clean coal technology. In its report of 2004 on the Review of Feasibility of UCG in U.K., UCG has been identified as an additional source for energy security within the context of a low carbon economy, if planning and environmental issues can be dealt with. China has carried out 16 field trials since 1980s and has involved a number of agencies in order to address various issues in a comprehensive manner. Technology transfer agreement was executed with DTI-UK and a UCG Centre has been created in China University of Mining and Technology. Attempts are also being made in China to carry out gasification at deeper depths. Recently Australia has carried out a successful trial in Chinchila involving several agencies like Sydney University, Ergo Energy, Linc Energy, GE etc. Japan has overseas coal interests and has involved University of Tokyo for experimental studies. New Zealand carried out a small trial in 1994 with the help of USA. Other countries like Pakistan, Ukraine and Romania are also interested in UCG. In India, a beginning was made in UCG in 1980s. Two pilot bore holes were drilled north of Mehsana town of Gujarat to see the suitability of application of UCG technique. However, further study on the subject has not been made since then. Recently there has been a surge of interest in UCG and as a consequence ONGC has signed an agreement with Skochinsky Institute of Mining (SIM), Russia. MOUs are also being executed with other coal/lignite based companies like Coal India Ltd, Gujarat Mineral Development Corporation Ltd, Gujarat Industries Power Corporation Ltd., Neveli Lignite Corporation Ltd., etc. The paper attempts to highlight continuous worldwide efforts for technological development for harnessing coal through in-situ gasification. The technology assumes all the more significance in view of limited resources of oil/gas and abundance of mineable and un-mineable coals.

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1. Principle of UCG

Concept of converting coal into gas has existed for many years. Basically it involves drilling a pair of wells into a coal seam and injecting gasifying agent like oxygen or air through the Injector and after ignition and gasification of coal, the gas is brought to the surface through the other hole (Producer) and used as fuel or chemical feedstock. Though the principle is simple, practical conversion of coal into gas in-situ and ensuring a consistent and environmentally safe exploitation of coals especially deeper seams is a challenging task. Overcoming these difficulties provides a good opportunity for today's highly developed drilling and engineering technologies. A number of disciplines like geology, chemistry, chemical engineering, mechanical engineering, production, drilling etc. needs to be applied for the exploitation of coal.

2.1. Historical perspective

In the year 1868, Sir William Siemens was perhaps the first to suggest underground gasification of waste coal in the mine. The first experimental work can be traced to 1912 when William Ramsey began work on UCG in Durham but was not able to complete it till the onset of First World War. All the efforts in Underground Gasification in Western Europe were discontinued till the end of Second World War. On the other hand, intensive work on coal gasification began in the then USSR in 1930s in coal seams at shallower depths. This led to industrial scale UCG in several parts of USSR particularly in Russia and Uzbekistan. One project of Uzbekistan is still operational today. These trials established the basic technology of underground gasification. Shortage of energy from 1944 to 1959 induced of a renewed interest in situ coal gasification in Western European coal mining countries. The first attempts were directed at thin seams at shallower depths. Borehole method was tested in Britain in Newman Spinney and Bayton (1949-50) and a few years later attempt was made for a commercial pilot in P5 trial in Newman Spinney (1958-59). During 1960s, low cost fuel was available in plenty and therefore there was lull on progress of UCG in Europe. However, after the first oil crisis USA again embarked on the development of UCG in 1972 involving in the process a number of institutes. This led to considerable technological development.

French attempted to gasify the coals at deeper depths which were conventionally un-mineable and their objective was to bring to surface the medium value caloric gas through injection of oxygen and steam and convert the gas into high caloric value methane at the surface. Two main tests carried out in Bruay-en-Artois (1978-1981) and Haute Deule (1982-85) and they provided some valuable insights; Adequate well fittings to withstand pressure variations, possibility to link by hydro fracturing, easy ignition of coal with an electric heater, difficulties to carry out reverse combustion according to spontaneous combustion problems near the injection well, possibility to prevent spontaneous combustion with the injection of low oxygen content. In a related development, in Loire field electro-linking was tried. The results were successful and the same was confirmed by open casting the coal seam and back checking the results. Work on these attempts stopped in 1989.

