COAL – AN ENERGY SOURCE FOR PRESENT AND FUTURE

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ABSTRACT

The technological advancement would be an important element for future energy strategy of the country, as it is related to a range of future demand and supply scenario. The issues of technological choices both on the supply and demand sides need to be understood at this stage, since they are to become an important part of India’s energy solution in the future. India has aimed to achieve an economic growth at a rate of over 8% in the next two decades in order to be able to meet its development objectives. However, rapid economic growth would also imply the need for structural changes in the economy as well as for induced shifts in the patterns of end use demands. To meet the needs of the Indian populace in the most effective manner, it is not only important to map out the energy demand and supply dynamics in the country but also to utilize the available fuels efficiently and economically. It is observed that coal would continue to account for 50% of the energy mix, with around 70% being used by the power sector. Hence coal industry has to take up this challenge to achieve the goal.

Coal is considered to be a non-renewable energy source and its resources are finite. And as such the same have no part in sustainable development. This view overlooks the ability to substitute one form of capital for another. To the extent that substitution at the margin is possible, depletion of one type of capital is consistent with sustainability if offset by an increase in other types of capital. Therefore, the use of coal is consistent with sustainable development if, while meeting our present needs, it produces new capital and options for future generations – such as infrastructure, new technologies and new knowledge. An associated risk is that coal’s use may degrade natural capital, such as the environment to an unacceptable or irreversible extent, leading to unsustainable development. From a sustainable development perspective it is instructive to reflect on coal’s role at the start of industrial society and subsequently. Apart from their inherent practical limitations at that time, supplies of biomass, wind and water were limited. Coal being abundant and available, new technology allowed it to be used for steam raising and iron making. The environmental consequences of rapidly growing and uncontrolled coal use were, of course, unacceptable. However, continual
technology development over time allowed coal to be used with much greater efficiency and with greatly reduced environmental impact.

In this paper, the stress is given to study the current energy scenario and efforts made by coal industry (e.g. CIL & WCL) to get prepared to face present & future challenges of supply & demand on affordable price with due consideration to conservation and safety of human and nature as a whole.

1. INTRODUCTION

“Sustainability” in simple words can be defined as “Better living for all”. In the similar way, we can define “Sustainable development” in reference to environmental, economic and social well-being for today and tomorrow.

Sustainable development has been defined in many ways, but the most frequently quoted definition by World Commission on Environment and Development (WCED) Our Common Future, also known as the Brundtland Report is as under:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

The concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and

The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

Power, steel and cement are three basic needs involved in development of country and coal is required to produce all these three. Coal plays a vital role in sustainable development. The coal is a non-renewable source of energy (including electricity). As for non-renewable resources, like fossil fuels, their use reduces the stock available within the earth for future generations. But this does not mean that such resources should not be used. In general the rate of depletion should take into account the criticality of that resource, the availability of technologies for minimizing depletion, and the likelihood of substitutes being available. By mining, the land should not be degraded beyond
reasonable recovery. With fossil fuels, the rate of depletion and economy of use should be calibrated to ensure that the resource does not run out before acceptable substitutes are available. Sustainable development requires that the rate of depletion of non-renewable resources should foreclose as few future options as possible.

2. INDIA’S ENERGY SCENARIO

Coal is a source of energy since Homo sapiens and use since 3000 years in China to smelt copper. The coal is used since Stone Age for heating and cooking. It was mined commercially first in Virginia in 1740. In 18th century James Watt invented steam engine using coal as prime mover. After Industrial revolution, in 1880 coal was used for electricity generation. Coal is the world’s most abundant and widely distributed fossil fuel with reserves of all types of coal estimated to be about 990 billion tonnes, enough for 150 years at current consumption rate. The largest deposits are in the region such as China, India and United States and are mostly used for power generation. Coal fuels 42% of global electricity production and is likely to remain a key component of the fuel mix for power generation to meet electricity demand, especially the growing demand in developing countries.

The historical facts regarding Indian coal mining industry after independence is as under:

1947 - Power Generation was 1500 MW with coal production of 30 Million Te
1956 - NCDC formed & by 1960, Coal production reached to 60 Million Te
1975 - Coal India Limited was established

Main purpose of nationalization was to stop unplanned coal production and unethical practices prevailing prior to nationalization of coal mines and increase coal production efficiently by systematic and scientific manner with due consideration to quality, safety and conservation of environment.

Sector-wise coal consumption in India for the year 2010-11 in respect of major consumers is as under: Electricity- 70%, Steel- 7% Cement- 3%, others- 19%

The statistics showing the Sources of electricity generation is as below:

Thermal-80.83%, Nuclear- 3.69% Hydro- 14.88%, Import- 0.60%
(Source: Annual report, Ministry of coal)

Power, steel and cement are the three main sectors consuming coal i.e. about 80% of total production.

(1) Power Sector:
India has emerged as the third largest coal producer in the world after China and USA. With global total coal production of 6.2 Billion te, the share of China, USA & India is about 51%, 15% and 9% (8.7%), respectively. About 75% of global hard coal production is from these 3 countries. India is the world’s fifth largest energy consumer, accounting for 4.1% of the global energy consumption. Maharashtra is the leading state in electricity generation. The current per capita consumption of
energy in India is 0.5 toe against the global average of 1.9 toe, indicating a high potential for growth in this sector. Of the total electricity consumed in the country, approximately 80% is produced from coal i.e. Coal plays a vital role in Indian current energy scenario.

