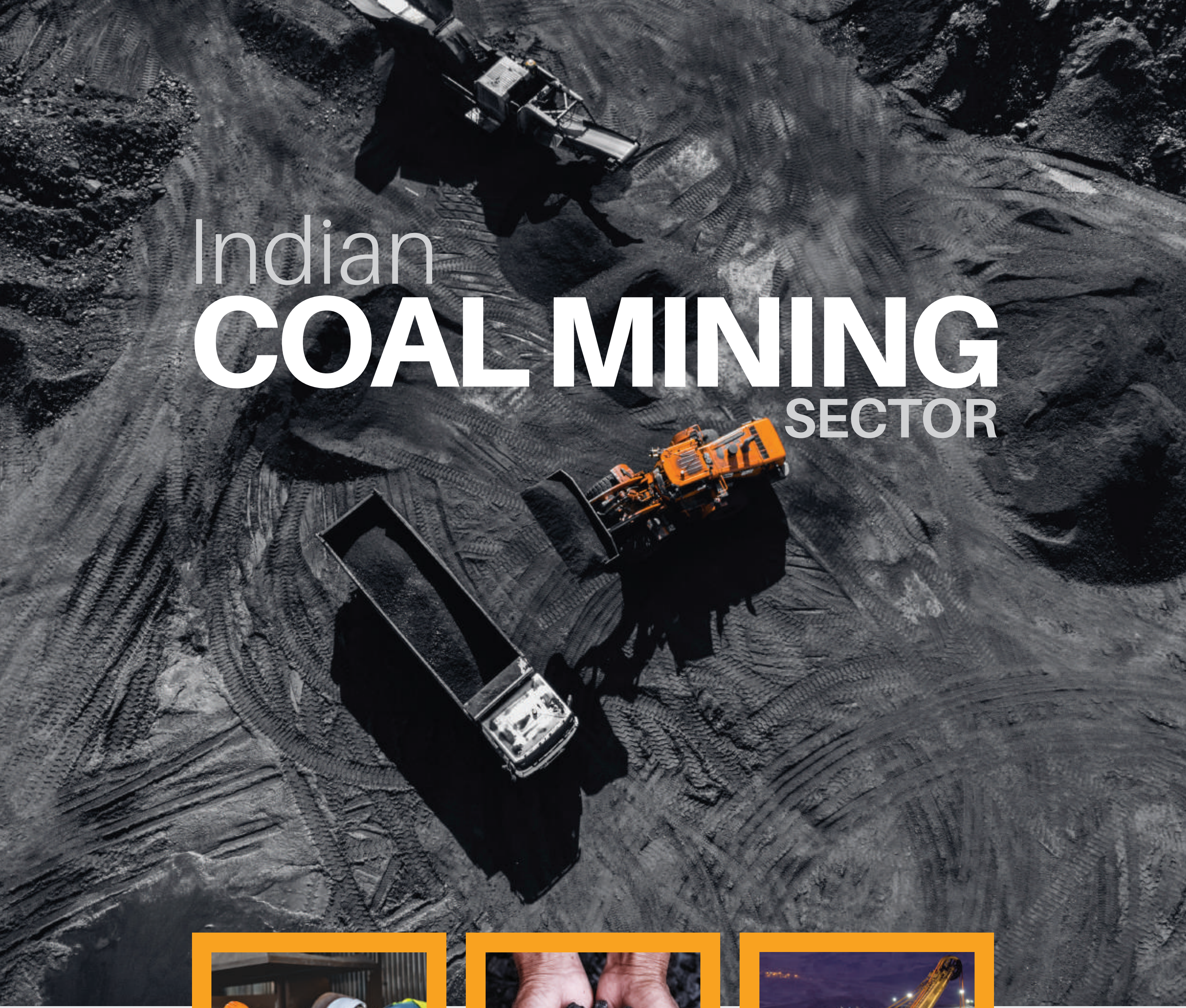
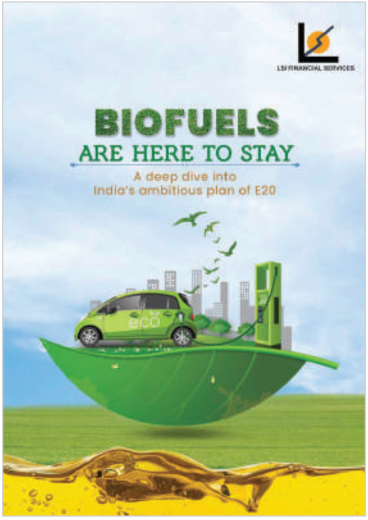


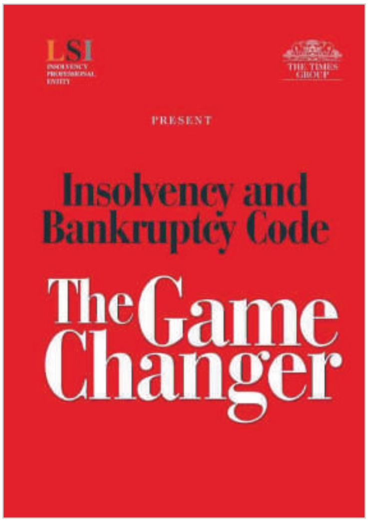
Indian COAL MINING SECTOR

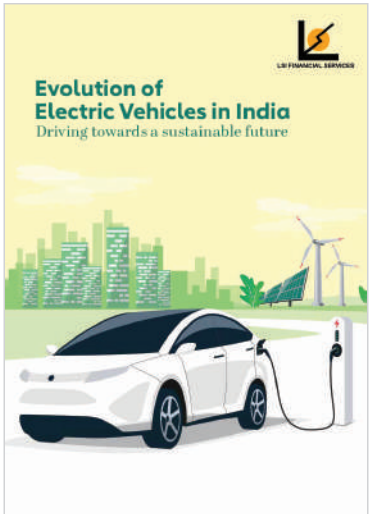
Supporting Energy Security for Years to Come