2. Recent developments

2.1. Belgo-German experiment: deep UCG

Attempts were made to link wells by Reverse Combustion in a Belgo-German trial at Thulin. The attempt was unsuccessful because of high overburden lithostatic pressure. The wall behaviour is different at deeper depths. It tends to weep towards the hot cavity created impairing the fire progression into the coal seam. Reverse combustion attempts were stopped. However, a collaborative project in 1985 attempted connecting existing wells at Thulin through lateral drilling. The two wells were linked through lateral drilling and side tracking. A small gasifier circuit was established and about 340 tons of coal was gasified at a depth of 860 meters for about six months. The gasifier pressure was maintained at about 20 -30 bar. The greatest benefit of this trial was that it was established in deeper coals that could be gasified through deviation and horizontal in-seam coal drilling for linking wells. Another innovation was insertion of "flexible casing" into the deviated and horizontal section of the well. Technical risks included inaccurate azimuth, insertion of flexible casing, less permeability of coal at deeper depths, corrosion and high temperature. Economic risks included high cost of deep boreholes, uncertainty about consistent heating value of produced gas, efficiency of gasification and percentage of unburned coal.

The results of this experiment encouraged further research and this resulted in the formation of European Working Group on Underground Coal Gasification for formulating a proposal for further research. The Group submitted a proposal for a larger scale experiment involving the Belgian team of Thulin experiment, Spain and UK. The aim of this project was to test the technology on coals which are thinner and deeper and typical of Europe. Initially, it was proposed to test the technology at about 500m and later at 1000m and beyond. Deviation and in seam drilling was used to establish link between injector and producer and different methods for Gasifier control and development were to be tested. The project was proposed in "Al Tremidal" in the province of Tereul, NE Spain. The site was chosen on the grounds of geological suitability. Extensive borehole data was also available for this site. The trial was successful and it proved the viability of directional drilling and benefits of CRIP (Controlled Retractable and Injection Point). About 90 m of channel was created and estimates concluded requirements of about 300 tons of coal for conversion into power of 8MW. The quality of gas was very high in this case. The programme also included a post burn activity material analysis, environmental impact monitoring, cavity sampling etc. The pilot duration was short but lessons were learnt on the detailed engineering, drilling and plant design. Sustained gasification for a longer duration would provide an opportunity for economic and commercial assessment of the UCG process.

UK has large coal reserves. Department of Trade and Industry (DTI), U.K., identified UCG as a potential. Technology targets for UCG were described in detail in DTI's Energy Paper 67 (1999) and they were as under:

- Improved accuracy of in-seam drilling.
- Assessment of the implications of burning UCG gas in a gas turbine.
- Estimates of the landward reserves of coal that could be technically suited to underground gasification.
- Identification of a site for a semi-commercial trial of UCG.
- Identification of the parameters that underground coal gasification would have to meet to compete with current North Sea gas production costs.
- A pre-feasibility study for the exploitation of underground coal gasification off-shore in the southern North Sea.

Following this, DTI submitted a report entitled "Review of Feasibility of Underground Coal Gasification" in the U.K. and was presented in 2004. The report highlights that coal will continue to play a prominent part in future as a source of energy. It becomes all the more pertinent to look for clean coal technology and out of a suite to technologies, UCG could provide a combination of high generating efficiency and potentially satisfactory method for clean coal technology. The report also mentions that evidence to date suggests that UCG compares well with, for example Integrated Gasification Combined Cycle (IGCC) and supercritical thermal plant. The report also informs that UCG however, is less advanced than either of these technologies and questions specific to UCG like planning approval, environmental impact and operation at commercial scale needs to be worked out. Full scale trial before commercial decisions can be taken and would cost approximately £10-£20 M.

UK coal reserves including that of off-shore is probably the largest in Western Europe and it is estimated that only 1-2% has been mined since Industrial Revolution. Most of the coal in UK is bituminous and exists right from the outcrop to a depth of 2000m. Exploitation of this resource at deeper depths is not possible through conventional mining. As per an estimate, 17 billion tonnes of un-mineable coal are suitable for UCG. The report concludes that 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.

