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Underground Coal Gasification –a future source of Energy Security

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Summary:

With a targeted GDP growth rate of 7 to 8 percent, and an estimated energy elasticity of 0.80, the energy requirements of India are expected to grow at 5.6- 6.4 percent per annum over the next few years. In spite of various policy initiatives to diversify the fuel mix, considering the limited reserve potentiality of petroleum & natural gas, ecoconservation restriction on hydel project, improvement in technology for harnessing renewable energy and geopolitical perception of nuclear power, it is becoming increasingly evident that coal will continue to occupy centre-stage of India's energy scenario. Indian coal offers a fuel source to domestic energy market for the next century & beyond.

The coal reserves in India are estimated at around 264.53 billion tonnes as on January 1, 2008 out of which 41.28 billion tonnes are recoverable. The lignite reserves are estimated at around 38.93 billion tones out of which only about 5.49 billion tonnes are regarded as "mineable" leaving a large chunk as unmineable. It is therefore prudent to find ways and means to exploit these unrecoverable Coal and Lignite reserves of 256.69 billion tones to meet part of the ever increasing energy demand of the country

At present UCG is the only feasible technology to harness energy from deep unmineable coal seams, in an economically and environmentally clean way. Underground Coal Gasification (UCG) has the potential to convert coal resources to coal reserves. Underground Coal Gasification is a process to convert unmineable coal / lignite into combustible gases by gasifying the coal/lignite in-situ. Subsequently the product gas can be used to generate power, or make urea for fertilizer, or produce ammonia and methanol and their derivatives and / or can be converted into clean synthetic liquid fuels using Fischer-Tropsch process.

1. Introduction

Commercial primary energy consumption in India has grown by about 700% in the last four decades. With a targeted GDP growth rate of 7 to 8 percent, and an estimated energy elasticity of 0.80, the energy requirements of India are expected to grow at 5.6- 6.4 percent per annum over the next few years. This implies a four-fold increase in India's energy requirement over the next 25 years and India faces significant challenges to meet this.

Coal is the most important & abundant fossil fuel in India and accounts for 55% of India's energy need. India's industrial heritage was built upon indigenous coal, largely mined in the eastern and the central regions of the country. Thirty per cent of commercial energy requirements are met by petroleum products, nearly 7.5 per cent by natural gas and 3.5 per cent by primary electricity.

India is, however, poorly endowed with oil assets and has to depend on crude imports to meet a major share of its needs (around 70 percent). A large population of India in the rural areas depends on traditional sources of energy such as firewood, animal dung and biomass. The usage of such sources of energy is estimated at around 155 mtoe per annum or approximately 47 percent of total primary energy use.

Coal has been recognized as the most important source of energy for electricity generation in India. About 75% of the coal in India is consumed in the power sector. In addition, other industries like steel, cement, fertilizers, chemicals, paper and thousands of medium and small-scale industries are also dependent on coal for their process and energy requirements.

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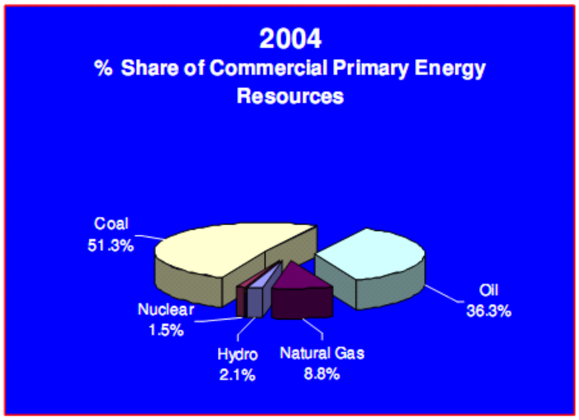
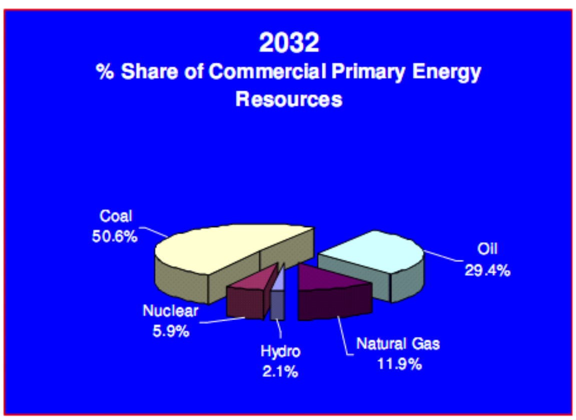




