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Integrated Development Of Both Conventional And Unconventional Coal Fuels In India

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Abstract:
The world energy demand is mostly driven by coal. The rising oil prices, mature stage of oil fields with increasing cost in exploration and production of petroleum resources have further fuelled the interest towards integrated studies of coal fuels i.e. Coal, Coal Bed Methane (CBM), Coal to Gas (Underground coal Gasification), Coal to liquid (CTL), Coal Mine Methane (CMM) etc. Prospective coal deposits in India mostly occur in: i) Gondwana lying along five major tectonic lineaments i.e. Damodar- Koel, Wardha- Godavary, Pench- Kanhan, Tawa valley and Rajmahal area; ii) Tertiary coal deposits in Assam, Meghalaya and Arunachal Pradesh; and iii) lignite deposits of Tamil Nadu, Rajasthan and Gujarat. However, the total coal –fuels resources in India are much greater than present conventional approach which permits only utilization of coal from mineable depth. It is rational to view all coal-fuels such as CBM, UCG, CTL and CMM etc for meeting challenges of increasing energy demand in India. The paper presents and discusses an overview of integrated development of coal fuels in India and their resources assessment.

1.Introduction

Coal is rapidly substituting fuel to suffice the growing energy requirement of today's world. It has been playing dominant role for many centuries. Natural gas, coal and oil supply about 85% of the nation's energy, with coal supplying about 53% of the total (fig1). The percentage contribution of coal to the energy supply is expected to increase rapidly for the coming years (fig 2). It fuels almost 40% of electricity worldwide and so the ever existing gap between demand and supply of petroleum resources have further fuelled the interest towards utilization of coal fuels i.e. Coal, Coal Bed Methane (CBM), Coal to Gas (Underground coal Gasification), Coal to liquid (CTL), Coal Mine Methane (CMM) etc. India has abundant coal resources. As per the Geological survey of India and Coal India limited reports India has more than 293497.15 million tonnes coal resources, including 118144.82 million tonnes of proved reserves (the discovered, economically recoverable fraction of the original resources). India is the 3th largest coal reserves in the world. About 99% of the coal reserves of India are found in the Gondwana basins while 1% is within the Tertiary basins (fig 3). The huge potential of coal resources lays in Damodar Valley basins i.e. Jharia, Raniganj, East Bokaro, West Bokaro, Ramgarh, Girdeeh, North Karanpura and South Karanpura and Kamthi in Godavari valley. The coals of Tertiary age are mainly in Assam, Meghalaya, Arunachal Pradesh, Tamil Nadu, Rajasthan and Gujarat and tertiary coals are of lignite to sub-bituminous in rank. Although India has huge coal resources, coal from greater depth are not mineable. Therefore it is rational to study how to utilize the all coal resources i.e. both conventional and unconventional coal resources present in India to bridge the gap between demand and supply.

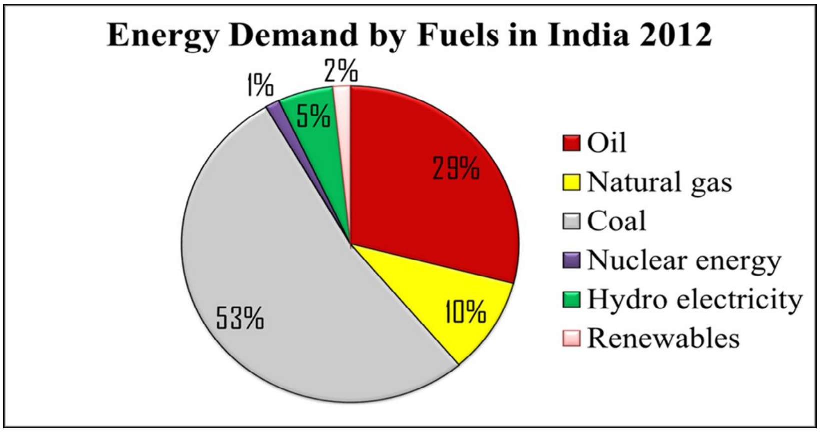

Figure 1: Energy Demand By Fuels In India (Modified From BP Statistical Review, 2012)