Position of Electric Power Generation (in MW) in India (As on Aug’2014)is as under:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Coal</th>
<th>Gas</th>
<th>Diesel</th>
<th>Total</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>Res</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>46525</td>
<td>7066</td>
<td>0</td>
<td>53591</td>
<td>4780</td>
<td>10622</td>
<td>0</td>
<td>68993</td>
</tr>
<tr>
<td>State</td>
<td>55290</td>
<td>6974</td>
<td>602</td>
<td>62867</td>
<td>0</td>
<td>27482</td>
<td>3803</td>
<td>94153</td>
</tr>
<tr>
<td>Private</td>
<td>50495</td>
<td>8568</td>
<td>597</td>
<td>59660</td>
<td>0</td>
<td>2694</td>
<td>27888</td>
<td>90242</td>
</tr>
<tr>
<td>All India</td>
<td>152310</td>
<td>22607</td>
<td>1199</td>
<td>176118</td>
<td>4780</td>
<td>40798</td>
<td>31692</td>
<td>253389</td>
</tr>
<tr>
<td>% age</td>
<td>60.11</td>
<td>8.92</td>
<td>0.47</td>
<td>69.50</td>
<td>1.89</td>
<td>16.10</td>
<td>12.51</td>
<td>100.00</td>
</tr>
</tbody>
</table>

(Res. Includes Small Hydro (3804), Wind Power (21136), Solar (2132), Biomass (4014), Waste (107))

From above statistics it is seen that coal constitutes major share i.e. over 60% in India’s power generation and in near future the coal will have its prominent share.

**Private - Coal Industry structure**

Currently, the government enjoys a monopoly in producing coal with over 90% of the production coming from government-controlled mines. The policy for captive mining was introduced in 1993. This opened the coal sector to private investment, although no promising progress has been made in the captive coal blocks allotted by the government. Out of the 200 allocated blocks (22 have been de-allocated), only 30 mines could commence production due to various reasons. The combined production from these was merely 36.30 MT in FY 2010-11 against a target of 104 MT. Contentious issues, availability of geological data, land acquisition and R&R, environment clearances, mining lease, etc. are the primary reasons behind the dismal production. Currently, coal block auction is proposed and detailed mechanism is being formulated for transparency and efficient processing.

(2) **Steel sector**

Coal is an essential input in the production of steel. In 2011, the world crude steel production reached 1,518 MT, reflecting a growth of 6.2% over 2010. The per capita finished steel consumption in 2011 is estimated at 215 kg for world and 460 kg for China, while that for India it is estimated currently at 55 kg (provisional). This clearly indicates scope for increasing the per capita steel consumption, a factor which correlates to the coking coal availability and production within the country. India has very limited reserves of coking coal which is a key raw material for the production of steel. Coking coal accounts for only 15% of the country’s overall proven coal reserves. The Jharia coalfield, located in the state of Jharkhand, holds the majority of the coking coal reserves. The Indian steel industry has been facing acute shortage of coal for the last several years. As per the report of the Working Group of Coal and Lignite for the 12th Five Year Plan, the steel production by 2016-17 is projected to be 105 MT. The corresponding requirement of coking coal for this quantity of steel is worked out at 67.2 MT in 2016-17. About 770 kg of coal is required to produce 1 tonne of steel.
(3) Cement sector

Cement is made from a mixture of calcium carbonate (generally in the form of limestone), silica, iron oxide and alumina. A high-temperature kiln, often fuelled by coal, heats the raw materials to a partial melt at 1450°C, transforming them chemically and physically into a substance known as clinker. This grey pebble-like material is comprised of special compounds that give cement its binding properties. Clinker is mixed with gypsum and ground to a fine powder to make cement. Coal is used as an energy source in cement production. Large amounts of energy are required to produce cement. It takes about 200 kg of coal to produce one tonne of cement and about 300-400 kg of cement is needed to produce one cubic meter of concrete (World Business Council for Sustainable Development).

India is the second largest producer of cement in the world. Large amount of energy is required during the production of cement and coal is used as an energy source. Cement industry is power intensive and about 120 kwh of power is required to produce one tonne of cement. The cement industry is the third largest consumer of coal in the country. Due to the high cost and inadequate availability of oil and gas, coal is used as the main fuel in the industry. However, in the last few years due to rapid adoption of the dry process, the specific consumption of coal for producing cement has reduced significantly. It has also improved efficiency in cement kilns and increased the use of fly ash (produced in power plants) and granulated slag (produced in blast furnaces of steel plants) in the production of cement (Coal Vision, 2025).

3. PROBLEMS ASSOCIATED WITH COAL MINING

There are variety of problems associated with mining operation & use of coal.

Mining operations are hazardous. Major mine hazards include roof falls, rock bursts, and fires and explosions. The latter when flammable gases (such as methane) trapped in the coal, are released during mining operations and accidentally are ignited. Also, the repeated inhalation of coal dust over extended periods of time can result in serious health problems—for example, black lung. Coal mines and coal-preparation plants have caused much environmental damage. Surface areas exposed during mining, as well as coal and rock waste (which were often dumped indiscriminately), weathered rapidly, producing abundant sediment and soluble chemical products such as sulfuric acid and iron sulfates. Nearby streams became clogged with sediment, iron oxides stained rocks, and “acid mine drainage” caused marked reductions in the numbers of plants and animals living in the vicinity. Potentially toxic elements, leached from the exposed coal and adjacent rocks, were released into the environment.

A. Main Problems associated with coal as under:
(i) Widening the gap between demand and supply
(ii) Deteriorating quality
(iii) Inefficiency in production
(iv) Socio-environmental condition continued to deteriorate, ineffective enforcement

Above problems are cropping up and they are not merely due to non-availability of the coal reserves, technologies and workforce to implement but it needs overall wisdom and wider perspective at both coal producer’s and user’s end. The quality of coal is inherited as per its geology which cannot be changed. However proper care has to be taken during planning, production and dispatch with due consideration to safety and conservation at producer’s end. On other hand the user has to use the technologies suitable for the available quality of coal to get optimum output.
B. Environmental Problems associated with coal mining:

1. Destruction of forest and biodiversity
2. Air pollution
3. Land degradation
4. Stress of water resources

Both Underground and opencast types of coal mining are affecting the environment. The opencast mines normally cause extensive and more visible impacts on the surrounding landscapes than underground mines, primarily due to the huge amounts of waste and overburden dumped around the mines and the damage forest, biodiversity, land, water resources, scenery etc. by the surface operations themselves. Noise and vibration also disturb the surrounding environment, and therefore it is necessary to place a safety zone around the mine pit to protect from pollution.

