Policy and Regulatory Issues for Underground Coal Gasification in India

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Abstract. Underground coal gasification (UCG) is in its nascent stage of development. Most of the projects are in the nature of pilot projects. UCG technology requires acceptance in general commercial framework as it matures with the progress of time. Policy and regulatory framework, therefore, is considered here only in the expectation that UCG technology may finally be rolled out sooner than later. India is actively pursuing consultations with major countries which have recorded successes in implementing UCG technology in varying measures. In this background, the discussion on policy and regulatory framework is essentially an effort to capture the broad outline of the understanding of the UCG process in a regulatory construct as compared with other regulatory regimes of similar nature.

1. Introduction
Underground coal gasification (UCG) is being developed internationally as a leading source of unconventional gas reserve. Number of initiatives internationally are focussing upon the creation of framework for UCG for its safe, environmental-friendly and economic deployment. Thus, a background of norms, rules and safety practices are required to bring UCG to the forefront of energy security in India. Many reasons can be cited for the delayed development of UCG in India. However, a robust background of policy framework can be said to be a major reason attributable to slower-than-usual development of gasification based economy in India. Both underground coal gasification and surface gasification have not reached a commercially viable level despite various efforts by the governmental, policy, industrial and academic stakeholders. It should be noted that while early efforts for UCG were taken up in the early 1980’s itself with concerted inputs of Coal India and ONGC. One lignite block in Rajasthan was found to be suitable but pilot operations could not begin due to fears of impending ground water contamination [1]. Similarly, surface coal gasification efforts began in the erstwhile CFRI in the 1960’s [2]. Iyengar and Haque [3] and Krishnudu et al [4] performed trials on laboratory scale for understanding of gasification processes in Indian high-ash coals. However, as Shahi [5] points out, gasification never really “took-off” so as to meet societal needs in sustainable manner. It is important to understand that proper implementation internationally has been accompanied by proper regulatory framework. In India itself, development of coalbed methane (CBM) and mine drainage has been successful with sufficient policy inputs. Thus, understanding the modalities in terms of UCG feasibility in terms of rules and acts, environmental norms and so on need to be understood. This paper intends to understand the global policy developments in UCG technology through a overview of some of the work performed in this area. It should be noted that this is only a preliminary understanding of the work ahead. For instance, the Government of India recently issue
new emission norms for coal-fired power plants. Should UCG-based power plants be subject to similar or lower norms in terms of particulate and gaseous emissions? If UCG is expected to be accompanied with CO₂ capture and storage (CCS), would the regulations for UCG-CCS be similar to PC-CCS plants and IGCC-CCS plants? If not, what are the possible areas where regulations may be different? Further, since conventional coal mining activities led to significant fugitive methane emissions, the Directorate General of Mines Safety (DGMS) has established norms for degrees of gassiness of coal mines. Similar classifications also need to be developed for UCG projects.

2. Summary of international policy studies
Mao [6] reviewed the important factors related to UCG development in China. Some of the important highlights of the study are shown in Table 1.

| Area                      | Highlights                                                                 |
|---------------------------|-----------------------------------------------------------------------------|
| Environment and safety    | • Approval of over eighty eco-friendly coal gasification projects by China in the last decade |
|                           | • Inability of gasification projects to solve many fundamental problems, leading to emergency shutdown of many projects |
|                           | • However, reduced subsidence and damage to hydrosphere/lithosphere damage can be of help |
| Energy efficiency         | • Comprehensive efficiency of 50% for UCG for power production and 63% for chemical industry, as compared to only 23-30% for pulverized coal plants |
|                           | • Mining recovery efficiency for gasification plants of 90%, as compared to only 66% for coal mining |
| Economic feasibility      | • Gasification of 150×10⁴ tonne per annum brings advantage of economies-of-scale |
|                           | • Payback period of 7-12 years depending on scale of project |

A major issue in UCG projects is groundwater damage, which has been studied for some time now. As back as in 1978, Humenick and Mattox [7] studied the contaminants released into groundwater due to gasification of lignite. They determined that groundwater pollutants arose from ash leachate, which contained sulfate, calcium, and hydroxide while condensed vapours contributed organics and ammonia. The lignite and clay strata were found to sorb the groundwater contaminants. Liu et al [8] analysed the organic pollutants and found the presence of phenols and benzene. They found that the flow of groundwater after gasification could be attributed to migration of the polluting substances and could be predicted using suitable numerical modelling techniques. Dong et al [9] developed a 3D hydrogeological model for optimizing water pumping and injection into UCG reservoirs. They found that more attention should be paid to control induced fractures in the roof. Thus, active regulations should be targeted in this area. They also established suitable water pumping and injection levels of (160 and 120 m³ per day respectively). Similar tasks may be performed, at least on a block level to find suitable ranges for Indian UCG projects.