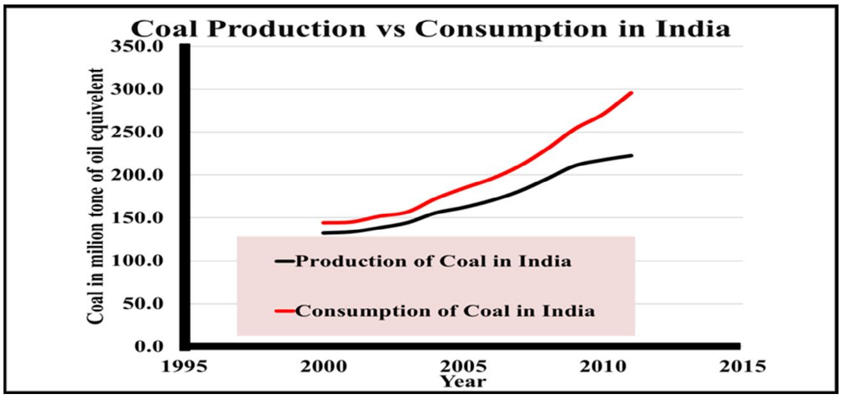

Figure 2: Increasing Trend Of Coal Demand Versus Production In India (BP Statistical Review 2012)

This paper presents the importance of integrated development of conventional and unconventional coal resources to utilize as much as of total coal resources in order to meet the future energy needs of India. It also presents a summary of unconventional coal prospects, and details the environmental considerations related to shale gas development.

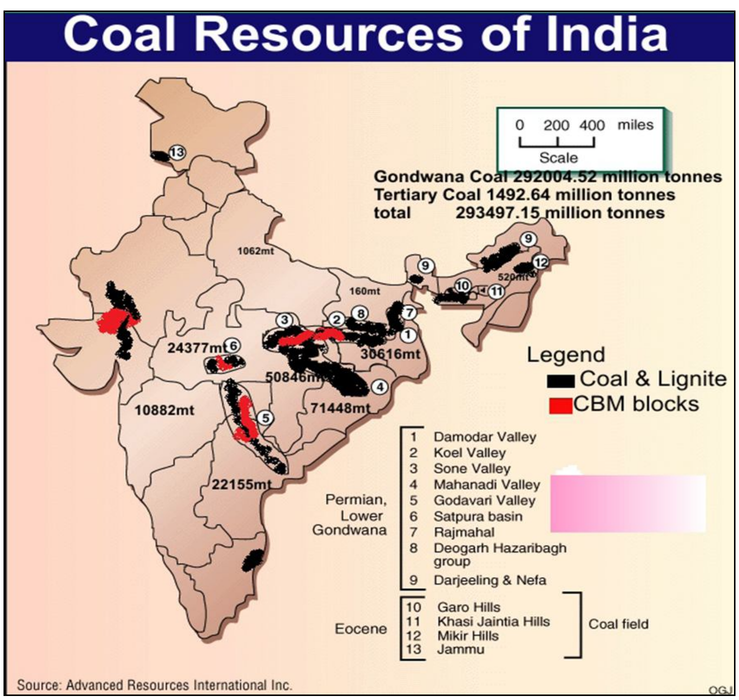

Figure 3: Coal Resources In India (Modified After Advanced Resources International Inc.)

2.Coal As Source Rock And Reservoir

Coal is sedimentary rock. It is classified into three major types namely anthracite, bituminous, and lignite. Anthracite is the oldest coal from geological perspective. It is composed mainly of carbon with little volatile content and practically no moisture. Lignite is the youngest coal from geological perspective. It is a soft coal composed mainly of volatile matter and moisture content with low fixed carbon. Fixed carbon refers to carbon in its free state, not combined with other elements. Volatile matter refers to those combustible constituents of coal that vaporize when coal is heated. The common coals used in Indian industry are bituminous and sub-bituminous coal.