5. COAL - RESERVE, REQUIREMENT, PRODUCTION

In reference to India, the estimated reserve of coal is 286 Billion Te (IBM-2012) up to 1200 meters depth which will be sufficient to meet India’s demand for at least next 100 years. But mining of coal currently or in near future is not likely to go beyond 300 meter deep. It is estimated that the coal reserve i.e. reserves that can be economically mined by current technology and the prices, only 44 billion te (Chikkatur et al 2009) can be mined and this estimated reserves will exhaust in next 30 – 60 years on the current rate of production. Therefore, till any viable substitute is not found out, Coal would continue to play a key role in meeting the country’s energy requirements. The indigenous availability of coal is expected to plateau in the next couple of decades with the current exploitation plans and technology.

The country’s coal production has increased from 431 MT in 2006-07 to 554 MT in 2011-12 (an increase of 28.5%). On the other hand, the demand for coal has grown at a CAGR of more than 7% in the last decade and has reached around 600 MT. The India Energy Book, 2012 pegs the country’s total demand-supply gap (incl. coking coal) at about 98MT. Out of this; India imports about 85 million tonnes of coal.

Coal accounts for over 50% of India's commercial energy consumption and about 70% of domestic coal production is dedicated to power generation. The inventory of Coal in India are estimated to be about 0.8% of the Global Coal reserves, whereas its production contribution is around 7%. Presently, about 90.72% of CIL's production comes from Opencast Mines.

Western Coalfields Limited (WCL) is one of the Eight Subsidiary Companies of Coal India Limited, contributing about 8.19% of the national coal production as against its proved reserve of 7193.48 Million Te which is mere 6.30% of all India. There has been a phenomenal growth in coal production of WCL from a level of 6.53 Million Tonnes in 1973-74 to 43.65 Million Tonnes in 2010-11. There are total 83 mines situated in ten command Areas of WCL (Opencast: 38, Underground: 43, Mixed (OC+UG): 02). The overall man productivity (output in tones per man shift) of WCL has increased from a level of 0.70 Tonnes to 2.65 Tonnes during the period 1973-74 to 2010-11.

In the last two decades, coal mining in India has witnessed a phenomenal growth in production from 75 million Te in 1971-72 to 429 million Te in 2005-06 and has touched about 490 million Te (including lignite) during 2007-08. Coal Vision 2025 estimates the demand of coal for future up to 2024-25 for the different sectors based on the forecast made by TERI considering the coal demand and the change in the GDP. The adopted approach indicates that the overall growth in coal demand is expected to be 5.62% with 8% GDP growth scenario and 5.04% with 7% GDP growth. Sector-wise coal demand as assessed with the above approach for the two scenarios are given in the table below:
Requirement of coal as per Five Year Plans

<table>
<thead>
<tr>
<th>Consumer</th>
<th>Terminal year of five yearly plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Growth</td>
<td>7% 8%</td>
</tr>
<tr>
<td>Power utilities</td>
<td>317 412.69</td>
</tr>
<tr>
<td>Power Captives</td>
<td>43.26 44.33</td>
</tr>
<tr>
<td>Steel</td>
<td>42.70 53.13</td>
</tr>
<tr>
<td>Cement</td>
<td>25.40 38.40</td>
</tr>
<tr>
<td>Others</td>
<td>59.82 62.52</td>
</tr>
<tr>
<td>Total</td>
<td>473.18 611.45</td>
</tr>
</tbody>
</table>

Production from Underground / Opencast mining:
Actions have been taken for Technology up gradation for Coal Production at Underground Mines and Opencast Mines. Usually, after a mineral deposit has been discovered, delineated, and evaluated, the most appropriate mining method is selected based on technical, economic, and environmentally accountable considerations.

The trend of coal production (1974-75 to 2010-11) from opencast and underground mines is shown in following graph:
In above graph, the production from underground mines is showing downward trend and the same is compensated by the opencast mines. The first step in selecting the most appropriate mining method is to compare the economic efficiency of extraction of the deposit by underground mining / opencast mining methods. The choice of mining method is largely determined by the geology of the coal deposit.

A brief comparison is made with respect to the advantages and disadvantages of various mining methods. Open cast mining is the most common method for large-scale operations, whereas underground mining is generally the most effective for small-scale operations. Larger mines offer higher productivity and lower operating costs than smaller mines. Furthermore, open cast mines, typical of larger operations, have much higher normal productivity and lower unit operating costs than for comparable underground mines. However, the productivity and operating cost of an underground mine are heavily dependent on the mining method employed, the rock conditions, the quality and economic value of the coal, and the degree of automation/mechanization amongst other factors. Opencast mines have very few limitations on the operation of large machines with high capacity, whereas underground operations are considerably restricted by narrow working spaces and rock conditions. Moreover, less commuting time is required at opencast mine, whereas much longer time is consumed by transportation in an underground mine because of the typically long distance from the mine entry to the working face. Thus, more net working hours are available at surface mines, which results in higher production rates per employee. Therefore, production rates per employee for open pit mines are superior to those of underground mines.

A number of opencast mines operate 24 hours/day and almost 365 days/year in order to use opencast machinery for as many hours as possible, thereby reducing the number of machines required. In contrast, underground operations are often interrupted by the need for maintenance in addition to nonproductive hours required for commuting and evacuation from blasting and explosives gases. Consequently, higher utilization of equipments and miners is usually difficult in underground mines, and higher capital per ton of coal is also required. Furthermore, it is not uncommon for underground miners to be paid more per hour than a worker doing a similar job on the surface. For these reasons, in conjunction with the better productivity and time utilization of surface operations, the labor cost per effective working hour in underground mines is much higher than on the opencast. Underground mines also require additional energy and expenditure for ventilation, transportation to the surface, pumping, and lighting etc. Surface mining is generally considered to provide better recovery, grade control, flexibility, safety, and working environments than underground mining.