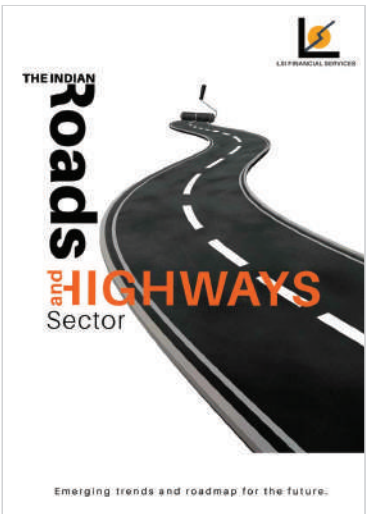
LSI FINANCIAL SERVICES PRIVATE LIMITED

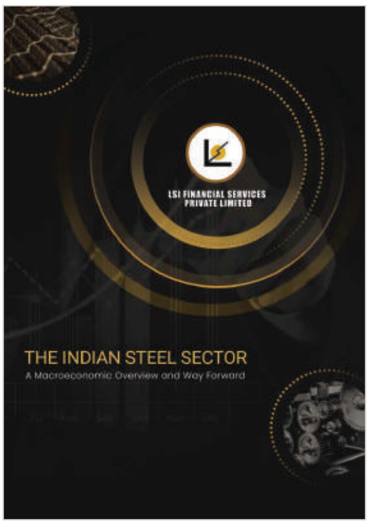
OUR PUBLICATION











FROM THE MANAGING DIRECTOR'S DESK

Raj Kajaria

Managing Director

Energy is one of the prime factors of production of which 84% of the global primary energy demand is met by non-renewable sources. Though coal is the most carbon-intensive non-renewable energy source, it still supplies just over a third of the global electricity generation. India is the second largest coal producer in the world, where coal consumption has synchronously grown with economic growth over the years. The practice of mining coal not only helps to add value to the GDP of the country but also results in environmental issues within its gamut. Therefore, with the pledge to reduce carbon emission, India is in the midst of transition from fossil fuel to renewable led energy. However, particularly for an emerging nation like India, the toughest challenge is to ensure energy competitiveness, security of energy and environmental protection, in unison. Government of India has committed not to fall short in supplying safe energy and make available required amount of electricity. To cater this objective coal becomes an evident choice. Understanding the importance of coal mining, government has also given thrust on increasing the domestic coal production. In recent times, coal mining in India has become commercialized to increase the domestic coal production to support the growing energy demand. Miners are increasingly incorporating Environmental, Social and Governance (ESG) factors into their decisions related to business practice. Progressive mining plans are moving in a flexible path to decarbonization.

In-spite of many initiatives from the government to increase the share of renewables in the energy mix, there is still a significant gap from their share to meet rising power demand. Coal accounts for more than 50% of total primary commercial energy supply in the country and about 70% of total electricity generation. It is likely to remain a key energy source for India in the medium to long run. Moreover, the availability of affordable and reliable power generation is a key factor in sustainable growth of the country. Hence, to ensure the ability to sustain the increased production of coal in the country, sustainable development of the Indian coal sector is necessary. This study deals with the market scenario analysis of coal incorporating coal mining technology into the production process. And in-depth analysis of coal demand has been carried out in this research report by considering the technology of the coal-based utility sectors (downstream sectors using coal as input of production). The study also extends to understand the scope of ESG factors and risk involved in coal mining.

OUR PROFILE

LSI Financial Services Pvt. Ltd.

LSI Financial Services Pvt. Ltd. was established in 1997 and is a SEBI registered Category 1 Merchant Banker. The vision of the company is to provide services relating to Project Finance Advisory, Techno Economic Feasibility Study, Financial Restructuring and Asset & Equity Valuation to esteemed Financial Institutions and corporate houses. With senior bankers and eminent industry experts, who are supported by 150 professionals in the team, the company has gathered vast experiences in almost all the sectors in the last two decades.

LSI has empowered more than 200 large corporate houses in India with its suite of financial solutions. Today LSI is present across the major Tier I and Tier II cities of country.

The company in addition to its focus on debt syndication, Issue Management, PE Advisory, & M&A Advisory, lays significant stress on creating knowledge pools on economically important topics.

LSI Financial Services Pvt. Ltd. has three other group companies under its umbrella offering a gamut of services in the engineering, legal and financial advisory domains.

LSI Engineering & Consultants Ltd.

Established in 2015, LSI Engineering & Consultants Ltd. is a project management consultancy company. It has undertaken numerous large projects across India in road sector under NHAI, PWD across the country. It has a strong team of very experienced engineers having domain knowledge in road, water & other infrastructure projects.

The company is also registered with Indian Bank Association (IBA) as an agency for specialised monitoring and it is handling project monitoring/-cash monitoring etc. for various large industries on behalf of esteem financial institutions of the country.

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LSI Resolution Pvt Ltd offers a spectrum of services related to Resolution & Insolvency encompassing the Insolvency and Bankruptcy Code (IBC 2016), which was enacted to provide the legal and legislative framework to support lenders effectively to recover or restructure defaulted debts in a time bound manner. As an entrusted IBBI registered Insolvency Professional Entity, the company has helped insolvency professionals to successfully manage & completed more than 30 corporate insolvency resolution process of big companies across India in all sectors.

Resolute Valuers & Consultants Pvt Ltd.

Resolute Valuers & Consultants Pvt Ltd. Is a key player in valuation appraisals. Its efficient and experienced team is composed of senior bankers, technical experts, industry experts, registered valuers, experienced engineers, chartered accountants, cost accountants, etc. Registered with IBBI as a Valuer Entity, the company carries out valuation of all classes of assets i.e., Land & Building, Plant & Machinery and Securities & Financial Assets. It has undertaken valuation of very large infrastructure and manufacturing companies. The company has also participated in Government of India's disinvestment projects.

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Project Appraisal	Financial & Technical Appraical	Qualitative Appraisal	Appraisal for Land Allotment

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LSI ENGINEERING & CONSULTANTS

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AGENCY FOR SPECIALISED MONITORING (ASM)

RESOLUTE VALUERS & CONSULTANTS

Valuation	Asset Valuation	Equity Valuation	Enterprise Valuation

Executive Summary

- Power sector is dominated by coal in India where coal has 76% of share in electricity generation.
- High energy demand is met by increasing the supply of coal where it is reported that in 2021, 811 million metric tons of coal has been produced.
- Majority share of the coal is produced in government coal mines – Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL).
- Coal consumption and economic growth in India has synchronously grown over the years but the carbon consumption reduction policies will possibly slow down the growth in the country.
- India has a practice of both opencast and underground coal mining. To make the mining operation more sustainable, real-time monitoring, reducing cost through manpower optimization and safety and preventive measures should be undertaken.
- Technology plays a pivotal role in maintaining the steady growth in production of coal and balancing the demand supply situation. Technology advancement in the coal mining sector and coal-based utility sector acts as a catalyst in reducing Carbon emission.
- Domestic coal supply is constrained by certain factors creating the gap between demand and supply which needs to be minimized by better understanding of coal resources, improving coal extraction, coal quality and transportation.
- India is following the world-wide target of curtailing carbon emission by increasing the share of renewable in power sector mostly.
- Given the constraints of supply of renewable energy, the energy transition policies from non-renewable to renewable has to be meticulously designed, keeping a space for coal in the energy portfolio mix optimally.
- Miners are increasingly incorporating Environmental, Social and Governance factors into their decision making to achieve net zero carbon emission.
- The mining industry is exposed to economic and geopolitical risks. The financial institution should have an in-depth assessment of the risk exposure while lending the money for risk mitigation.