Source: Planning Commission of India, 2006

In spite of various policy initiatives to diversify the fuel mix, considering the limited reserve potentiality of petroleum & natural gas, eco-conservation restriction on hydel project and geo-political perception of nuclear power, it is becoming increasingly evident that coal will continue to occupy centre-stage of India's energy scenario. Indian coal offers a fuel source to domestic energy market for the next century & beyond. Based on estimates, the consumption of coal is projected to rise by nearly 40 percent over the next five years and almost double by 2020.

2. India Energy Scenario

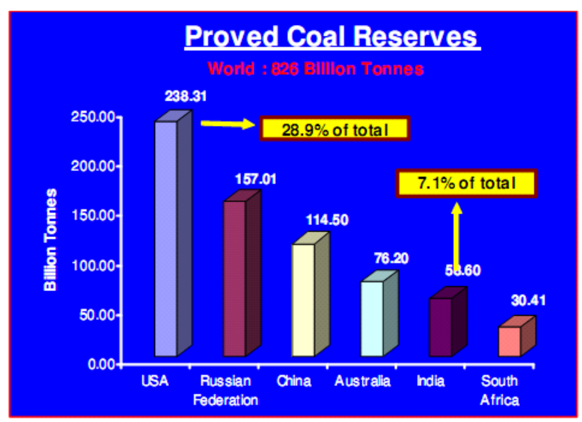
i. Coal

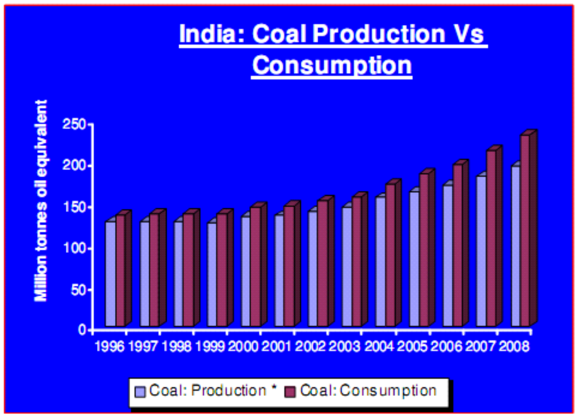
Coal is the most abundant and important fossil fuel of India and accounts for 70% of India's energy need. The coal reserves of India up to the depth of 1200 meters have been estimated by the Geological Survey of India at 264.53 billion tonnes as on January 1, 2008 of which 101.83 billion tonnes are proven.

India has the 4th largest coal reserves in the world and ranks 3rd in coal production. The total recoverable reserves of coal are only about 15.6 % (41.28 billion tones) leaving a large quantity (~223.26 billion tones) of un-mineable coal reserve.

The lignite reserves in India are estimated at around 38.93 billion tonnes, of which 87.5% occur in the southern State of Tamil Nadu. Other states where lignite deposits have been located are Rajasthan, Gujarat, Kerala, Jammu and Kashmir and Union Territory of Pondicherry. Out of the 38.93 billion tones of lignite, only about 5.49 billion tonnes are regarded as "mineable" leaving a large chunk of (33.44 billion tonnes) of unmineable lignite reserve

It is therefore prudent to find ways and means to exploit these unrecoverable Coal and Lignite reserves of 256.69 billion tones to meet part of the ever increasing energy demand of the country.