Due to advance technology and education/skill, the injury rates have declined both in surface and underground mines. However, the total number of injuries per one million employee-hours for underground coal mines is higher than for opencast mines. The difference between the injury rates per one million tons of coal production further demonstrates this point – underground mining is less favorable and accidents in underground mines are more serious than for opencast mines.

A. Underground Mining: Methods, Mechanization & Technology

Keeping in view the objective of phasing out manual loading, all coal companies shall identify appropriate technology suitable for the prevailing geo-mining conditions and introduce the same in such a manner so as to phase out manual loading operations completely within a period of five years in coal seams with gradient of 1 in 5 or less, and within a period of seven years in coal seams with gradient steeper than 1 in 5. While formulating the strategies for face mechanization in underground workings, it shall be ensured that back up facilities like coal evacuation, support system, ventilation arrangements etc. are compatible with face mechanization. The schemes of face mechanization are based on proper scientific investigation. The schemes also include arrangements
for monitoring strata behavior and environmental conditions. Following actions / technologies required for underground mechanization:

1. Phasing Out of manual loading by mechanized loading at coal face.
2. Use of mass production technology like continuous miners – shuttle car at coal face.
3. Increase in powered support long wall (PSLW) in dipper horizon.
4. Introduction of short wall mining with powered support to extract already developed pillars.
5. Use of road headers for faster development of headings.
6. Replacement of conventional bolting by mechanized roof bolting machine.
7. Transport equipment like Chain conveyors, Belt conveyors for underground coal transport.

Possibility of deployment of multi-skilled miners in the face has to be explored to reduce the exposure at hazardous area without affecting employment. Suitable training for efficient & safe operation of machinery is imparted to all concerned. While planning for face mechanization, due considerations has been given for long term sustainability of the technology. A policy document has framed by each coal mining company for addressing the implementation issues. It has also been ensured that all safety precautions are incorporated in the policy document as it is the single major contributing cause of underground accidents.

There has been concerted effort for introduction of new technology and technology upgradation not only in the sphere of exploration and exploitation but also in other spheres like Safety and Conservation, beneficiation etc. The major areas for technology upgradation are – Underground Mining; Opencast Mining; Coal Handling Plant; Mining Electronics.

Technology upgradation at Underground mining: The mining methods & associated technologies in vogue in UG mines of CIL are as under:

(1) Conventional Board & Pillar (B&P) system with manual loading of coal onto tubs.
(2) Semi-mechanized B&P system with loading by Side Discharge Loaders (SDLs) or Load Haul Dumpers (LHDs) or mechanized drilling by Universal Drilling Machines (UDMs).
(3) Mechanized Bord & Pillar/ Room & Pillar system with Continuous Miners (CMs).
(4) Mechanized Powered Support Longwall (PSLW) mining system.
(5) Methods with hydraulic stowing technology in conjunction with sand or alternative filling.
(6) Special methods (i.e. site specific methods), like Blasting Gallery (BG) method, Cable bolting method, wide-stall method, steep mining methods, etc.

Technology-wise break-up of underground coal production in CIL (2011-12) is shown in the following Figure:

- Bord &Pillar Intermediate Technology 32.31, 85%
- Roadheader 0.32, 1%
- PSLW 0.18 , 0%
- Highwall 0.15 , 0%
- Continuous Miner 1.79 , 5%
- Conventional B&P (& others) 3.54, 9%
B. Special Methods for mining:

Some ‘Special Methods’ with specific technology application in one or more mining operations or specific seam conditions, which have found application in CIL mines are:

(i) Short wall Mining with reduced face length
(ii) High pressure water jet mining (Hydro-mining) for winning of coal
(iii) Integrated sub-level caving for thick seams
(iv) Short longwall method for extraction of standing pillars
(v) Jankowice Method (for Steeply dipping seams)
(vi) Sub-level caving (retreat) (for Steeply dipping seams)
(vii) Scraper assisted chamber method (for moderately dipping seams)
(viii) Highwall (HW) mining (actively under consideration in one CIL block)
(ix) Underground Coal Gasification (UCG) for coal/ lignite deposits which are conventionally not workable (actively under consideration in three CIL blocks).

The technologies for extraction of resources by underground mining in geologically disturbed areas and deep seated coal resources will depend primarily on the intensity of geological disturbances and depth of occurrence. The prevailing technologies will also find their applicability in most cases with or without modifications.

The technologies used at the underground mines in reference to WCL are as follows:

(1) Bord & Pillar Mechanization by SDL, LHD, Continuous miner:

In room-and-pillar mining, coal deposits are mined by cutting/driving a network of 'rooms/boards' into the coal seam and leaving behind 'pillars' of coal to support the roof of the mine. These pillars can be up to 40% of the total coal in the seam - although this coal can sometimes be recovered at a later stage. Loading: In early days, Coal production was done manually i.e. basket loading with the help of picks. In beginning manual cutting was phased out by solid blasting and coal cutting machines. Now coal cutting machines have been phased out and these have been replaced by Side Discharge Loaders (SDLs) and Load Haul Dumpers (LHDs). Continuous Miner is working at Tandsi UG Mine of Kanhan Area. It produced 0.124 Million Tonnes of coal during 2010-11. It is also working at Kumberkhani UG mine of Wani North Area. It produced 0.083 Million Tonnes of coal during 2010-11. There is a fleet of mining equipments deployed to enhance the production at
underground mines in WCL i.e. 72 SDLs, 117 LHDs and 2 Continuous Miners are in operation at both development and depillaring districts in underground mines.

(2) **Powered support Long wall (PS LW) Mining**

Long wall mining involves the full extraction of coal from a section of the seam, or 'face' using mechanical shearers. A long wall face requires careful planning to ensure favorable geology exists throughout the section before development work begins. The coal 'face' can vary in length from 100-350m. Self-advancing, hydraulically-powered supports temporarily hold up the roof while coal is extracted. When coal has been extracted from the area, the roof is allowed to collapse. Over 75% of the coal in the deposit can be extracted from panels of coal that can extend 3km through the coal seam. At Pathakhera Area one PSLW is working.