Table of Contents

CHAPTER 1

INDIAN ENERGY SCENARIO & IMPORTANCE OF COAL

Introduction

Economic development and progress of a nation with realization of basic human needs into the bargain is crucially dependent on the availability and development of modern energy at the highest degree. The principal problem faced in the policy arena across the globe in recent times, has been - solving the puzzle of sustainable development, comprising of: **energy competitiveness, security of energy and environmental protection**, in the vertices. Exponential population growth, advancement of technology followed by rapid industrialization, increased urban settlement and development is creating increasing energy demand across the world. According to the estimates of US EIA, global energy demand is going to increase by 47% by 2050. Beside capital, labour, and material services, energy being one of the prime factors of production must have optimum supply at affordable prices. Predominantly the 84% of the global primary energy demand is met by the fossil fuel sources(non-renewable).

Energy is relatively the scarcest resource amongst all the other resources. Security of energy is the matter of greatest importance in current times across the globe and India is no exception. Securing of energy is facing dual challenge, one from rising prices of energy and another from the geopolitical crisis. The high degree of concentration of oil supply sources in the volatile region of the world where over 68% of oil and 67% of gas reserves are concentrated respectively in the Middle East and in Russia, clearly involves risks in terms of the reliability of the supply of energy for many energy importing countries including India. Import of energy especially crude and a part of coal, is comprising of a major share of the import bill. Given this background, India is diversifying the sources of energy and finding a stable solution for the supply of energy.

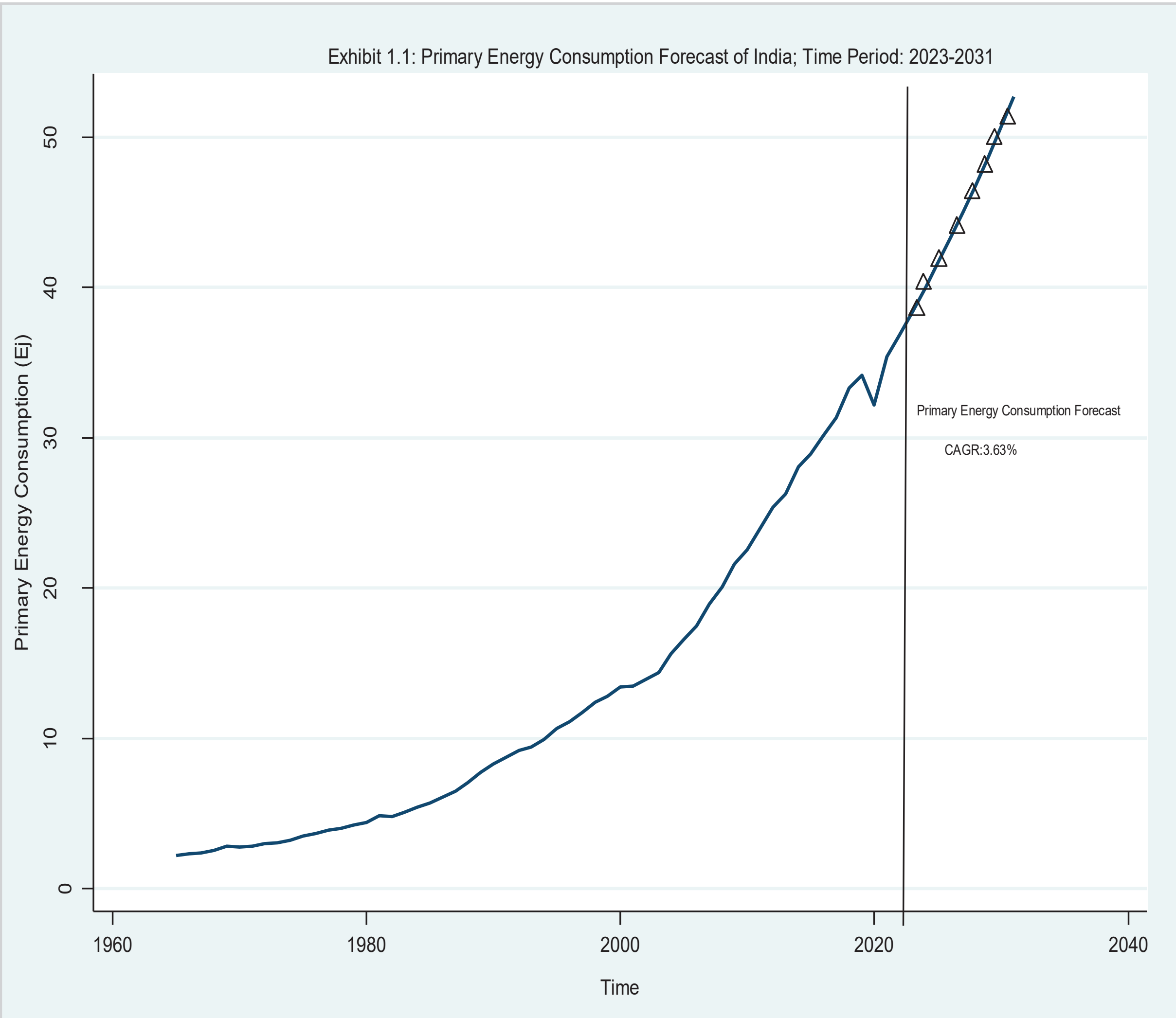
India Energy Scenario

India is an emerging economy in advanced stage with proliferating population currently standing at 1.3 billion. Massive industrialization and rapid urbanization undergoing in India is the major determinant of towering energy demand. Sufficient supply of energy is required to propel the growth of the Indian Economy at 7%- 8%, to achieve the target of 7-10 trillion-dollar economy by 2030. Increasing income and enhanced standard of living is causing high consumption demand substantiated with increasing energy demand. India currently stands as the third highest consumer of energy in the world after China and United States of America.

According to the estimates of International Energy Agency (IEA), energy usage in India has doubled since 2000 and still 80% of energy demand is met by coal, oil and biomass. Since 2000, India has contributed to 10% of global energy demand and per-capita consumption of energy has increased by 60%. IEA states that per-capita coal demand has increased from 25% in 1990 to 60% in 2019.

India has been the net importer of fossil fuel in terms of oil and is net price taker in the global oil market, affecting the current account deficit with huge import bill. In-spite of India having the fifth highest reserve of coal in the world, a portion of high-quality ultimate consumption of coal (less ash content coal) has to be imported partly for steel industry and power generation. The decadal average amount of coal import is about 200 million tonnes. Service sector, relatively less energy intensive than manufacturing sector, has been the major contributor of growth in the last two decades. But the growth led by the service sector has increased the income of a major section of population directly, and that respective income is generating increased amount of income by means of multiplier effect across the economy. And so, this increased income is going to cause a surge in demand in the manufacturing sector, especially in the core sectors- power, iron & steel, cement, roads, other building materials and infrastructure.