Underground coal gasification also must lead to long-term emission stabilization both in terms of gaseous and particulate emissions since many Indian cities such as the capital city of New Delhi, have been plagued by major air pollution. Further, in view of the Paris Climate Agreement, carbon mitigation and inclusion of clean coal technologies in the energy mix is of prime importance for decarbonisation of the electricity sector. Blinderman and Anderson [10] have studied the CO₂ emissions at the Chinchila UCG-IGCC project in Australia. They estimate that the CO₂ emissions of this plant showed a 55% reduction compared to a supercritical coal-fired power plant and a 25%
reduction compared to a gas-fired power plant. They also suggested that the turbine efficiency in such operations was 25% higher than that in natural gas combined cycle (NGCC) plants. Verma and Kumar [11] found the life-cycle greenhouse gas (GHG) emissions to be 0.91 and 18.00 kg-CO$_2$-eq/kg-H$_2$ in hydrogen production aided by UCG, with and without CCS respectively. It has also been estimated that the life-cycle CO$_2$ emissions through UCG process are only 98%, 80% and 72% of the said emissions from IGCC plants, supercritical PC plants and subcritical PC plants respectively [12]. The direction of life-cycle CO$_2$ emissions is showed in Figure 1. This demonstrates considerable superiority of UCG technology in terms of reduction of atmospheric CO$_2$ and the technology may be of use if implemented in conjunction with the clean development mechanism (CDM) or other proper carbon pricing incentives. An environmental life cycle-assessment (LCA) may be taken up for UCG in India to determine with maximum impact to the environment. Further, an understanding of the social perspectives on UCG for various segments of people, policy-makers, industry personnel, researchers and common people may be useful. This will also help in panel weighting for LCA.

Cost-effectiveness of clean coal technologies vis-à-vis renewable technologies is a key aspect that will determine their success. Olateju and Kumar [13] projected that the price of hydrogen production without CCS would be US$ 1.78/kg-H$_2$, which will increase to US$ 2.11-2.7/kg-H$_2$ with addition of CO$_2$ capture. The range in the latter case is because of the difference in the storage costs. Naturally, if UCG and ECBM can be implemented together in a coal rich area, it will lead to multiple benefits. This may be possible in western India since Singh and Mohanty [14] have estimated total storage potential of 3 Bt-CO$_2$ for Cambay and Barmer-Sanchor basins. These basins also have rich prospects for UCG in many coal mines such as Vastan, Valia, Umarsar and Kapurdi [15, 16]. Friedmann et al [17] project that UCG may produce gas at costs ranging from one-fourth to half, as compared to surface gasifiers. Sheng et al [18] estimate that UCG in conjunction with CCGT and CCS technologies will be able to produce electricity at less than €80/MWh. This is considerably cheaper than PC-CCS plants, as well as CSP plants [19, 20].

3. Perspectives on suitable acts and rules

There are two distinct regimes of minerals related regulatory regimes in India. One regime administers all minerals but petroleum and the other regime addresses petroleum itself. In some aspects, UCG is more like mineral such as coal and in some important aspect it is more like gas (such as CBM). The policy and regulatory theme for UCG has to draw mostly from regulations of coal having greater accuracy of resource determination than CBM where resource estimation has lesser accuracy. But since the resultant product is essentially gas and as such measurement, marketing and pricing may draw upon the regulatory construct of CBM.

The higher echelon of regulatory framework i.e. Mineral Act and Rules would require to be supplemented as in-situ chemical process is envisioned in the case of UCG. Generally, occurrence of minerals is defined in a manner which does not recognize in-situ chemical transition. It may appear to be a significant departure from the generally perceived notion of mineral, but then this form of utilization of coal can be suitably incorporated by defining the process of UCG as part of mineral processing which occurs in the place of occurrence with the specific reference to coal. Once this supplement is in place in the relevant Rule/ Act, issues such as lease for UCG testing and commercial production can be administered in similar lines as in the case of coal.