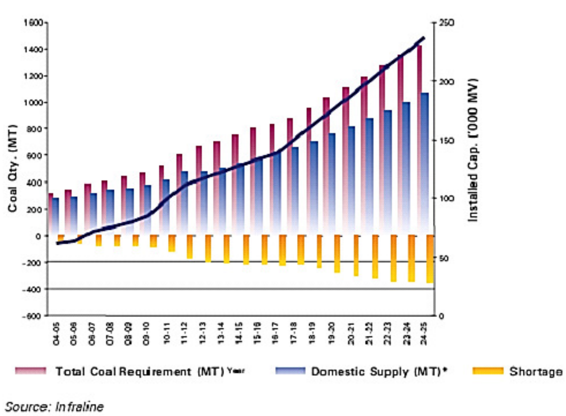




Source: BP Statistical review 2009

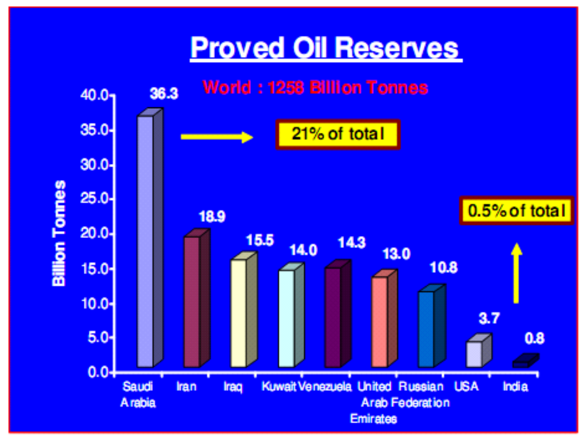
The demand for coal, both planned and unplanned is exerting severe pressure on the supply side. As per the government's own estimates, production will lag behind demand by about 100 MMT as of 2011-12 and by 250 MMT by 2019-20.

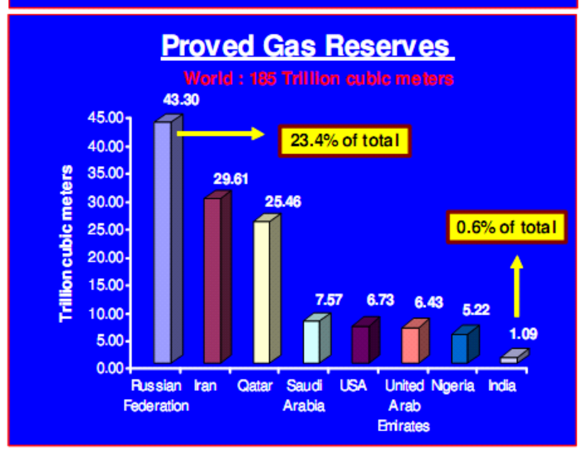
Coal Requirement vs availability



ii. Oil and Gas

The oil sector in recent years has been characterized by rising consumption of oil products, declining crude production and low reserve accretion. India remains one of the least-explored countries in the world, with a well density among the lowest in the world. Demand for oil is expected to grow from 119 MTOE from 2004 to 250 MTOE during 2025 at an annual growth of 3.6 per cent, India is the fourth largest oil consumption zone in Asia, even though on a per capita basis the consumption is a mere 0.1 tonne, the lowest in the region - This makes the prospects of the Indian Oil industry even more exciting.





Source: BP Statistical review 2009

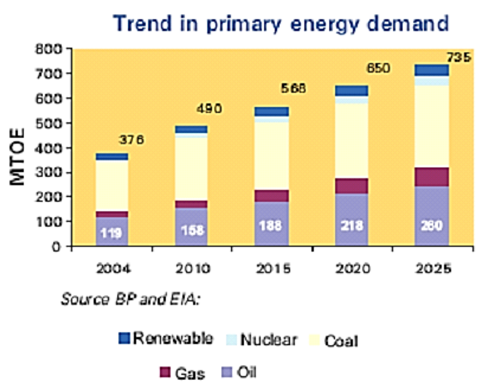
Exploration

India remains one of the least explored regions in the world with a well density of 20 per 10000km^2. Of the 26 sedimentary basins, only 6 have been explored so far.

NELP

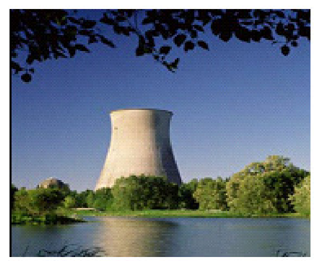
The government in order to increase exploration activity approved the New Exploration Licensing Policy (NELP) in March 1997 which would level the playing field in the upstrem sector between private and public sector companies in all fiscal, financial and contractual matters.

Demand for oil, comprising of 36 per cent of India's primary energy consumption, is expected to grow both in absolute and percentage terms to 196 MMT in 2011- 12 and 250 MMT in 2024-25. To address the growing demand-supply gap, the government has stepped up exploration and production efforts through private participation under the NELP, and has also developed a more holistic strategy for acquisition of equity in oil abroad.