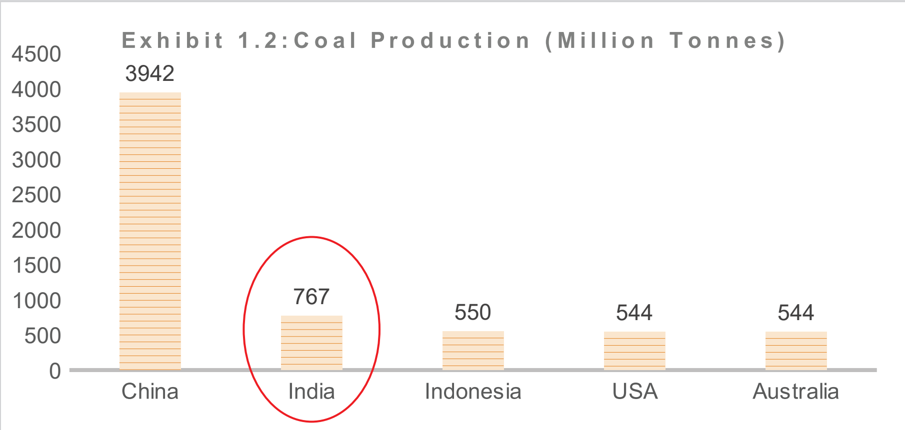
The supply side economy is therefore going to have high energy demand. Empirically it has been observed that rate of increase in consumption of primary energy on absolute basis is more than the per-capita basis. The difference in absolute primary energy consumption and per-capita primary energy consumption is critically getting caused due to high degree of income inequality prevailing in India.



Source: LSI Research Calculation based on data from Ministry of Coal, GOI

It is forecasted that absolute primary energy consumption is going to increase with a CAGR of 3.63%, whereas per-capita primary energy consumption is going to increase with an increasing trend and CAGR of 2.70% for the period of 2023-2031.

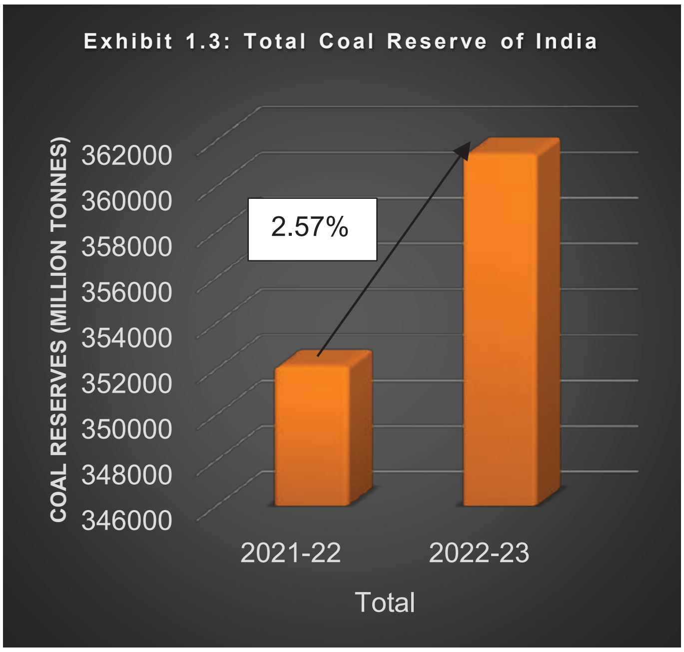
Coal in context to India



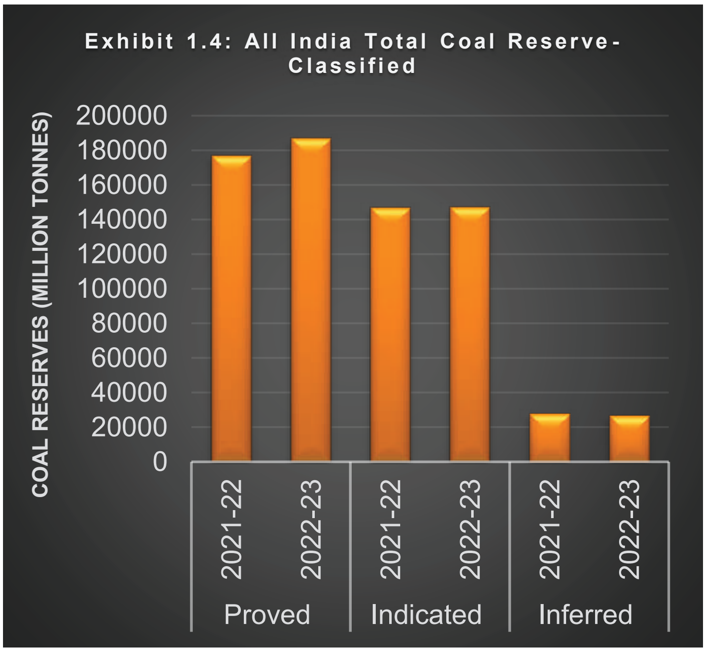
Source: LSI Research Calculation based on data from Ministry of Coal, GOI

Coal plays a pivotal role in securing and supply of safe energy to meet the high energy demand, because it is the most abundant and economical among all the fossil fuels. Coal is likely to remain the main source of stable energy till 2030-40. At Present, in India, coal has more than half share in the primary energy supply, i.e., 56.3%, and India is the second largest coal producing country in the world after China.

Power sector is dominated by the coal in India where coal has 76% of share in electricity generation. At current rate of coal production, it is estimated that proven and likely coal reserves of India is going to last for 300 years.