(3) **Mass Production Technology: (Proposed)**

In order to open large and high capacity underground mines with Mass Production Technology, 3(Three) blocks have been identified, namely, Murpar Expn., Borda Block, Nand Block. Bid documents are under modification on the lines of tender document floated by BCCL for similar nature of work.

(4) **Man Riding System in Underground mines:**

Where the workings are very deep and far from the surface, Man Riding System is introduced in some of the underground mines. The system reduces travelling time & fatigue of workers which results in increased efficiency. Presently, Man Riding System is working in Tandsi UG mine and Maori UG mine of Kanhan Area. Further, it is proposed to introduce Man Riding System in 2 (two) phases. In first phase, it will be deployed in the 5 Mines which is under installation (i.e.. Saoner UG Mine No.–I, Tawa UG, Sarni UG, Shobhapur UG & Kumberkani UG ). In the second phase, Man Riding System will be deployed in the 2 mines( Ballarpur 3&4 Pits, Saoner UG Mine No.II ).

C. **Challenges of Underground Mining**

There is down trend in the production from underground mines as shown in the graph at Para 4(C) above. The reasons for decline in coal production from underground mines are attributed to:

- UG operations at shallow depth has given way to quarry or surface mining
- Closure of number of underground mines due to exhaustion of coal reserve or losses
- Reduction or stagnation in production due to attrition of workforce or natural retirement
- Reduced production and productivity due to old, long & arduous mines
- Low technological, R&D or skill-development input in underground mines
- A number of underground mining operations or processes involve human effort or drudgery
- Low productivity of manpower
- Geological disposition and exploration of coal seams has also affected indirectly

Besides reasons enumerated above, several other constraints and challenges, are to be faced which have been briefly elaborated as under:

(a) **Size of the Mine / block**

Selection of comparatively small size of a mine or block with limited reserve available. It restricts overall dimensions of a mine, thereby further constraining economic dimensions of mineable panels or coal sub-block, thus limits production capacity and life of the mine. The
mine/block area of most of the underground mines in CIL is generally less than 5sq. km. The extractable reserve in these mines rarely exceeds 15-20Mt. Hence, it presents a challenge to plan and operate a large mine block consisting of extractable reserve in excess of 20Mt so that an underground mine with a capacity of 1.0Mt or more can be planned or operated.

(b) Geological Complexities and Exploration

Indian coal deposits present varieties of attributes to coal deposit – multi-seam (upto 30 coal horizons), seams thickness (upto 35m), proximity of seams (parting <3m), gradient (from flat to upto 45deg.), quality of coal, low rank or maturity of coal, etc. The deposit has been further complicated with the presence of structural disturbances, like multiple faults, occurrence of intrusive bodies, burning of coal, etc. Such disturbances further constrained economic dimension of working panels or coal sub-sub-blocks for mining. The role of exploration is to facilitate complete exploration for delineation of all structures and other deposit attributes.

(c) Mine Approach & Development: high gestation period

Drivage of mine entries and further mine development & construction have been pathetically sluggish. Typically, it takes about 6-12 years to develop an underground mine. Of this, drivage of main mine entries, inclines or shafts, takes about 50-60% of total gestation period due to slow rate of drivages through stone/rock or coal. Rates of drivages in underground are as low as 20-30m per month in stone/rock (single/twin roads) and about 30-60m per month in coal (two or more roadways). It is no way near the rates achieved elsewhere in the world. It presents a challenge to match the international benchmark.

(d) Technological Development & Implementation

Technological Innovation in underground mining did not exist in our country. The problems in technology or operations are being managed through in-house supportive efforts (Indian ‘Jugaad’). Dependence on overseas technological development and its adoption has been the way of upgradation of technique and technology in underground mines. Regarding its implementation, most of the projects have missed its deadline and have been delayed by varied period of time, generally 3-10 years.

(e) Absorption of Technology – Skill development

Measures need to be taken to indigenize the technological import by suitable in-house manpower and skill development and promote such efforts through appropriate policies at corporate and operation level. It a challenge to maintain, upgrade and utilize trained persons at its appropriate and needed locations.

(f) Strata Management & Control

The most important component of success of underground mining technology is strata management and control during mining operation. It is required to develop appropriate understanding of its various aspects and trained manpower for success of technology. Further, an appropriate system & organization are required to record, monitor and manage such system in underground mines.

(g) Mechanization – Productivity Enhancement Needs

The current status of technology and productivity reflects urgent need for mechanization of underground mines. Still many of the underground mines, mining operations & processes are carried out manually without any automation or understanding to minimize human effort and enhance
productivity. This aspect needs to be absorbed with respect to every mining activity to improve overall productivity of the mines.

(h) Equipment Supply & Maintenance – Vendor Development

The technological upgradation in mines is taking place without any focus on indigenous development of either equipment or its spare parts sourcing. Procurement from overseas is costly as well as time consuming (longer gestation). It is necessary to insist on local vendor development to cut down future procurement or maintenance costs indigenous vendor development. This would help in cutting down cost of mining and technology implementation.

(i) Long & Arduous Travel / tramming routes – Man-riding / Material Supply

Travelling of the work persons to their work places and timely material supply at required places are very pertinent for success of technology and effective utilization of work force efforts. A large number of mines are still operating without any man-riding system or any effecting system for timely conveying of materials to required work places. It is a challenge to select an appropriate to select and provide a mine with such effective system.

(j) Mining hazards

Underground mining is fraught with hazards, like fire, inundation, subsidence, explosion, roof fall, air blast, etc. Large area in BCCL has been on fire. Several mines are connected through underground. Roof does not collapse easily during extraction of coal posing threat of air blast or overriding. The threat perception of such hazards holds enormous impact on production operations and other related processes in an underground mine, Active mitigation and management of such hazards is a challenge to Coal Mining Industry. It requires quality technical & training input to persons working in underground mines.