Coal may contain natural fractures that enable some movement of gas. These fractures are caused by pressure from the overlying rock and the natural movements of the earth's crust. Stress loads in the reservoir determine the geometry of the fractures. The mechanisms for gas flow in the coal involves: a) desorption of the gas from the coal surface inside the micro pores; b) diffusion of the gas through the micro pores governed by Fick's law;

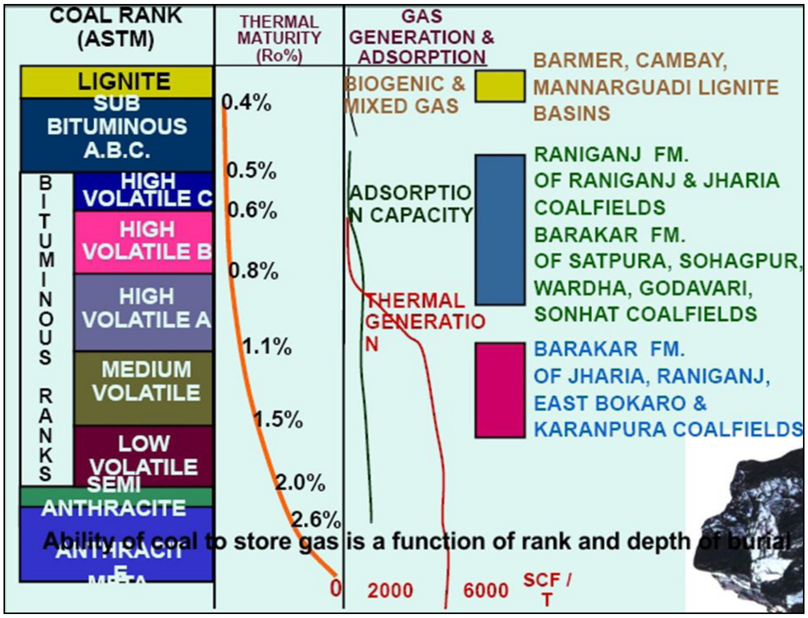

Figure 4: Relationship Between Maturity Of Coal And Gas Generation; Hunt, J.M., (1979)

and c) Darcy flow through the cleat system, natural fracture network in the coal to the wellbore. Gas is produced from coal with natural fractures. Recently, there has been a lot more development of CBM due to the use of techniques that create artificial fractures around well bores. This procedure is known as hydraulic fracturing. Horizontal wells are being used in different basins worldwide to increase the sweep area and sweep efficiency and also to connect maximum natural fractures. Based on the fracture and cleat orientation vertical and horizontal wells are drilled and hydro fracturing is done. Horizontal wells are drilled down vertically to the coal formation perpendicular to the most common fracture orientation, which allows it to intersect a much greater number of fractures.

Natural gas production from gas rich coal formations are known as coal bed methane. The gas generated during coalification process and stored in coal seams in the adsorbed state on the internal surfaces of coal matrix. It forms in two ways i.e. i) during the early stage of coalification when plant detritus turns into coal, ii) as a by-product of bacterial respiration which is biogenic gas. The generation volume of methane is related to volatile matter as well as rank. Gas generation capability of coal is controlled by numerous factors: Optimum depth, thickness of the

prospective coal seam, gas content, thermal maturity, coal chemistry permeability saturation and reservoir pressure. Methane is normally adsorbed in the internal surface of the coal and cannot be easily detected by conventional gas-well drilling technology. Network of naturally occurring micro fractures i.e. cleats which provide the important parameter for flow mechanism in coal. In coal bed methane (CBM) prospect, it is very important to study the cleats as the key of estimating production potential lies in presence of cleat networks or fractures in coal seam (K.K. Roy, 2006) Face cleats and butt cleats (fig 5) are the primary conduits for CBM which are well developed in vitrinite rich coal. Rift related Gondwana basins show a network of faults to induce better permeability. Free from major compressional folding. Sometimes artesian conditions associated with coal beds indicate better permeability for CBM production. Coal seams show vitrinite reflectance of 0.7 to 1.69%, rank suitable for thermogenic methane generation.