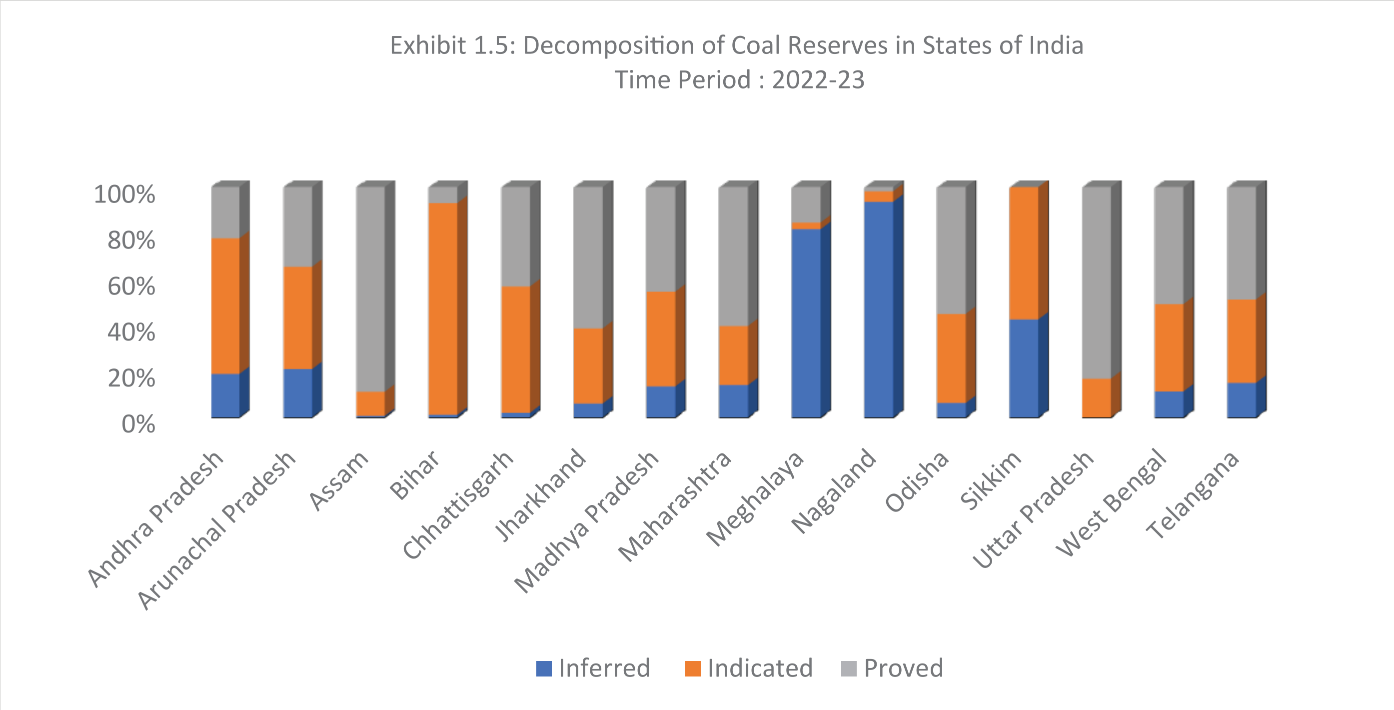


Source: LSI Research Calculation based on data from Ministry of Coal, GOI



Source: LSI Research Calculation based on data from Ministry of Coal, GOI

- Proved reserves is generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.
- Inferred: Coal in unexplored extensions of Demonstrated Resources for which estimates of the quality and size are based on geologic evidence and projection.
- An Indicated Mineral Resource has a higher level of confidence than an Inferred Mineral Resource but has a lower level of confidence than a Measured Mineral Resource.



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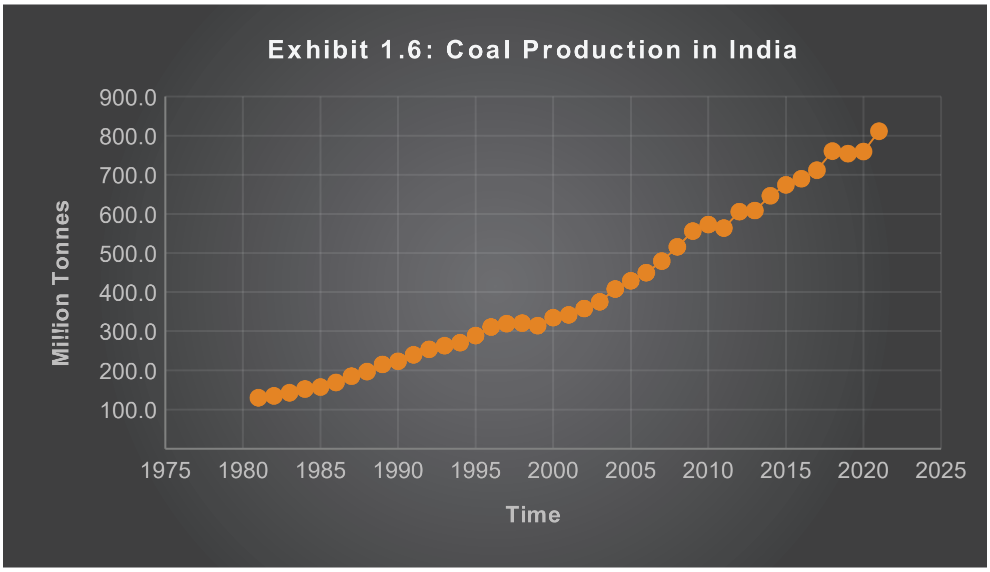


Source: LSI Research Calculation based on data from Ministry of Coal, GOI

In India coal has been mined for more than 250 years. Previously most of the mines were privately owned until the coal mines were nationalised in 1970. Coal sector was nationalised with the purpose of coordinated and rational scientific development of the sector, to increase the supply of coal in meeting high energy demand. Since nationalisation, coal production has increased tenfold, and in 2021 it is reported to have produced 811 million metric tons of coal. Majority share of the coal production is from the government owned coal mines, Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL).

Coal extraction and production process is associated with negative externalities borne by the society as environmental cost. Alongside many nations in the Paris Agreement in 2015, India also pledged to lower down the carbon emission step wise.

And according to Nationally Determined Contribution (NDC), India has planned accordingly to deploy alternative energy (non-fossil fuel/renewable-energy) in phased manner both in production and consumption side. In present times India, with all its policy framework and institutional guidelines, seems to be in the transition phase- fossil fuel to renewable energy (RE). But the empirical facts, limitations in the deployment and supply of renewables at the face of high energy demand put forward questions towards the justified transition of renewable energy according to NDC.

Economic fundamentals classify India as a developing nation with an ever-growing demand and high growth requirement intertwined with the requirement of massive employment generation, and sufficient supply of energy is required continuously to complement the aforesaid objectives. Notwithstanding, renewable energy faults at the continuity of supply, creating lot of uncertainties in entire supply chain catering to the ultimate demand of the economy. Market forces are not supporting to the fullest extent to drive the deployment of renewables in full swing and displace coal in India, because of the characteristics of developing economy, which otherwise is relatively uncomplicated for developed economies. Nevertheless, India is committed to NDC to reduce carbon emission and add new source of supply of energy along with the mission of clean coal technology (CCT). Successful deployment of renewable energy is severely constrained by the energy storage technologies and facilities. Power supply risk is very high involving renewables, especially with solar the most domineering of all the renewables- because generation of solar power is high during the day time, but during the night time there is relatively more demand of electricity and electricity generated from solar energy falls short to meet the peak time demand. Renewable energy penetration problem is magnified due to the weak grid infrastructure with limited fast-ramping capacity and its evening demand peak.

When it comes to the cost comparison between coal and renewable energy, the general notion is RE costs less than coal, but this is not a hard drawn conclusion since there cannot have an exact comparison between the two. RE costs are levelized cost of energy and not the actual cost, so it doesn’t include system and hidden costs. These cost of RE does not account for the peak time cost when there is huge supply deficit of power from renewable energy.

