Sustainability of Coal Energy and Environment

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A developing country like India has ever-growing thrust on faster economic development. As energy is the lifeline of all economy, India is genuinely concerned about its energy security. To meet the projected energy demands, Government has declared that fossil fuels, particularly coal, are going to be the mainstay fuel for power generation.

However, in business as usual scenario, out of 253.30 BT of geological coal resources, only 52.24 BT is extractable reserves, which is 21% of the total. Considering future demand and coal production, it may not last for long. Even under envisaged best-case scenario, extractable reserves percentage may enhance by another 50%, thus making possible extraction of at the most 30% of total resources, and leaving 70% of the energy untapped and un-recovered forever.

Apart from this, continuance with coal causes serious threat to the environment. Though, India as a developing nation does not have any commitment for GHGs reduction, however, the costs of environmental damage, measured in terms of loss in potential GDP, have been estimated to be in excess of 10%. Moreover, a general belief is emerging that environment cannot be protected without sacrificing economic growth.

Therefore, the greatest challenge is to negate this belief by identifying and developing appropriate technology to demonstrate simultaneous sustainability of both environment and economic development by extracting energy from the remaining 70% of the non-extractable coal.

The paper deliberates on above, and examines the application of closed-loop fossil fuel systems in non-extractable coal and abandoned mines to convert coal, a finite energy resource, and sequestered CO_2 into a clean and renewable source of methane using biotechnology, and extracting more than the total energy available in coal deposits. Advanced Indian biotechnology is likely to provide an edge over other countries in this endeavor.

INTRODUCTION

Coal provides the single most vital input for the growth of Indian industry. It is the key contributor to the Indian energy scenario. Out of the four major Indian fuel resources i.e. oil, natural gas, coal, and uranium, coal has the largest domestic reserve base, and the largest share of India's energy production. In the year 2003-04, coal & lignite combined together contributed about 6602 peta joules of energy to the nation, sharing about 53% in primary sources of conventional energy (Energy Statistics, Central Statistical Organization).

The national coal resource inventory reveals that out of 253.30 Billion Tonne (Bt) of geological resources, only 52.24 Bt i. e. only 21% of the geological reserves are extractable (Refer Table 1). The main reasons behind this are that (i) coal reserve in India are located over forestland, national parks, bio-reserve, and other eco-sensitive zones. Current regulations restrict coal mining in such identified areas. Thus, the coal reserve occurring over such areas are not available for mining. (ii) It is well known that all geological resources are not mineable and all mineable reserves are not extractable. The mineability and extractability of a deposit depends on the grade and pricing, available technology of extraction, infrastructure availability, safety and environmental considerations, etc.

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In the year 2024-25, the projected raw coal demand, at 8% national GDP growth throughout, is 1267 Million Tonne (Mt), and at 7% GDP, it is 1147 Mt, whereas projected coal production is about 1086 Mt. What would be the average production level during this period, and how long coal is going to last and provide energy security to the country? The opinions vary, and it is estimated that indigenous coal reserves would last for anywhere

between 30 to 100 years. However, one thing is certain that coal industry's maximum efforts, at present, are directed towards only 21% of extractable reserves and its extraction at the earliest possible i.e. extraction of only 21% of the total energy available in country's coal deposits and mines.

Table 1: National Coal Resource Inventory: Tentative Extractable Reserves

(As on 1st January 2006: Source GSI)

Area	Geological Coal Resources (in Bt)				Extractable Reserves (in Bt)
	Proved	Indicated	Inferred	Total	
Total	95.87	119.77	37.66	253.30	52.24

EXTRACTION OF ENHANCED PERCENTAGE OF ENERGY

Is coal industry not eager to extract more and more available energy in country's coal deposits and mines, by making possible extraction of higher percentage of geological reserves? Yes, it is. It is possible by changing the present trend of producing roughly 85% coal by opencast methods and only 15% coal by underground mining.

It is true that in the technology front, open cast mining practices in India is close to international level. Current depths of open cast ranges from 70 mts. to 120 mts, and operations have now been planned even up to 300 mts. However, considering the large deep-seated reserve base (Refer Table 2), which can only be exploited with underground technology, there is a need to increase the underground coal production level, which remains stagnant at around 65 Mt for the last 25 years.

The adverse geological mining conditions of coal, and an unscientific mining in the early phase of coal mining (up to early 1970s) that led to fires in coal seams, land subsidence, degradation of land, air and water pollution mostly in Jharia & Raniganj coalfields have made underground coal mining difficult & unsafe.