Current regulations permit right to multiple forms of same mineral. Petroleum and Natural Gas Rules allow exploitation of multiple forms of petroleum such as conventional and unconventional hydrocarbons. It is only that each of these forms may be regulated in isolation and also in combination. The choice really depends on the nature of resource and technology of exploitation. Concurrent development of coal mining or CBM may not be technically possible along with UCG. Co-development, therefore, is ruled out. In the nutshell, it means that Government may allow UCG while precluding the Contractor from other coal related resource or any other mineral available at different stratum.
Figure 1. Complete life cycle model of UCG-CCGT plant showing GHG emissions in terms of CO$_2$ equivalency for various stages of life cycle. Source: Ref 12, with permission from Springer Netherlands.
4. Modalities of UCG contract development

UCG has a unique paradigm not encountered with any other resource. The development of UCG is a coupled concept as far as exploitation of resource and its utilization are concerned. The first i.e. exploitation of resource is a subject matter of mineral management and that of relevant rules and Act in that regard. The second part of the proposition i.e. utilization of UCG is subject matter beyond the scope of mineral management. Since these two parts of UCG is inseparable, the regulatory framework, therefore, needs to undertake a commercial exercise with the aim to (a) protect the value of mineral at one hand and (b) ensure commercial viability of utility project on the other. The twin requirement, though work against each other, needs to be worked upon while framing a policy or constructing a Contract.

It is evident that a minimum syngas price is assured so that exploitation is profitable and a minimum utility price (such as price of power generated) is also assured so that end use process is also profitable. Still another way to look at the utility process would be to consider it as a mere extension of in-situ processing on the surface by the same Contractor. This later consideration appears to be more realistic in the sense that it simplifies construction of a UCG Contract a lot easier. First of all, this setup resolves the conflicting aspect of two coupled processes which otherwise is bound to give rise to frequent conflicts. Only minimum syngas price is to be determined which will vary with product (such as power) price with a datum. It may be emphasized that a failed utility venture or failed UCG process in two different hands shall create a situation where public resource shall be at the mercy of contractors due to the legality involved. The provisions in the Contract should specially address situation where the process is discontinued earlier than envisaged.

5. Other specific considerations

Environment protection is a prime consideration while drafting a UCG contract. The regulation through Environment Impact Assessment (EIA) should address issues such as measurement of harmful products & mitigating provisions, Ground water preservation requirements and site restoration obligation. Various approvals would be required to be obtained from State and Central water authorities (SGWA, CGWA), MoE, National Board for Wildlife, Sanctuary, National Park, monuments etc. A body like DGMS would require to be empowered to oversee Safety and Site Restoration Activity.

In order to ensure proper control on revenue, statutory levies and profit, provisions would be required to be made to define measurement point (delivery point), unit of measurement and Standard Operating Procedure. There should be explicit provisions codifying elements of inspection, calibration, and periodicity and reporting requirements.

The contract must be designed to control the process of exploitation and utility in a controlled fashion with adequate flexibility. Generally, the control of process can be achieved by specifying timeline and corresponding extension clauses and preventive application of liquidated damage wherever required. Among other elements, these provisions may address issues relating to start time, period of different phases, submission of bank guarantee, submission and approval of development plan & utility facilities and start of commercial phase. Special considerations may be elaborated in the contract to ensure that production of syngas is synchronized with the commissioning of utility facility.

6. Conclusions

Development of UCG in India can bring several advantages in terms of efficiency, environment and economics (3E). International studies have demonstrated that UCG shows considerable advantage in terms of resource recovery as well as power plant efficiency. Further, the CO₂ emissions of UCG plants can be 70% as compared to subcritical power plants as stated in Section 2. Further, the cost of electricity (even with CCS) can be very less, when compared to combustion power plants. Having said that (in view of international experience), several apprehensions have been cast in respect to UCG in India such as fears of groundwater contamination, subsidence etc. Needless to say, to dispel off such fears, there is a need for robust and all-inclusive policy and regulatory framework, such that
sustainable resource recovery can take place to give rise to “affordable electricity to all”. The outline of such a framework is shown in Figure 2.

![UCG Regulatory Framework Diagram](image)

**Figure 2.** Proposed outline of UCG Regulatory Framework

Some of the specific regulatory recommendations in this study are:

- The regulatory framework for UCG has to take several aspects from coal having greater accuracy of resource determination than. But since the product is essentially gas, the pricing may have features from CBM pricing. Further, the Government may allow UCG whereas impeding the Contractor from additional coal related reserve or any other mineral accessible at different stratum.
- The regulatory outline is required to assume a viable implementation with the objective to safeguard the worth of mineral and guarantee commercial feasibility of utility development.
- Environmental protection should be an important part of the norms. Also, as in the case of coal mines, a separate statute needs to be developed for safety in the commercial UCG projects.

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