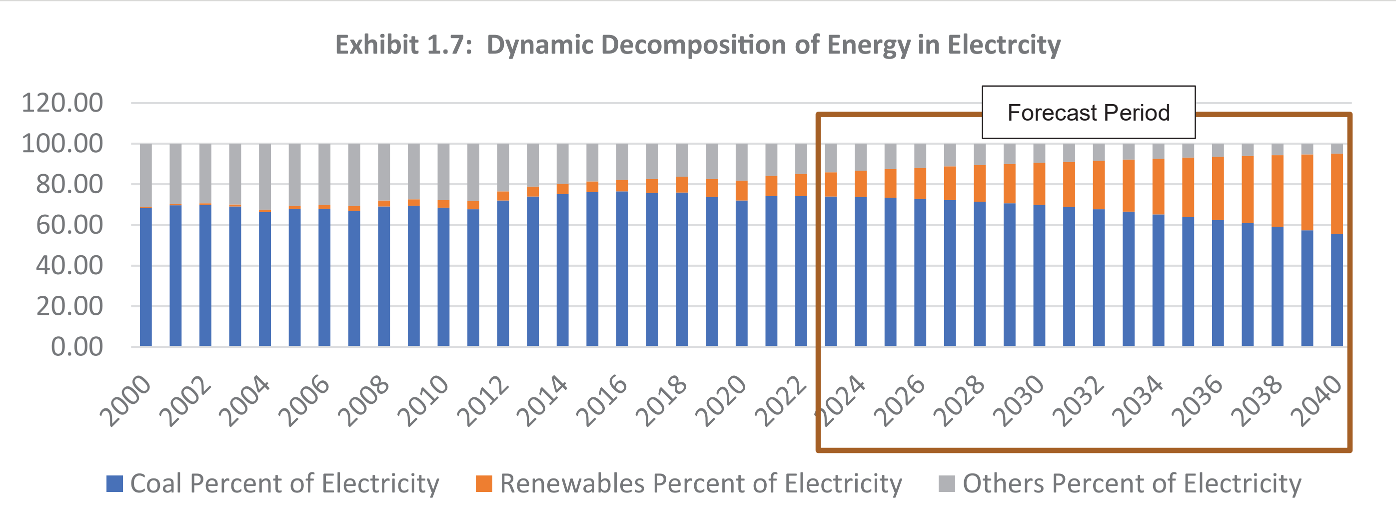
For several reasons India needs to shift to renewable energy but coal will be dominating the energy portfolio for subsequent times in near to medium term. Renewable energy is still not sufficient enough (with 2.08% share in primary energy supply) to oust coal in big proportion from the energy system. Solar energy the most assertive form of renewables in power generation space has 12.43% share in electricity grid capacity and 3% share in electricity generation with a very low-capacity utilization factor. Power sector has the dominant share in the primary energy consumption and coal is the low-cost prudent source of energy supply in this sector. It can be concluded from the current energy supply base and demand requirement that India is constrained to completely specialise in RE, and hence it is rational to incompletely specialize with an energy portfolio mix of - RE and “clean coal”. A portion of the designated fund for clean energy can be diverted for the clean coal production which can lower down the carbon emission and India can optimise the energy supply with a given constraint of targeted low carbon emission.

Future of Coal in Power Sector

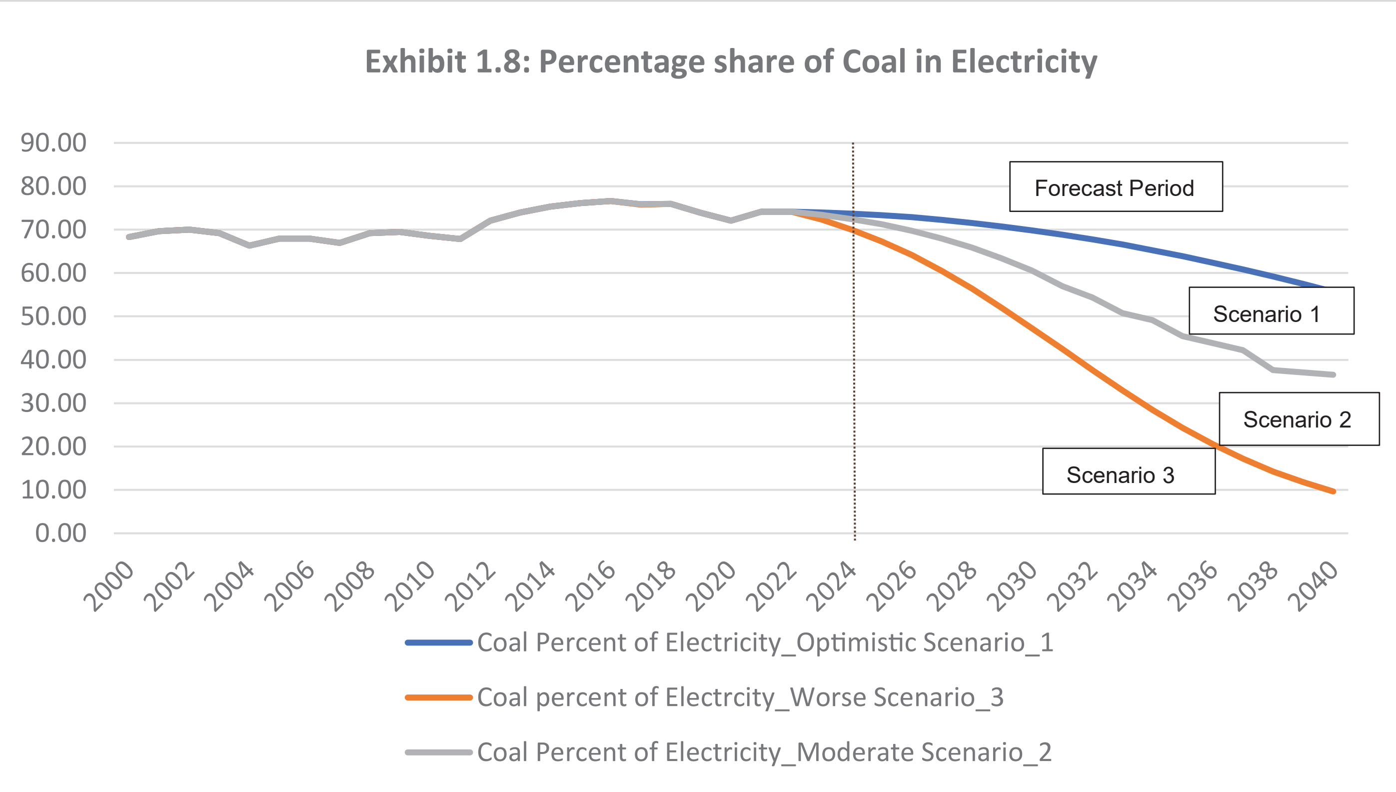
There is a prevailing ambiguity in the industry, both at the developer and investor end, about the future of coal demand, especially from the power sector- major stakeholder in the consumption of coal. The uncertainty is mostly arising due to the worldwide target of curtailing carbon emission, and India is following the suit with stepwise target to increase the share of renewable in various energy uses and the spotlight is on power sector. But to address the cloud of uncertainty that is hovering across the stakeholders, a detail study has been carried out to give the future projection of coal consumption in power sector.