(k) Technological Gap – Focus on Specific R&D

Understanding of the Indian mining conditions required to be understood in right earnest with regard to technological requirements and prevailing geo-mining conditions. Precious little effort has been made to further the cause underground mining problems. Specific R&D input is required from research interface developing a better understanding of the Indian geo-mining conditions. Besides above, there are several other problems specific to a mine or coalfield, at macro and micro level, which require proper analysis and identification and seek a justifiable solution in Indian context. The problem identification is a bigger problem in underground mines, as a difficulty in any operation or process is considered as inherent and part of the operation or process rather than identifying it as a suitable problem and then try to seek appropriate solution.

D. Renewed Focus on Underground Mining

With the increase in coal demand and growing awareness towards sustainable development, the coal industry has drawn a consensus over the need for increased production from underground coal mines. From the current share of about 10 per cent, the industry aims to reach a total coal production of 30 per cent from underground mines by 2030. With just 10 per cent share of coal production from UG mines in India, there is a need for a quantum jump in production and productivity from such mines as there are more opportunities in productivity improvement and cost benefits in underground mining. This is more relevant considering the likely exhaustion of shallow depth coal reserves and hurdles in surface land acquisition in future.
E. Opencast Mining:

When coal seams are near the surface, it is economical to extract the coal using open cut (also referred to as open cast or open pit) mining methods. Strip mining exposes the coal by the advancement of a moving open pit or strip. The earth above the coal is known as overburden. A strip of overburden next to the previously mined strip is usually drilled. The drill holes are filled with explosives and blasted. The overburden is then removed using large earthmoving equipment such as draglines, shovels and trucks, excavator and trucks, or bucket-wheels and conveyors. This overburden is put into the previously mined (and now empty) strip. When all the overburden is removed, the underlying coal seam is exposed as a strip known as a 'block'. Coal in the block may be drilled and blasted (if hard) or ripped (if soft or friable), and loaded on to trucks or conveyors for transport to a crushing or washing plant. Once all coal is gone from the current strip, a new strip is created next to it. Open cast coal mining recovers a greater proportion (up to 90 percent) of the coal deposit than underground methods. Globally, about 40 percent of coal is produced by opencast mining. Opencast coal mines can cover many square kilometers. Mountaintop removal is a form of surface mining that involves scraping off the topmost portion of a mountain to expose the underlying coal. It is highly controversial because of the drastic changes in topography, the creation of hollow fills (valleys filled with mining debris), the covering of streams, and the disruption of ecosystems.

Open cast methods employ a conventional mining cycle of operations to extract minerals: rock breakage is usually accomplished by drilling and blasting for consolidated materials and by ripping or direct removal by excavators for unconsolidated soil and/or decomposed rock, followed by materials handling and transportation.

All Opencast mines in WCL are mechanized. The open cast mines in WCL are equipped with 1009 nos HEMM (Heavy Earth Moving Machinery) for mining activities i.e. drilling, excavation, loading & transportation (i.e. Draglines -4, Shovel- 152, Dumper-643, Dozer-173, drill-106).

5. IMPACT OF MINING ON ENVIRONMENT

Historically, coal mining has been a very dangerous activity and the list of coal mining disasters is a long one. Underground mining hazards include suffocation, gas poisoning, roof collapse and gas explosions. Open cast mining hazards are principally mine wall failures and vehicle collisions etc.

The environmental impact of mining is dependent on several factors, including the extraction technique and where the mine is situated. For instance, in regards to coal mining, underground mining has different impacts compared to open cut mines. However, both technologies of Coal mining create environmental impacts such as land use, waste management, water and air-pollution. In addition to atmospheric pollution, coal burning produces solid waste products annually, including fly ash, bottom ash, and flue-gas desulfurization sludge, that contain mercury, uranium, thorium, arsenic, and other heavy metals. According to the reports issued by the World Health Organization in 2008 and by environmental groups in 2004, coal particulates pollution are estimated to shorten approximately 1,000,000 lives annually worldwide. Coal mining generates significant additional independent adverse environmental health impacts, among them the polluted water flowing from mountaintop removal mining.

The impact mining associated with underground mining on environment of is summarized as follows:

1) Change in land use pattern and land depredation.
2) Ground Vibration with blasting.
3) Suspended particulate in the atmosphere.
4) Noise and vibration menace due to mining and vehicular movement.
5) Societal problems due to cultural, economic invasion and displacement.
6) Disturbance to wildlife.

The underground mining causes land degradation because of surface subsidence, solid waste and coal dumping, fire underground and silting of the surface. The disturbance of the aquifers and subsurface water table followed loss of green cover and vegetable mass.

Opencast mining creates more severe environmental impact than underground mines. It causes air quality deterioration because of dust and gaseous pollutants. It not only affects mining premises but also surrounding areas, atmosphere and water sources. Although economic development is must but not at the cost of overexploitation of resources which degrades the environment. The sustainable development that can balance environmental protection and economic goals is needed. Economic impact assessment plays a crucial role in balancing development objectives with concern for environmental quality. It is valuable and decision making tool that can help to predict and evaluate environmental impacts and encourage sound environment management. In WCL, due care is being taken to avoid above said aftereffects. For every opencast project, the Environment report is also prepared prior to mining for its implementation.

6. MANPOWER

Coal mining is basically a labour intensive industry. Due to increased demand of coal, the stress has been given on intensive mechanization and deployment of heavy earth moving machinery. The same has improved the output per manshift and to that extent the manpower has considerably reduced. WCL has made concerted progress in rationalizing its manpower. Despite increase in production from a level of 24.74 Million Tonnes to 43.65 Million Tonnes during the period 1991-92 to 2010-11, WCL is able to gradually reduce its overall manpower from 85742 in 1992 to 59003 in 2011 and thereby improving the output per man shift with the help of heavy equipments and skilled.

7. COAL QUALITY & DISPATCHES

The quality of the raw coal is dependent upon Geological and deposition features; mining methods. The mined coal has to undergo through processes i.e. Crushing, Screening, segregation, Deshaling, Sizing, weighment etc. These also includes removal of extraneous material i.e. impurities such as stone/overburden/shale, iron pieces etc, then crush and screen to proper size and stocking / transport. Coal testing laboratories have been set up at all Areas of WCL so also to check the quality of coal.