Table 2: Depth wise Coal Resources as on 1.1.2005

Depth (in m)	Proved (in Bt)	Indicated (in Bt)	Inferred (in Bt)	Total	
				In Bt	In %
0-300	73.75	66.63	14.38	154.76	61.09
300-600	6.74	41.41	17.52	65.67	25.93
0-600 (Jharia)	13.71	0.50	Nil	14.21	5.61
600-1200	1.67	11.23	5.76	18.66	7.37
Total	95.87	119.77	37.66	253.30	100
Percentage	37.85	47.28	14.87	100	

Right now, on an average, coal industry is able to extract only about 40% of the underground coal associated with a particular deposit. However, efforts are now directed towards adopting mass production technology for ensuring higher productivity with due regards to safety and conservation.

Full mechanization of underground coal mining operations, introduction of scientific mining in a very planned and systematic manner, and adoption of most appropriate technologies with the best mining practices are liable to produce about 60% of the deposits.

So even from the mines, where application of advanced underground technology would be feasible, at the most 60% of the total energy would be recovered and 40% of the energy would remain untapped and un-recovered forever in coal deposits of those mines.

Thus with best of our abilities and efforts, an optimistic estimate may be that instead of 21%, the extractable reserve would be as high as 30%, and coal industry would be able to recover up to 30% of the total energy available in the coal deposits.

EXTRACTION OF ALMOST TOTAL ENERGY/ SUSTAINABILITY OF COAL ENERGY

However, it is possible to extract or recover almost total energy available in 253.39 BT of coal deposits, in cleaner forms, from underground coal and coalmines, without entering into the mines, from the surface itself, by adopting new technologies and practices, and making fuel and energy production totally safe and environmentally benign.

These new technologies and practices are mainly application of closed-loop fossil fuel systems, in which the carbon rejected in the fuel production or use is “recycled”.

The carbon in plants and fossils buried underground get converted into petroleum, coal, and other fossil fuels with passage of time under high temperature and pressure. The same fossil fuels are the source of CO_2 emissions, which we want to mitigate to save the environment. Using CO_2 sequestration technology, this carbon can be put back in the abandoned and non-extractable underground coal formations, and converted into cleaner fossil fuel using biotechnology.

CO_2 sequestration technology is capture, separation, and storage or reuse of CO_2. It can be stored in many geological formations (sinks) including coal in underground by its injection there. Sequestration of CO_2 in geological formations is an old practice. However, sequestration of CO_2 in coalbeds, with accompanied benefits of enhancing methane recovery, is a new concept and is still under investigation and on trial run.

Application of these concepts is capable of recovering almost all the energy available in the underground coal deposits.

In application with the above, some of the other new technologies and practices need to be adopted. These are collection and recovery of methane emitted during underground coal mining operations and migrated in the working mines from other disturbed strata, extraction of methane emitted from left out coal in abandoned mines and its enhanced recovery by CO_2 sequestration, extraction of methane from non-extractable coal by CO_2 sequestration there, conversion of coal and sequestered carbon dioxide into renewable source of methane using biotechnology (methanogenesis), in-situ coal gasification, etc.

TECHNOLOGIES & PRACTICES FOR SUSTAINABILITY OF ENVIRONMENT

1. Methane from working mines

Methane emits from coal during coal mining operation in each and every mines. It is a hazard and nuisance in underground coalmines, however if it can be collected and produced, it can be a good source of clean energy. Per tonne of underground coal extracted, on an average, produces 4 cubic meter of methane. 50% of this gas can be produced very easily.

When ever coal is being taken out from a particular seam, upper and lower strata of that seam also get disturbed and emit methane. The emitted methane migrates in the working or abandoned mines. In some of the mines like Amlabad, even migration of 200 cubic meter of methane gas has been noticed for every tonne of coal produced. It can be assumed that, on an average, 20 cubic meter of methane with 50% concentration migrates in the working seam for every tonne of coal produced. 50% of this gas can be recovered with ease for energy.

2. Methane from abandoned underground mines

At the most 40% of coal can be extracted from an underground coalmine, and rest of the coal has to be left out there. As work ceases and mines get abandoned, though the rate of gas liberation decreases, but does not stop completely. Following an initial rapid decline, abandoned mines can liberate methane at a near steady rate over an extended period of time, unless it is getting flooded. Thus abandoned mines are source of AMM (Abandoned Mine Methane). For each tonne of coal left out in the abandoned mines, on an average, 4 cubic meter of gas emits, 50% of which can be recovered easily. However, with the help of CO_2 sequestration in these mines, recovery can be enhanced even up to 90%.