3. UK-China collaboration

Coal meets 70% of energy requirements of China and consumes 1 billion tons of coal per annum and this is a cause for major air pollution, acid deposition and green house gas emissions. One of the options they have explored is that of UCG. China has adopted two approaches for the exploitation of coal. One is Undersurface Gasification (UG) method and the other is Long Tunnel, large section, two stage method. Undersurface Gasification is an extension of underground mining in which gasifier replaces working faces and is controlled independently from underground for optimal performance. The access is made all the time from underground. In the other method, a long tunnel is constructed using mining methods and connections to the surface are made using production and injection wells drilled. The system is monitored and operated from the surface. The two stage method involves injecting air first so that a high temperature is attained. Then the steam is injected resulting in the process of gasification. The method has been shown to produce gas with heating values of 12-14 MJ/m3 and a hydrogen content of 50%. The method has been found to be difficult to control.

The principal partners in this project were Wardell Armstrong, Cranefield University, Alstom Power, University of Nottingham, China University of Mining and Technology and many other organizations.

China as per the latest reports has embarked on a programme of testing UCG at deeper depths.

4. Chinchila project, Australia

Chinchila IGCC Project has been under development since 1999.This is the largest UCG trial so far and resulted in the gasification of 35,000 tons of coal and has claimed 95% recovery of targeted coal resource. Consistency and high quality of syngas has been claimed and availability of gas has been ensured for 28 months at a time. The project has claimed no contamination of aquifer and has had a special shutdown programme.

5. UCG site selection & characteristics

Over the last half century, coal gasification has proven itself as a technologically feasible process for gasifying coal, with the potential to be commercially viable under certain conditions. The Large uncertainty about the viability of UCG stems from the unknowns associated with suitable UCG sites. Surface gasification provides a precise process with the ability to control nearly every variable. In contrast, underground gasification relinquishes a significant degree of control for the ability to utilize coal without mining it from the seam. The precision in UCG comes from careful site selection. A gasifier can only rely on coal available within the seam, so there remains a number of critical factors, a developer must consider to ensure the quality and quantity of syngas needed for a project's lifetime.

5.1. Geology

In-situ coal gasification is a high technology area. Some countries such as UK, USA and Australia have developed their own sets of criteria depending on local conditions. Following the important features concerning geology are taken into consideration during site selection for UCG:

a. Geography, topographical and technological features of the area.
b. Presence of faults, fractures, fissures etc and their orientation and extension.
c. Complete geology and geo data of coal seam as well as roof and floor which include complete lithology of overlying beds, coal bed and the floor rock.

5.2. Coal rank

The coal rank under combustion helps determine the quality of the syngas and the feasibility of Conducting UCG. Researchers recommend using the lowest ranking coals of lignite and sub-bituminous coal or low-rank high volatile bituminous coals. Low-rank coals generally shrink when burned, which improves the connection from the injection to the production wells. However, a trade-off exists between using low rank coals that tend not to swell and high rank coals that have higher heating values which produce more energy from less coal.

5.3. Coal composition

The amount of ash, sulphur and moisture in the coal also affects the quality of the gas. Coal with Ash content above 50 percent decreases the heating value of the coal. Additionally; ash contents above 60 percent can inhibit the UCG process. The higher the sulphur Content, the more the gas will need cleaning to remove impurities. Furthermore, moisture Contents below 15 percent are needed for optimum combustion. Without enough moisture in the Seam, the reaction will need additional water to facilitate the burn. On the other hand, too much Water can reduce syngas quality or even stop the UCG process entirely.

5.4. Coal porosity and permeability

The porosity and permeability of the coal within the coal seam can impede or improve the flow of the syngas between the injection and production wells. Researchers recommend permeability values of 50 to 150 mD. Highly porous coal-seams or highly cleated-seams lead to higher rates of gasification due to better movement of the gas between the injection and production wells. Alternatively, the faster movement between injection and production wells allows for more water to enter the coal-seam, potentially preventing the UCG process. Also, increased porosity and permeability can allow for more syngas to leak out of the coal seam into the surrounding geologic structures, reducing syngas output and increasing the risk of water contamination. Currently, the extent of the effects of porosity and permeability in the coal seam are unknown.