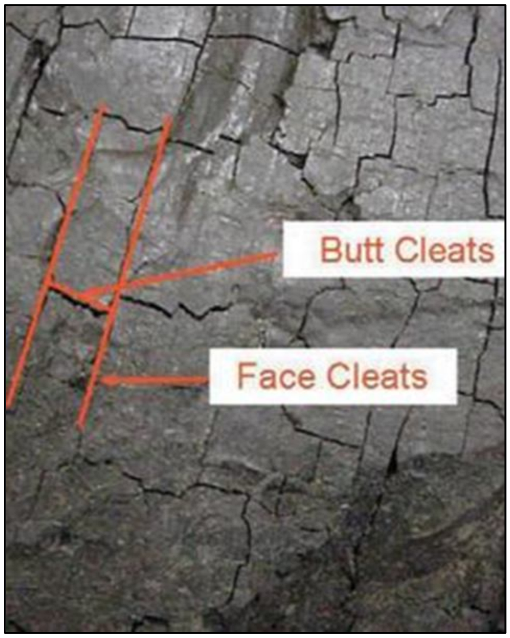

Figure 5: Cleats in coal

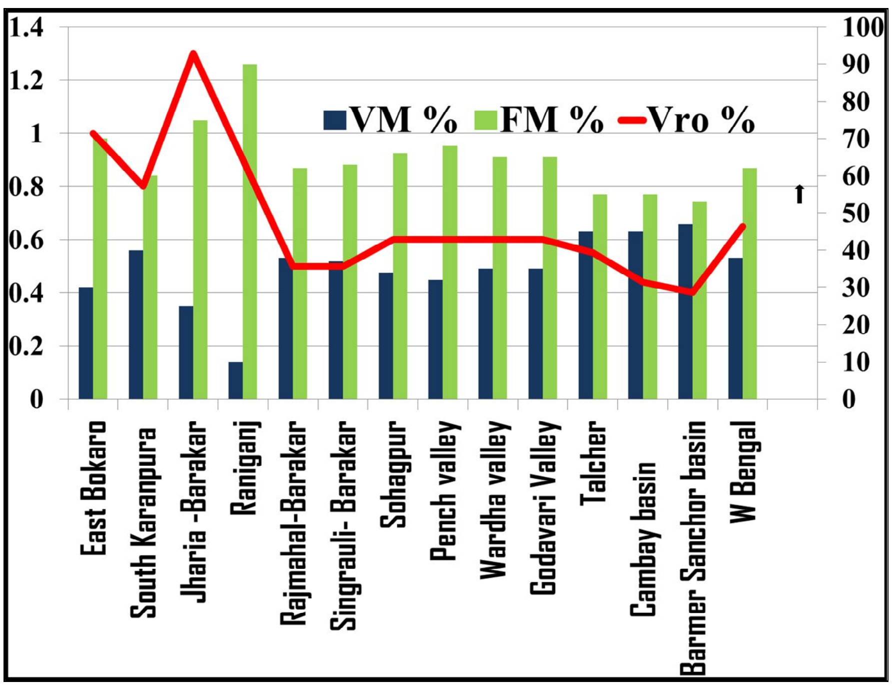

Figure 6: Characters Of Indian Coals

3.Integrated Coal Fuel Development Concept

3.1.Integrated CBM and UCG activities

CBM exploration requires integrated studies of geology, geochemistry, petro-physics, seismic and geomechanics. The parameters to be evaluated mainly are: Structure, Thickness and areal extent of coals, depth of the Coal seam, organic Matter Type and richness (TOC), maturation