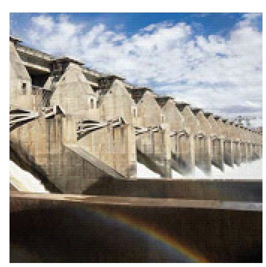
- Demand for oil is expected to grow from 119 MTOE from 2004 to 250 MTOE during 2025 at an annual growth of 3.6 per cent.
- During the same period domestic production from existing developed reserves expected to grow at approximately 2.5 per cent
- The gap in demand and output will catapult India to one of the largest consumers of crude oil along with China. The two countries will account for 35 per cent of the world's incremental energy demand

Per capita consumption of Natural Gas in India is currently amongst the lowest in the world; at 29 cu m as compared with a world average of around 538 cu m. The present share of natural gas in the energy basket is only around 9% in India, compared with a world average of around 24%. However, demand for NG (at more than 120 mmscmd) in the country has far outstripped supply (about 95 mmscmd), and there has been an increasing trend towards emergence of new NG demand as well as conversion from existing fuels to NG. Though India is a new entrant to natural gas (NG), the significance of the fuel can be gauged from the fact that, by 2025, the country is expected to rival both China and Japan in having the largest NG demand in Asia. Demand in each of these countries is expected to be in the range of 350 MMSCMD. More than 50% of NG volume in the country is expected to be as cleaner and cheaper substitutes to petroleum products, with the rest as cleaner substitutes to coal in the power sector. In total, the share of NG in the fuel mix is expected to go up to 22% in 2031-32.



iii. Nuclear Energy

The government is pursuing nuclear energy as a long term strategic alternative to coal. The importance accorded to this segment can be gauged by:
Aggressive targets, including construction of the first Fast Breeder Reactor (FBR) by 2010. Department of Atomic Energy (DAE) has planned to increase capacity to 10,280 MWe by the 11th Five year plan, to 20,000 by 2020 and to 50,000 MWe in 2030.



iv. Hydro

India has a very, large viable and exploitable hydro-electric potential, estimated at around 150,000 MW (84,000 MW at

60% load factor) compared with an installed capacity of 33,941 MW. In spite of having the 5th largest hydro potential in the world, India's utilization is only about 17% when compared with advanced countries having more than 30%. The largest potential for development exists in the Brahmaputra and the Indus basins.

v. Renewable Energy

Renewable Energy Sources (RES) are an important element of India's power policy aimed to meet the power needs of remote areas in an environmentally friendly way. Certain forms of renewable energy sources (such as wind energy, small-hydro and biomass) have taken off. Strong private participation is seen in sectors like wind power, in response to the policy and initiatives.

India has an enormous potential of renewable energy across the various sources as indicated in the table below.

Renewable Energy Sources (RES)	Potential	Existing Installed Capacity
Wind	45,000 MW	~ 7660 MW
Small Hydro (upto 25 MW)	15,000 MW	~ 1850 MW
Biomass power / cogeneration	19,500 MW	~ 950 MW
Solar Photo Voltaic Power	50,000 MW (20 MW / km2)	~ 30 MW Very low exploit.
Solar Water Heating	140 million sq.m	1.5 million sq.m
Urban and Industrial Waste-based power	70,000 MW	~ 34.95 MW
Biogas plants	12 million	3.8 million
Improved Biomass Chulhas (Cook-Stoves)	120 million	35.2 million
Source: Infraline		

3. Energy Security

Increasing pressure of population and increasing use of energy in agriculture, industry and the domestic and public sectors is an area of concern. At the same time, the need to meet energy demand has created huge capital requirements needed for setting up power plants, pipelines, ports, terminals, railway tracks to move fuel etc. As India continues to grow at the rate of 7-8 percent, energy security has become a core focus.

However as fossil fuel sources are finite and running out, considering new forms of energy is the clear alternative left for energy security. But large-scale renewable energy projects will cause widespread environmental damage by industrialising vast swaths of countryside. The amount of land required to produce substantial amounts of power for that renewable energy resources, including wind farms, biofuel crops and photovoltaic solar cells would be huge. It is found that enormous stretches of countryside would have to be converted into intensive farmland or developed with buildings and access roads for renewable energy plants to make a significant contribution to global energy demands.All of these renewable sources of energy are incredibly invasive and aggressive with regard to nature.