5.5. Partings

Partings are layers of clay, limestone, shale, sandstone, or other rock that locally separate the coal into multiple layers within a given seam. Partings can be problematic if they are located near ignition points, injection wells and production wells. Researchers recommend a single layer parting that should be less than one meter in thickness. With a parting more than one meter thick, the syngas heating value will drop and gasification may prove impossible In addition, a coal seam with over 20 percent of its volume occupied by partings can cause the quality of the gas to decrease to the point that UCG becomes economically impractical.

5.6. Depth and aquifers

Optimal coal seam depths exist between 92 to 460 m, with the preference for seams below 200 m to avoid major subsidence issues. Deeper gasification projects are also desirable due to their increased separation from potable groundwater aquifers. Thus, deeper the coal seam, the less risk of contaminating underground sources of drinking water (USDW). Researchers recommend that aquifers above the coal seam should not be within a distance of 25 times the coal seam height (S. In addition, no overlying strata with water should be within 31 m of the seam. There are also problems with drilling wells too deep. The cost of drilling increases at greater depths. More importantly, the pressure on the gas created at deeper depths can alter the gas composition. At greater depths the gas composition may prove inefficient for powering a gas turbine for an electricity plant. In addition, drilling to depths more than 460 m creates complications that restrict the flow of the gas in the coal seam and potentially stop the gasification process.

5.7. Depth and subsidence

Structural integrity of the geologic layers above the coal seam is required to support the overlying strata and the grounds surface. Researchers recommend no less than 15 m of consolidated rock above the coal seam to prevent subsidence from occurring. Additionally, relatively impermeable rock around the seam helps to prevent the escape of product gases as well as reducing the flow of ground water into the seam.

5.8. Hydrology

Despite recommendations that no overlying strata with water should exist within 31 m of the Coal seam, some water inflow whether from surrounding water aquifers, direct injection into the Coal seam or present within the coal seam, remains necessary to maintain the gasification Reaction. High moisture content in the seam relieves the necessity of surrounding water sources. Lacking high moisture contents, permeables and stone above the coal seam or within rock layers that are relatively impermeable allow water to flow into the coal seam.

5.9. Coal seam thickness

The thickness of the coal seam should remain between 2 to 15 m with no more than 25 percent variation in the thickness throughout the coal seam. Variations in thickness can complicate drilling for wells. Greater coal seam thickness leads to higher utilization of the coal seam for gasification. Moreover, researchers have shown that coal seams thicker than 2 meters greatly increase the heating value and consequently the amount of energy available in the output gas.

5.10. Coal seam angle (dip)

The recommended dip or angle of the seam should preferably lie between 0 and 70 degrees with less than 2 degrees in angle variation in order to avoid problems with drilling. As the angle in the seam increases, the potential for damaged equipment and material in the seam rises accordingly. Still, a coal seam with a slight angle is favourable for UCG because it helps to move water and ash away from the area where oxidation occurs.

5.11. Coal reserves and accessibility

Depending on the amount of electricity and the life Cycle of the power plant, varying amounts of coal are needed to meet the energy requirement.

For a general reference, using results found in experiments at the Chinchilla plant in Australia, Researchers calculated the amount of coal required to run a 300 MW UCG combined-cycle powerplant operating for 20 years with a50 percent efficiency, producing a syngas with a heating value of 5 MJ/m3. The researchers found that under the site conditions, 33 million metric tons of coal converts to roughly 75.6 billion m3 of syngas.

Some amount of coal must be left in the seam after gasification to prevent large scale collapse of the overburden and subsidence of the ground surface. This limits the amount of coal available in a given site to meet specific energy demands. The amount of coal required depends on specific characteristics of the site, such as the thickness of the coal seam, the structure of the overlying rock, the spacing between the injection and production wells and the depth underground. For a point of reference, the distance between injection and production wells in the UCG operation Hanna, Wyoming stood between 16 and 18 m. The site in Wyoming successfully gasified 4,600 tons of coal at a depth of approximately 130 m without any subsidence issues or contamination to overlying potable aquifers.