Firstly, we understand the dynamic decomposition of three forms of energies - Coal, Renewables and others (Hydro, Nuclear, Oil & Gas) in electricity production from the period of 2000-2022. From exhibit 1.7 it is observed that Coal's share is dominating throughout the entire period, and initially the energy space was shared by Coal and Others (mostly hydro) and share of Renewables had gradually increased its presence since 2010 (due to the advent of National Solar Mission) and after the Paris Agreement in 2015 visibility of Renewables became magnified. Renewables has increased its share in the energy space mostly competing with the "Other" categories and relatively less with Coal.

Based on different economic structural and fundamental characteristics capacity deployment progression rate of Renewables will be very different and following that, the share of Renewables in the electricity production in India. Consequently, there will be a shrinkage in the share of coal in the electricity production. But the significant question which is intriguing, is about the nature and extent of shrinkage for a substantial period of time. In this section of the report, we enquire that crucial question by analysing three different underlying scenarios of Renewable energy progression in the electricity production in India and produce the dynamic forecasting of share of coal in the same.



Source: LSI Research Calculation based on data from BP-Statistics



Source: LSI Research Calculation based on data from BP-Statistics

Three scenarios have been considered to understand the future share of coal in electricity production (for a period of 2023-2040) given the predicted demand of electricity:

Scenario 1- Optimistic: In this case we consider the capacity deployment progression rate of renewable energy, following the estimated historical trend of deployment. Exhibit 1.7 is giving the projection of share of coal vis-à-vis its competitors Renewables and “Others” in electricity production. Given the current progression of renewables deployment, the share of renewables is going to increase from 2024-2030 at a moderate rate and going to increase at a relatively higher rate thereafter. For the entire forecasted period renewables share is going to increase from 11.95% to 39.53% with a CAGR of 12.26%, “Others” share going to decrease from 14.05% to 4.89% with a CAGR of -0.17% and Coal share is going to decrease from 74% to 55.69% with a CAGR of 4.21%.

Scenario 2- Moderate: In this Scenario growth of Renewables has been considered in align with the target set by the government of India and consequently the share of share of Coal in electricity production is forecasted given the increasing share of Renewables in electricity production. By 2030 government has targeted to increase the renewable share by 500GW which implies enhancing of the renewable capacity by 40% given the current status. We give a projection beyond that till 2040 about the dynamic decomposition of different energies in electricity production. In this case with the forecasted renewable capacity deployment progression the share of renewable is going to increase from 74% to 55.56% in 2040 and consequently the share of coal is going to decline to 36.55% in 2040 and rest of energy space is going to be shared by the “Others” (especially hydro). This scenario is approximately likely to get realised if and only if government’s renewables capacity addition targets are well achieved and the capacity utilization factor of renewables are very high. Along with that the cost of renewables also has to decline in support of achieving the target and all the incentive schemes has to be completely compatible for the stake holders. In exhibit 1.8 the forecasted dynamic percentage share of coal from 2023 to 2040 is depicted.

Scenario 3- Worse: In this case we consider the growth of renewables to happen at the massive rate conditioned upon- the production of the input materials completely to happen indigenously and rapid decline in cost of production and deployment of renewables. Consequently, the share of renewables in electricity production is going to have huge leap from 11.95% in 2023 to 88% in 2040, “Other’s” share is going to decrease from 14.05% in 2023 to 1.37% in 2040, and Coal’s share is going to decrease from 74% in 2023 to 9.65%. But this scenario seems to be quiet out of feasible and non-economical given the expected towering power demand and possibly unmatched supply of renewable energy due to lack of continuity in supply of renewable energy. Also, to arrive at such a scenario the development of Concentrating Solar Power (CSP) technology in India has to play a major role, whose respective capacity currently is negligible at 350 MW approximately and development of CSP technology involves huge development and operating cost. In exhibit 1.8 dynamic percentage share of Coal is represented in case of scenario-2.

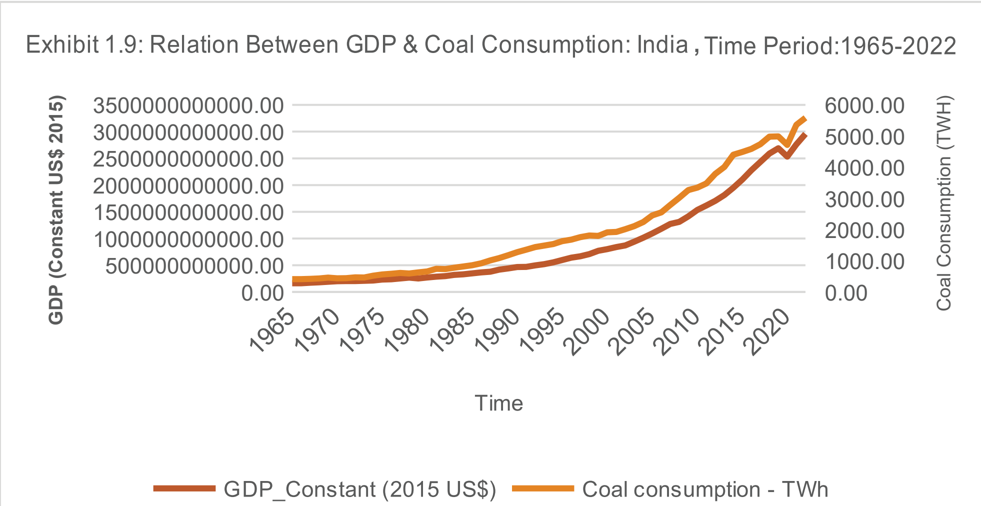
Importance of Coal in India

Many factors mentioned above makes coal a dependable source of energy for spurring economic growth. But alongside it is also believed and coal consumption is a major source of global warming, because burning of coal majorly contributes to rising atmospheric concentrations of the greenhouse gas carbon dioxide (CO2). So, generally coal is coined as the sinner for global warming. Despite the fact coal consumption has its cons, nevertheless coal has acted as a nation building mineral resource ever since independence, being an important source of energy supply and energy security. Hence, this double-edge sword characteristics of coal has necessitated to research more on to investigate the causal side of economic growth and coal consumption.

Based on the causality relationship between coal consumption and economic growth the policies related to energy conservation must be designed. At the very outset of causality analysis, the hypothesises are defined as follows.:

- **Hypothesis 1:** If there is an existence of running unidirectional causality from coal consumption to GDP, then it implies that shortage of coal is going to negatively affect the economic growth.
- **Hypothesis 2:** Otherwise, if the direction of causality runs in the opposite direction i.e., economic growth causes coal consumption then the policies dedicated to reduce coal consumption will have very little effect on economic growth by means of economic feedback system.
- **Hypothesis 3:** If there exist a bidirectional causality between coal consumption and economic growth, then it implies that coal consumption can stimulate economic growth and in turn economic growth may induce more demand for coal. In this case, coal consumption and economic growth complement each other and coal conservation measures may negatively affect economic growth.
- **Hypothesis 4:** If there is no causality running in any direction, the neutrality hypothesis is accepted.