According to a study, Hydroelectric energy is the least efficient way of using land to produce power, one square metre on average produces 0.1 watts of hydro electric power whereas for biofules a generator burning biomass requires crops from 250,000 hectares to match the electricity output of a nuclear power station, similarly wind farms generate around 1.2 watts for every square metre of land. Whereas photovoltaic cells covering an area of 150,000 square kilometres would be needed to meet US electricity needs for a year.

Coal has the most widely distributed reserves in the world and is mined in over 100 countries. While scientists believe there are still adequate reserves of coal to serve the world's energy needs for some years to come, the impact of burning coal is environmentally devastating.

Oil and petroleum products supply a third of the primary energy used in the world. Apart from being finite in nature, one of the chief problems with reliance on oil is the difficulty and cost involved in drilling for and gathering it – meaning the cost of wholesale oil is continuing to rise.

Natural gas burns cleaner that the other fossil fuels and produces less greenhouse gases when processed. For an equivalent amount of heat, burning natural gas produces about 30% less carbon dioxide than burning petroleum and about 45% less than burning coal. Scientists suggest that reserves of gas will have been exhausted by 2085.

Nuclear energy is a clean form of energy in that it releases almost none of the CO_2 emissions associated with fossil fuels. While the amount of energy that can be produced through nuclear power is significant, so too are the possible side effects. Disposing of radioactive nuclear waste is a serious issue to consider. Nuclear energy is a controversial source of energy, with the effects caused by nuclear spills such as the Chernobyl disaster having long term and detrimental effects on the environment and human health.

Wind farms are one of the fastest growing green sources of electricity generation, wind power offers a compelling alternative to fossil fuel power, and it's also renewable and emission free. If wind energy were to provide a significantly larger chunk of global energy, then the land needed for wind farms would have a big impact on more and more people's living space. There are also concerns that wind farms offshore interrupt ecosystems and local wildlife.

Transforming naturally occurring light rays into energy is a sustainable source of energy. However there are limitations to the technology that will need improvement so the process is optimized and more efficient - for example, the photovoltaic cells used in the process of solar harnessing only currently absorb around 15% of the sunlight's energy.

To alleviate concerns over energy security, multiple steps need to be taken which include encouraging private sector participation, a more holistic approach towards broad basing its supply base, and improving efficiency in the sector as a whole. The importance of cross linkages between different energy segments and the importance of developing an integrated energy policy to meet the common objective of energy security can not be ignored. Apart from exploring and improving the technology for harnessing the renewable energy, the importance of coal as a sustainable form of energy cannot be ruled out because of the sufficient amount of reserves. But unfortunately a significant part of the coal reserves is left underground as it is not minable with the available technology in the industry; Underground Coal Gasification offers a unique solution for Energy Security.

4. Underground Coal Gasification

At present UCG is the only feasible technology to harness energy from deep unmineable coal seams, in an economically and environmentally clean way.

Underground Coal Gasification is a process to convert unmineable coal / lignite into combustible gases by gasifying the coal/lignite in-situ. The coal reacts with injected air/oxygen and steam to form gases, liquids and ash. Produced gases are mixture of combustible (carbon monoxide, hydrogen & methane) and non-combustible gases (carbon dioxide, nitrogen & un-reacted water vapor).

i. UCG potential

All the 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.

India	Proved	Indicated	Inferred	Total	Extractable	Un-extractable
Coal	101.83	124.22	38.49	264.54	41.28	223.26
Lignite	4.82	26.07	8.03	38.93	5.49	33.44
Total	**106.65**	**150.29**	**46.52**	**303.46**	**46.77**	**256.69**

Coal and Lignite reserved as on 01.04.2008 (source GSI, Coal Wing).