In addition to underground characteristics, there are other limitations above ground to consider, once the production wells begin to receive syngas. Engineers mush take into account available Infrastructure for the gasification process, transportation of syngas, existing land use, environmental and other land-use restrictions when choosing an appropriate site for UCG Development. Researchers suggest that land-use restrictions for UCG most likely present the same restrictions as typical underground coal mines.

5.12. Lab studies of gasification

Lab studies of gasification of the coal under simulated condition should be carried out to help in assessment of injection parameters. Along with temperature measuring devices, tracer such as argon (Ar) can be used during gasification to understand the in-situ phenomenon including cavity growth, to ascertain the other properties of the coals and to assess the impact of the various factors of gasification

5.13. Well completion/ linking of wells

Availability of high temperature resistant(NTR) cement, special completion design, keeping provision for well bore cooling and use of high pressure temperature and corrosion resistant well head, flow line, down hole casing and tubings etc. is a pre-requisite.

Evaluation of reservoir parameters of coal seam and roof and floor rocks and finding out of most economical and feasible linking technique suiting to the coal seam conditions is a must. The main factor determining the cost effectiveness is the specific consumption of linking fluid on a unit of the obtained channel. The intensity of the connecting blast on a burning point depends not only on the consumption of blast injected but also the distance between the injection and burning point, thickness of coal seam and design of the borehole. Significantly, it also determines the filtration characteristics of the coal rocks and surrounding rocks.

5.14. Chemical analysis of coal

A comprehensive analysis as given below has to be performed to ensure that the site is suitable. This includes the correlation of the individual coal beds, seam structure, rank and quality of the coal seams.

- Band by band analysis
- Proximate analysis
- Ultimate analysis with sulphur distribution
- Calorific value
- Coking properties
- Low temperature gray-king essay
- Coal petrography
- Ash analysis
- Ash fusion temp-range
- Coal reactivity
- Chlorine and phosphorous content
- Permeability and porosity of coals.

Table below provides recommended values for different parameters associated with UCG:

Table 1. Ideal Characteristics for UCG

Parameter	Desired Value	Imperial Units and Comments
Coal thickness(m)	2 - 15	5-50ft
Thickness variation (% of seam thickness)	<25	
Depth (m)	92 - 460	300-1,500ft
Dip (degrees)	0 - 70	
Dip variation (degrees/31m,100 ft)	<2	
Single parting thickness(m)	<1	<3 ft
Total parting thickness(%of seam thickness)	<20	
Fault displacement (%of seam thickness)	<25	
Fault density (Number of faults/31m)	<1	Number of faults/100 ft
Coal rank	Low rank	≤Bituminous
Coal moisture (wt %)	< 15	
Ash content (wt %)	<50	
Coal sulphur (wt%)	< 1	
Thickness of consolidated overburden	>15	50 ft
Seam permeability (mD)	50-150	
Immediate overburden permeability (mD)	<5	15 m(50 ft) above the seam
Distance to nearest overlying water-bearing unit(m)	>31	>100 ft
Coal aquifer characteristics	Confined	
Nearest producing well completed in coal seam(km)	>1.6	>1mile
Available Coal Resources(10^6 m^3)	15.4	~543x10^9cubic ft for20 year-long operation

5.15. Chemical kinetics/ environmental studies

Knowledge of chemical kinetics of in-situ gasification under the prevailing condition of the coal seam and determination of optimum composition of reactant, i.e. Air, steam, O_2, N_2 etc. during reverse combustion as well as forward gasification is required. Prediction of cavity growth and subsidence etc. during gasification with the help of UCG process models or simulators is also to be done. Identification of required sophisticated capital equipment and instrumentation and their availability for complete UCG process is also necessary. It is also necessary to evaluate environmental impact of UCG process such as ground water pollution and surface treatment and disposal of produced water and finally to work out economics of the overall process for its commercialization under possible utilization patterns.