WCL has adopted Maintenance of "Quality of Coal supplies" and "Customer satisfaction" as the key result areas. The following steps are being taken in this direction:

1. **Ensuring RIGHT Grade:**
   - I. By following right mining practices for eliminating extraneous material getting mixed with good quality coal.
   - II. By adopting beneficiation methods like picking of shales & stones.
   - III. By Sampling & Analysis through independent agency at loading / Unloading points.

2. **Ensuring RIGHT Size:** By creating sufficient crushing & optimization of blasting.
3. **Ensuring RIGHT Weight:** 100% weighment through Electronic Weigh-bridges with printout facility and introducing computer at all weigh-bridges.

4. **Ensuring supply at RIGHT Time:**

   WCL has entered into long-term coal supply agreement with all the major power sector consumers viz. MAGENCO, MPPGCL and KPCL, etc. Coal dispatched is covered under joint/third party/agreed sampling to determine the quality of coal and due compensation is made in case of the grade slippage. Location of the Mines of WCL is very strategic so far as the needs of the industrial sectors of Western, Central and Southern India are concerned. WCL has provided constant watch on quality of coal from winning to dispatch. All facilities i.e. crushing, weighment, testing laboratories, loading at the mines end have been provided to supply quality coal.

8. **CONSERVATION AND EFFICIENCY IMPROVEMENT**

   Conservation and efficiency improvements in respect of coal mining have been observed in WCL and they resulted in positive impact in power generation with several other benefits as under:

   - prolonging the life of coal reserves and resources by reducing consumption;
   - reducing emissions of carbon dioxide (CO2) and conventional pollutants;
   - increasing the plant efficiency, output from a given size of unit; and
   - Potentially reducing operating costs.

   However, in respect of power plants, the calculation of coal-fired plant efficiency is not as simple as it may seem. Plant efficiency varies from different plants in different regions are often calculated and expressed on different bases, and using different assumptions. There is no definitive methodology.

9. **SUSTAINABILITY DEVELOPMENT PLAN**

   Some argue that finite resources such as coal have no part in sustainable development. This view overlooks the ability to substitute one form of capital for another. To the extent that substitution at the margin is possible, depletion of one type of capital is consistent with sustainability if offset by an increase in other types of capital. Therefore, the use of coal is consistent with sustainable development if, while meeting our present needs, it produces new capital and options for future generations – such as infrastructure, new technologies and new knowledge. An associated risk is that coal’s use may degrade natural capital, such as the environment to an unacceptable or irreversible extent, leading to unsustainable development. From a sustainable development perspective it is instructive to reflect on coal’s role at the start of industrial society and subsequently. Apart from their inherent practical limitations at that time, supplies of biomass, wind and water were limited. Coal is abundant and available and new technology allowed it to be used mainly for steam raising and iron making. The environmental consequences of rapidly growing and uncontrolled coal use were, of course, unacceptable. However, continual technology development over time allowed coal to be used with much greater efficiency and with greatly reduced environmental impact.

   During the 20th century technological advances allowed a range of new energy sources to be developed – oil, gas and nuclear energy. These partially displaced coal in existing markets and powered new markets, such as transportation. Yet coal consumption continued to grow rapidly in the two applications where it was most suited: centralized electricity generation and iron making.
This illustrates that the principles of sustainable development were practiced early last century - even if by today’s standards the process was imperfect and there were some grave excesses. Finite resources fuelled economic and social development and continual innovation provided new technologies and energy sources in a continual and fluid interplay between social, economic and environmental priorities. Over the time, governments set minimum social and environmental standards and established a framework for markets to function and innovation to flourish.

The importance of coal’s advantages – it is abundant, safe to store, available and affordable – has not diminished with time. These attributes along with its wide resource distribution are essential for ensuring reliable electricity supply. Coal has a crucial role in meeting current needs and is a resource bridge to meet future goals through the enhancement of knowledge and technology. Technological advances have tamed coal’s traditional disadvantages: local and regional environmental impacts. Where state of the art technology is used, for example in Japan and in some North American and European locations, coal meets the most stringent environmental standards, and in most developed countries modern technology enables coal–based plants to perform acceptably. However, modern technologies, still less state of the art technologies, are not universally deployed, notably in some developing economies, and this must remain a high priority for governments, coal users and suppliers.

In order to sustain the current high growth rate of Indian economy, we need to augment our power generation capacity, as presently the country faces 12% shortage of peak power demand. In order to bridge the gap of power generation, we have to produce more coal, as it is the primary energy mineral. Keeping this core objective in mind, we have set our vision to emerge as a key player in primary energy sector with a view to provide energy security to the country. However, this objective shall be attained only through environmentally and socially responsible growth practices.

WCL has set its Mission as “To Produce planned quantity of coal efficiently and economically in an eco-friendly manner with due regard to Safety, Conservation & Quality” and their vision for sustainability as “Emerge as a key player in the primary energy sector committed to provide energy security to the country by attaining environmentally and socially sustainable growth through best practices from mine to market.”

In order to capture our sustainability performances for the year 2012-13, WCL has selected 10-point sustainability development indicators across environmental and social aspects of the company. They have included sustainability performances for their previous financial years to showcase improvement on a year-on-year basis.