CMPDI broadly assess the extractable reserves considering the formula:

$$\text{Extractable Reserves} = \frac{(0.9*\text{ProvedRes}+0.7*\text{IndicatedRes}+0.4*\text{InferredRes})}{4.7}$$

a. Detailed exploration connotes a confidence level of 90% of the reserves established.
b. Regional exploration establishes the resources in Indicated and Inferred categories. The Association of German Metallurgists and Mining Engineers place a 70% confidence level to Indicated and 40% to Inferred Resources.
c. A study by CMPDI (July, 2001) shows an average Reserves to Production (R : P) ratio as 4.7:1. While the R : P ratio of the individual mine/block will vary widely
(S. Chaudhuri, 1st Asian Mining Congress, 2006, Kolkata, India)

Coal / Lignite Reserves (In billion tones)

It is therefore prudent to find ways and means to exploit these unrecoverable Coal and Lignite reserves of 256.7 billion tones to meet part of the ever increasing energy demand of the country. In this endeavor a good part of the un-mineable Coal and Lignite deposits can be extracted by using underground coal gasification (UCG).

One tonne of coal has potential to generate approx.2500 m3 of syn gas

If we consider only 10% of un-extractable coal and lignite reserves as amenable for UCG i.e. 25.7 BT, total **64.17 trillion m3 UCG syngas** potential of **calorific value 3 – 5 MJ / m3** is available. This is equivalent to 6.17 Trillion m3 of Natural gas

ii. Key applications of Underground Coal Gasification

Historically the syngas produced from UCG was used as fuel gas / town gas in Former Russian states and China. However, recent research and development in technology has shown that it can be used for ammonia / fertilizer production, power generation or transportation fuel synthesis. It will not only result in significant economic benefits but also unlock the potential of coal which is un-mineable. In the ultimate clean coal form, syngas will lead to efficient capture of CO^2 and prove to be an enabler for the eventual shift to Hydrogen, the most promising energy carrier of the future.

a) Power

IGCC plants that combine gasification with a CCGT (Combined cycle gasification technology) are gaining ground in other countries mainly on environmental considerations. However for Indian conditions, IGCC plants, unless used in conjunctions with other high value applications such as chemicals may prove expensive compared to conventional Pulverised Coal technology.

Potential
UCG Syngas required for generation of one MW of power = 71428 m3/day

(Considering 2500 m3 natural gas /day required for one MW power generation, UCG syngas is with one tenth of calorific value of NG and 35% efficiency in power generation)

Therefore with the available **64.17 trillion m3 UCG syngas**, **49000 MW power can be generated for 50 Years.**

b) Urea for Fertilizer

In the longer term, fuel for urea will be switched over to Natural Gas. With no committed supply assurance of Natural Gas, Syngas from Underground Coal Gasification can be an alternative as a feed stock.

c) Chemicals (Ammonia and Methanol)

Two notable uses of syngas are in producing ammonia and methanol and their derivatives. Natural gas based methanol plants are of small size. Syngas from UCG provides good options for producing these valuable chemicals without getting exposed to international feedstock price fluctuations.

d) CTL:

Syngas from UCG can be used as a feed stock for CTL for production of clean synthetic liquid fuels using FischerTropsch process. The syngas is converted into liquid hydrocarbons, through a catalytic reaction using cobalt as catalyst by Fischer-Tropsch (F-T) Synthesis. The recent South Africa and Australia trials have shown that UCG Syngas can be converted into clean liquid fuel.

5. Efforts by ONGC for implementation of UCG

ONGC has taken Skochinsky Institute of Mining, Russia, world's foremost leaders in UCG Technology, as its technical collaborator. ONGC is working in partnership with a number of leading Coal / Power companies in this project viz. CIL, NLC, SCCL, GMDC and GIPCL. Fifteen different probable sites in India in the states of Maharashtra, West Bengal, Jharkhand, Andhra Pradesh, Gujarat, Rajasthan and Tamil Nadu have already been studied for suitability to UCG. Based on results of detailed analysis of exhaustive geological, geo-hydological and geomechanical data, some sites have been identified for further studies and five sites have been found to be suitable for UCG. One site in South Gujarat is likely to have the first UCG pilot by the end of 2010.

6. Conclusion

- India is estimated to grow at a targeted GDP growth rate of 7 to 8 percent, consequently the energy requirements of India are expected to grow at 5.6- 6.4 percent per annum over the next few years.
- With limited reserve potentiality of petroleum & natural gas, eco-conservation restriction on hydel project, improvement in technology for harnessing renewable energy and geo-political perception of nuclear power, it is becoming increasingly evident that coal will continue to occupy centre-stage of India's energy scenario.
- UCG is the only feasible technology to harness energy from deep unmineable coal seams, in an economically and environmentally clean way.
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