6. Indian initiative

In India Coal India Ltd., Neyveli Lignite Corporation, GIPCL, RSMM and GMDC they have initiated the UCG projects in some promising areas and work for site selection etc. and further line of action for Pilot Plant is under progress.

6.1. Surkha UCG block, GMDC, Bhavanagar dist., Gujarat

ONGC has signed an Agreement of Collaboration (AOC) with Skochinsky Institute of Mining, Russia on 25th November 2004 for Underground Coal Gasification (UCG). The UCG project is being carried out with the consultancy of the said Russian Institute. The project is envisaged to be completed in phases comprising of various stages right from site selection to construction of UCG Enterprise.

In accordance with the MOU signed by ONGC and GMDC for the Underground Coal Gasification Project for developing UCG project in some promising area of GMDC. Accordingly, it was decided to study feasibility for UCG of one block in Surkha north lignite block after analyzing geological parameters. Additional exploration required for reserve enhancement and hydro-geological and geo-mechanical analysis was carried out. One test well and two observation wells for long duration pump test were dugout. The lignite seams occur mainly in Eocene formation of grey / grayish grey Khadsalia clays. Lignite quality, depth occurrence of seam, seam dip, lignite reserves, seam floor and roof lithology and hydrological conditions are promising for gasification. The lignite seam roof reliably separates lignite seam due to the presence of aquicludes. Lignite seam floor contains unconfined trap rock. Aquifer sealed by clay of thickness more than 3 mtrs. The recommendation of consultant has suggested this block for UCG by air injection. Lignite reserve is 28 mT and gasifiable reserve is 18 mT for running 100 mW power plant syng gas required will be 2 bcm per year. Therefore, reserves are expected to last for 15 – 16 years. Before beginning design work for Surkha hydrogeological investigation of trap rock aquifer is to be carried out. This project appears to be suitable for UCG and efforts are being made for increasing the commercial viability of the project by exploration.

6.2. Various stages for execution of UCG project

After having selected a suitable site for UCG project, the following stages need to be followed:

6.2.1. Technical stages

- Identification of site as suitable
- Preparation of layout design for UCG pilot
- Preparation of detailed engineering design for UCG pilot
- Drilling of process wells for UCG and monitoring wells
- Erection of surface facilities
- Pilot commissioning and operationalization

6.2.2. Statutory clearances

- Filing application with Ministry of Coal through Govt. of Gujarat for award of block selected as suitable for UCG project
- Block allocation intimation to Govt. of Gujarat by Ministry of Coal
- Preparation of Mine plan which needs to be submitted for award of ML.
- Award of Mining lease by Govt of Gujarat.
- Obtaining Environmental clearance for UCG pilot project. Application is to be submitted to Ministry of Environment and Forests. For this, agency like National Environmental Engineering Research Institute (NEERI, Nagpur) may be involved for the preparation of Environmental Impact Risk Assessment Report. This shall be followed by public hearing and other stages for approval from Ministry of Environment and Forests.
- Approval of DGMS
- Pilot commissioning and operationalization

Benefits of underground coal gasification

As a method of exploiting coal, UCG represents an environmental improvement on the combination of coal mining and surface combustion of coal. It is also safer and intuitively more efficient.

Environmental benefits of UCG over underground coal mining for fuelling power generation include

a. Lower fugitive dust, noise and visual impact on surface
b. Lower water consumption
c. Lower risk of surface water pollution
d. Reduced methane emissions
e. No dirt handling and disposal at mine sites
f. No coal washing and fines disposal at mine site'
g. Lower overall capital and operating costs
h. No coal stacking and transport6
i. Smaller surface foot prints at power stations
j. Larger coal resource exploitable

Summary

UCG has the potential to exploit full resources which are either uneconomical to work by conventional underground coal extraction or inaccessible due to depth, geology or other mining and safety consideration. The successful development of UCG will not only depend on advances in the use of technology but also on demonstrating that a clean energy can be produced without detriment to the environment. UCG represents a sustainable environmental improvement on the combination of coal mining and surface combustion of coal.

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