10. SAFETY

Occupational Safety and Health in Mines - An Overview

Coal mining is Hazardous and accident prone industry. The mining operations involved in it are against the nature. Therefore special attention is given to safety of men, machine and material involved in the coal mining process. However, accidents cannot be totally eliminated. The statistics of accidents occurred and their causes in underground and open cast mines are as under:

Status of Safety in Indian Mines

(i) Predominant causes of accidents in underground mines:
1. Fall of roof 44.60 %
2. Fall of side wall 14.14 %
3. Rope haulage 16.91 %
4. Other transportation machinery 2.62 %
5. Machinery other than transportation machinery 2.48 %
6. Explosive 4.37 %
7. Fall of persons 5.40 %

(ii) Predominant causes of accident in opencast mines:
1. Wheeled trackless transport 53.70 %
2. Machinery other than transportation machinery 19.42 %
3. Electricity 3.70 %
4. Fall of persons 3.00 %

(iii) Predominant causes of accident in above ground:
1. Wheeled trackless transport 28.00 %
2. Other transport machinery 16.10 %
3. Machinery other than transportation machinery 15.25 %
4. Electricity 15.25 %
5. Fall of persons 12.71 %

(iv) Analysis of accidents occurred at mines:
1. Belowground accident contributes 60% of the total accidents in coal mines.
2. In belowground mines roof fall contributes about 44.6% accidents.
3. Fall of roof and fall side together contributes about 60% accidents.

Among the causes of accidents, ‘roof/side fall’ is the most important one for accidents in underground mines, followed by ‘haulage’. Other causes are also significantly important which indicate possible scope for improvement in management practices. From analysis of accidents, it may be seen that fall of roof though it is not generally considered as a contributory of major accident yet it has killed 840 persons in 136 major accidents which are more than the persons killed due to inundation, if we add other accidents due to (1/2/3 fatalities) roof / side fall. The underground mining is more accident prone mining method than opencast mining. In open cast mines, ‘dumper’ is the most important cause of accidents. ‘other transport machinery’, ‘other machinery’ and ‘miscellaneous’ are also significant causes for accidents.

11. ALTERNATE COAL TECHNOLOGY

Coal bed methane production and use: Extracting and using methane that forms in underground coal seams can reduce explosion hazards in coal mines while also providing sizable quantities of clean burning fuel and reducing emission of potent greenhouse gas that contribute to global warming.

Underground gasification: In situ gasification provides an alternate method for commercially extracting coal reserves that are not currently being mined through conventional methods, while also offering environmental advantages.

Clean coal technology: A range of clean coal technologies can reduce environmental impacts of coal, while also allowing for more efficient utilization of coal resources. The clean coal technologies suitable for large-scale power generation fall into two groups:

1. Advanced super critical (ASC): Coal is pulverized and burned in a boiler to generate steam that drives a turbo-generator. Flue gases are cleaned by electrostatic precipitators, flue gas desulphurisation (FGD) and selective catalytic reduction (SCR). By increasing the steam conditions
to advanced supercritical (300 bar, 600 °C) the overall plant efficiency is increased from the 35 %, average for the UK power plants, to 46 % increasing the target for future development 50 %.

2. IGCC: Coal is not combusted directly but reacts with oxygen and steam to form a "syngas" (primarily hydrogen and carbon monoxide). After being cleaned, it is burned in a gas turbine to generate electricity and to produce steam to power a steam turbine. Coal gasification plants are seen as a primary component of a zero-emissions system. The average efficiency of currently proposed IGCCs is around 42% and the long-term target is 50 %.

3. CCS technology involves capturing and liquefying CO2 gases and storing it deep underground (≥ 2 km) which is in the development stage but is popular with the British government. The three main CO2 capture technologies are as follow;

- Post-combustion solvent absorption (for supercritical and gasification)
- Oxyfuel firing (for supercritical only)
- Pre-combustion capture (for gasification only).

Above coal technologies are in developmental stage and their economic viability to prove their capacity to become alternative to present technologies is yet to be judged.

12. CONCLUSION

The scenario of Indian coal mining is changing very fast with the increasing demand for coal to meet the countries energy security and sustainable development. Much of the expected growth in electricity over the next few decades will likely be based on coal, particularly domestic coal.

The demand for utility-generated electricity is projected to more than double from about 520 TWh in 2001–02 to about 1300 TWh by 2016–17, with an annual growth rate of about 6–7% (CEA, 2000). Longer-term scenarios indicate demand to be around 3600–4500 TWh by 2031–32 (Planning Commission, 2006). The Planning Commission (2006) notes that the installed capacity (including captive power) is expected to be about 800–1000 GW by 2031–32, depending on GDP growth. This projected rapid growth in electricity generation is expected to be met by using coal, since other resources are uneconomic, have insecure supplies or are simply too complex and expensive to build (nuclear and hydroelectricity) to make a dominant contribution in the short to medium term.

The coal industry has to take up this challenging job to meet the requirement of coal for projected power requirement. In view to satisfy demand of coal, the Technology for production of coal, management and geotechnical environment will see great change in near future. As per CIL’s Coal Vision 2025 document, the expected coal demand would be 1267 Million Te per annum (including for steel & cement). To achieve this challenge, coal industry has to be equipped with proper infrastructure and mass production technology without exploitation of natural landmass, land degradation and impact on biodiversity and by attaining environmentally, socially sustainable growth through best practices from mine to market.

Coal is contributing major share in energy scenario of the country at present and it will continue till a viable substitute is not found out. Coal is a non-renewable & limited energy source gifted by nature for which the earth has taken millions of years to form. Therefore all the care has to be taken to mine/excavate this valuable mineral for sustainable development, by giving due consideration to its quality, safety & conservation without disturbing the environment and use it efficiently, economically with systematic and scientific manner keeping future in view.
REFERENCES


ABBREVIATIONS

- NCDC: National Coal Development Authority
- MT: Million Tonnes
- CIL: Coal India Limited
- TERI: The Energy & Resource Institute
- PSLW: Powered Support Long Wall
- OC: Open Cast
- SDL: Side Dump Loader
- UDM: Universal Drilling Machine
- BG: Blasting Gallery
- R&D: Research & Development
- IGCC: Integrated Gasification Combined Cycle
- R&R: Rules & Regulations
- MW: Mega watts
- IBM: Indian Bureau of Mines
- WCL: Western Coalfields Limited
- GDD: Growing Degree Day
- UG: Underground
- B&P: Bord & Pillar
- LHD: Load Haul Dump
- CM: Continuous Miner
- UCG: Underground Coal Gasification
- ASC: Advanced Super Critical
- CCS: Carbon Capture & Storage
- Toe: Tonnes Oil Equivalent

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