Once the rate of gas liberation decreases sufficiently, CO_2 is injected in the abandoned mines. CO_2, which is more strongly adsorbable than methane, gets preferentially adsorbed into the primary porosity system and drives CH_4 from the primary porosity into the secondary porosity system and the CH_4 flows to the mines to get produced. Though the produced quantity of methane would depend on quantity of coal left, gas content and adsorption characteristics of coal, methane flow capacity, time since abandonment, flooding, pressure of vent boreholes and seals, etc., however, recovery can be even up to 90%.

3. Conversion of coal and sequestered CO_2 into methane gas by methanogenesis

Microbial conversion of coal into methane is a continuous, natural, online phenomenon of producing biogenic methane. However, accelerating the rate of in-situ microbial conversion of coal and sequestered CO_2 in coalbeds into methane by injecting right kind of microbes is a new one. Injecting, and optimizing the bacterial colonies, by creating right conditions and providing sufficient nutrients can accelerate the natural process of bacterial generation of methane from underground coal and sequestered CO_2. Since this conversion of coal into biogenic methane will continue for a quite long time, therefore, in-situ coal will act as a renewable source of methane. It may be possible to convert almost the entire in-situ coal into methane in due course of time making possible extraction of almost total energy from underground coalmines. This biogenic methane can be extracted as an additional clean fuel for hundreds of years to come.

Methanogenes, a group of strict anaerobic archaebacteria, produce methane as the final product during methanogenesis. Methanogenes are anaerobic bacteria of the family Archea, and are found in such diverse environments as land fills, digestive systems of animals, in deep ocean vents, and in coal seams.

One tonne of coal, with 70% carbon content, can be converted into about 1372 cubic meter of methane by methanogenesis.

4. **Underground gasification of left out coal**

Underground coal gasification is a technology for utilising underground coal reserves, which cannot be economically extracted by conventional mining techniques. This technology, particularly, would suit to those coal formations where all the above technologies either have been applied separately or in a particular combination to extract maximum possible left out energy in coal, and no further extraction of energy would be possible by using these technologies.

UCG involves the controlled combustion of coal in coal seam by injecting air, or oxygen and steam, down a borehole from the land surface, and collecting the resultant combustion products (gas) from a nearby borehole. Product gas from coal gasification contains methane, hydrogen, carbon monoxide, and carbon dioxide. The gas can be substituted for natural gas in fuel applications for steam generation, dryer, furnaces, and gas turbines but may require burner redesign and modification. Vertical boreholes are drilled into the gallery to act as the injection and production wells. A system of alternating air and steam injection is used to improve the production of hydrogen.

The method is ecologically very favourable, because solid remains of combustion are left in the deposit itself, and would recover every bit of left out energy in coal.

All or any combination of these technologies can be applicable in a particular abandoned mine depending on its geometry and seal, and in the non-extractable coal deposits. By applying these technologies more than double the energy, possible through extraction of coal by conventional mining techniques, can be recovered from a particular coal property or deposit.

These technologies can be applied even to recover more than 10 Million peta joule of energy from non-extractable coal deposits of about 195 Bt. Even, if 50% of non-extractable coal can be converted into biogenic methane in 100 years of time, and even if 50% of that is being recovered using CO_2 sequestration technology, additional 25,000 peta joule of clean energy would be available every year compared to coal & lignite put together produced 6602 peta joule of energy in the year 2003-04, whereas country's total production of conventional energy from primary sources was less than 13,000 peta joule. Application of these technologies in non-extractable coal reserves is capable of revolutionizing the energy scenario of the country.

CONCLUSION

Application of these technologies is not only capable of doubling the per year energy production from a particular underground coal deposit or property, but is capable of recovering more than double the energy, which would have been possible by extraction of coal by conventional mining techniques, from the same property. Extension of these technologies in non-extractable coal is capable of converting coal into a renewable source of methane for hundreds of years to come, and revolutionize the energy production in India, and thus is capable of addressing the energy security concern of the country. Moreover, as the entire energy produced from the coal would be in the cleaner form, the energy extraction and its use would be environmentally sustainable also.

The concept of extraction of energy from coal in this way is new for the entire world. Various agencies, throughout the world, are engaged in mastering this art of extraction of energy from coal. However, as Indian biotechnology is quite advanced, therefore, by putting comparatively less efforts, India is in a position to occupy the front seat in development and application of this technology, as it is occupying in IT.

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