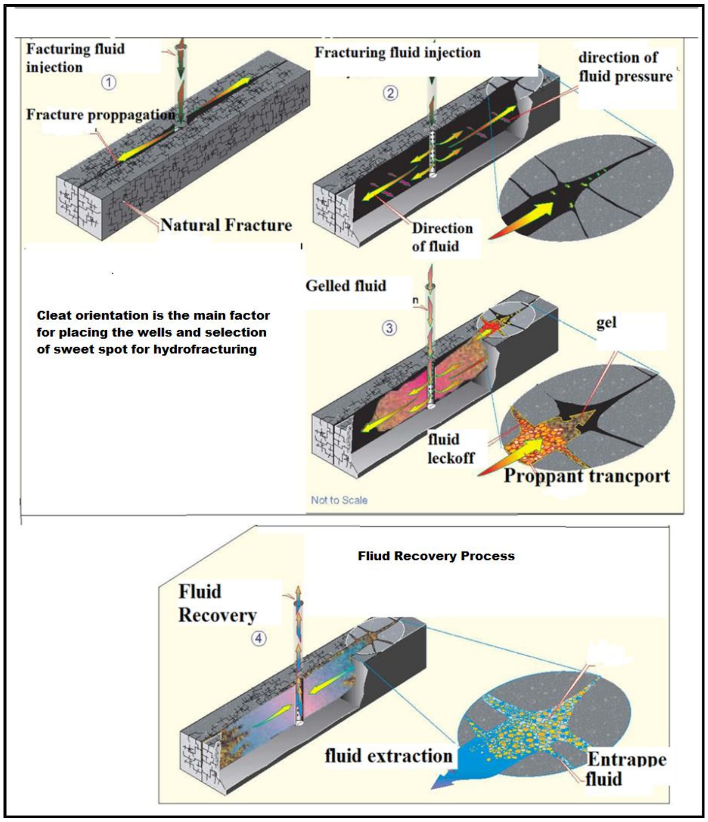

Figure 7: Hydro-Fracturing In Coal Horizon (Modified After Faraaz, 2012)

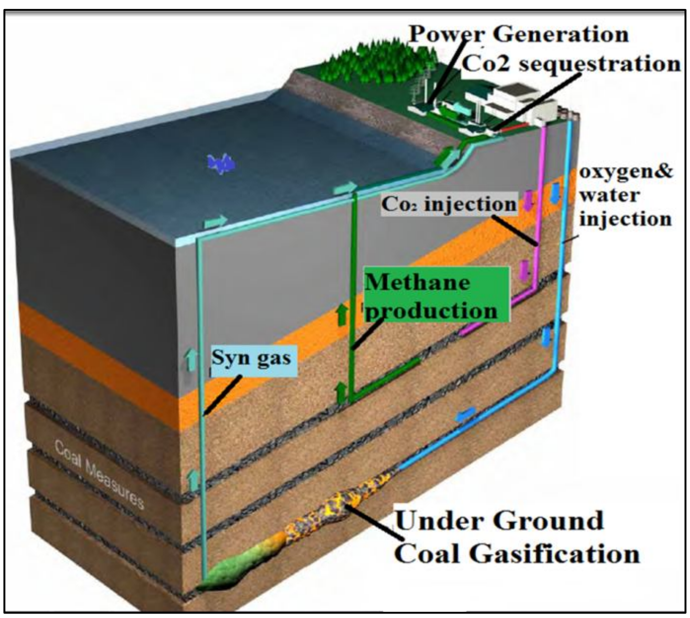

Figure 8 CBM extraction followed by UCG

(R%),density, porosity and permeability, mineralogy, brittleness, and cleats architecture, faults and fractures, pore pressure, stress and orientation, gas-in-place.

The concept of integrated development of both CBM and Underground coal gasification (UCG) is new (A. N.Thakre, 2007) and it requires exhaustive investigation of all parameters mainly geology, depth, technology etc. Horizontal CBM well completion provides pathways for propagation of burning zone of UCG front. Hydro-factures in CBM well creates conduit for UCG front (Fig 8). UCG technologies can be developed by utilizing abandoned coal mines drilling into the gallery, which acts as the production and injection wells (Burton et al., 2007). UCG gasification along a coal seam leaves highly porous cavities and stressed strata in its wake. As these areas cool down, the abandoned cavities can be accessed by directional drilling or through the existing production boreholes. CO_2 would then be injected at high pressure for storage and retention. Unconventional coal fuels development is a technologically driven process. Currently, the drilling and completion of shale gas wells includes both vertical and horizontal wells and the processes of both shale gas exploration and that of coal exploration are almost same.

Carbon sequestration in coal has been studied as a means of removing carbon dioxide, produced by human industrialization, from the atmosphere. CO_2 can be separated from flue gases of power plant and injected into coal bed to replace CH_4. CO_2/ CH_4 adsorption varies depending on the rank of coal. This process requires systematic studies of coal properties, delineation of coal seams.

4.Other Coal Fuels

Coal mine methane is one of the coal fues i.e._all methane release during , after mining and methane capture prior to mining can be captured as coal mine methane which helps in degasification to control methane emission prior to and during drilling. Depending on the gassiness of coal seam and the fractured strata, horizontal /vertical or gob (goaf) vent wells can be used for CMM drainage. Fault, paleo channel, clay veins, changes in permeability facies, coal rank etc are controlling factors of gas emission into working mine. Gas capture and use in coal mines is not new. The first recorded methane drainage occurred in the United Kingdom in 1730. More modern, controlled methane drainage systems were introduced in Europe in the first half of the twentieth century. Utilisation of mine gas for lighting was studied the 18th century and was recorded in the 1880s.By the 1950s, systematic and effective gas capture methods that were originally developed in Germany and which were being used throughout Europe. Since the 1960s, increasing use has been made of drained gas, initially for mine boilers and industrial processes and then later for power generation, pipeline gas. On the other hand Coal-to-liquids (CTL) is a process which generates synthetic liquid fuels i.e. Gasoline and diesel fuel from coal. However the huge amount of carbon dioxide (CO_2) emitted during the CTL process, the emissions can be reduced by carbon capturing and sequestration (CCS) technology in which CO_2 is sequestered in a geological formation.

5.Discussion

Coal rank is arguably the most important factor influencing methane generation in coal beds. It is important to note that coal quality is a combination of rank, grade and type. Rank is explained in more detail below but grade and type are also essential to take into account in order to understand the character of a coal reservoir. Coal grade usually refers to its level of purity and what are the relative amounts of organic and inorganic materials present within a particular coal. Different coal types are distinguished based on the composition of the organic material, which is ultimately related to the original vegetation type, which formed the original peat. Gas holding capacity of coal increases with coal rank. It is related to both a loss in moisture with increasing rank as well as an increase in porosity. However all other variables are also equally important as well as maturity (e.g. ash yield, organic composition) the more mature a coal, the more gas it can hold (Hildenbrand et al., 2006; Kim, 1977). Adsorption isotherm test measures the maximum gas holding capacity of a sample of coal at any particular pressure at a stable temperature. Here usually temperature is maintained as reservoir temperature. In many petroliferous basins (eg- Cambay Basin) Coal Formations are encountered in exploratory and development wells where coal can act as both source and reservoir rocks. It is imperative to combine petroleum exploration with CBM, UCG activities. Moreover, in some geological fields in India like Raniganj coal field, Jharia coal fields and in few fields in Cambay basin are having prospects of both coal fuels and shale gas but there is no licensing policy has established yet for integrated development of all resources together..

6.Conclusion

Methane in coal can occur as biogenic, thermogenic or as a mix of those gas types. The Key reservoir parameters of CBM are permeability and gas in place. Pore surface area, organic composition, quality and maturity, well type and placement are crucial for maximum certification value of coal production. Coal geology and chemistry as well as generation of gas within coal is depends on different parameters i.e. geology, chemistry, maturity, mechanical properties, porosity-permeability, numbers and orientation of cleat systems etc. and these may show wide variations in different coals and even most of the world’s commercial coal and CBM reservoirs exhibit wide range of these parameters. Therefor it requires exhaustive investigation of all prospective coal seams in India. Detail laboratory investigations includes the micro-cleat under UV light, Gas composition and percentages, desorption characteristics, adsorption isotherms study, Permeability and porosity Cleat and fracture pattern, analysis of cleat-filled minerals, quality of adsorbed water etc. Besides, reservoir engineering and modelling, the rock mechanical testing etc. are also to be carried out. Because coal has such a large internal surface area, it can store up to seven times more methane gas than conventional natural gas reservoirs of equal rock volume. Like Shale Gas, Coal Bed methane is also stored in unconventional reservoirs that often act as source and reservoir. Cleats with in coal seams play a major role for successful exploitation of CBM. Latest developments in seismic, drilling and production technologies paved way for successful prospecting of Coal Bed Methane. Technology combined with the economic benefits of the greater reservoir exposure that a horizontal well provides over a vertical well. While both well types may be used to explore the coal resource. Technology is the key to commercial development of unconventional coal resources. Combining CO_2 sequestration in coal bed and enhancing the recovery of CH_4 will make the CBM extraction economically viable with greenhouse gas reduction benefits. It is imperative to frame unified license for conventional coal, shale gas, CBM, UCG, CMM along with CO2 Sequestration .It is essential and rational to develop the all the coal fuels together.

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