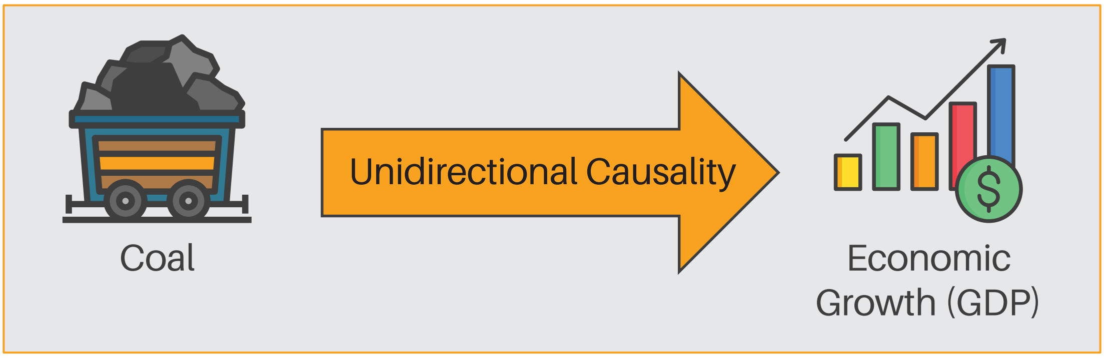
Coal Consumption and Economic Growth: Empirical Analysis



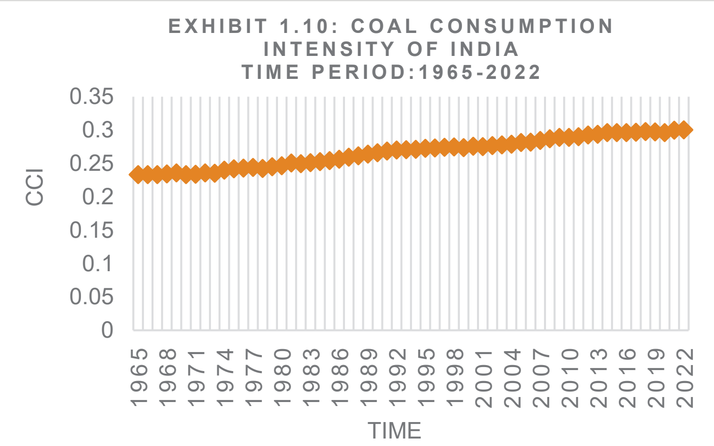
Source: LSI Research Calculation based on data from BP-Statistics & world Bank

India's economic growth reliance on coal consumption is estimated to be 12.71% over a period of 1965-2022. It has been observed empirically that coal consumption and economic growth in India grew synchronously. From exhibit 1.9 it is seemed to be relationship between the trend of national coal consumption and GDP is very close. But the relationship has to be testified statistically and long run economic equilibrium relationship has to be verified.

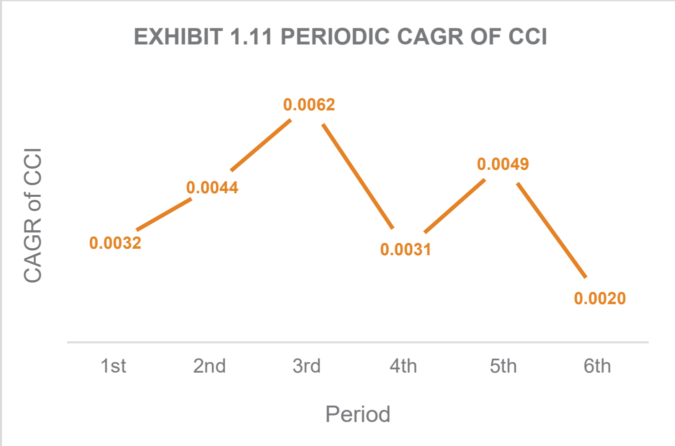
The first step before conducting the causality relationship test, we first explore the long run equilibrium relationship between the coal consumption and economic growth to rule out any case of spurious relationship. The series of coal consumption and GDP is found to have been cointegrated of same order (applying Johansen Cointegration test) and economically it signifies the existence of long run equilibrium relationship between them. Further investigating for the short run dynamics between coal consumption and economic growth error correction model (ECM) is applied and the coefficient of the short run equilibrating factor in the model appears to have negative sign associated with it and statistically significant (implying damped oscillation at a rate of 3.1%), ensuring that in long run both the series (coal consumption & GDP) is going to converge, despite having short run disequilibrium situation.



Further to explore the evidence of causal relationship between coal consumption and GDP, Causality test has been performed statistically (Granger Causality Test). The test results conforms that there is only evidence of unidirectional causality between coal consumption and economic growth i.e., coal consumption positively stimulates economic growth. Hence, only Hypothesis-1 is accepted and all other hypothesis defined above are rejected. The unidirectional causality running from coal consumption to economic growth is indicating that a change in coal directly affects the economic growth of the country and coal is playing a pivotal role in sustaining nation's economic progress and well-being. The strategies devised to implement coal saving and carbon emission reduction policies will possibly slow down the growth in India, if the practicing economic growth model has been followed. Energy a critical input in the production function cannot be compromised from the perspective of energy security and continuous supply. So, the energy transition policies from fossil to non-fossil fuel has to be meticulously designed, keeping a space for coal in the energy portfolio mix optimally, given the constraints of supply of renewable energy.



Source: LSI Research Calculation based on data from BP-Statistics & World Bank



Source: LSI Research Calculation based on data from BP-Statistics & World Bank

To understand the dependency of economic growth on coal consumption, the coal consumption intensity (CCI) is calculated. CCI is defined as the ratio of the coal consumption to the real national economic amount in GDP. As shown in exhibit 1.10 CCI for India has increased over the years from 1965 to 2022 at an CAGR of 0.436%. But diving deep to understand the pattern of CCI over the years the analysis has been broken into six periods and CAGR of CCI has been calculated for the respective periods. From exhibit 1.11 it is reflected that though over the long-time horizon the trend of CCI is increasing, but the short run dynamics has irregularity in trend. In recent times the growth rate of coal consumption intensity is falling, and plausible reason is due to the strict policies regarding carbon emission following the climate change. From the causality analysis discussion above it is inferred that lowering down of coal consumption is going to affect the economic growth negatively following the current practicing growth models. So, to bring in notice given the current energy demand and constraints of alternative energies, coal's presence seems to be assertive in in the near future.

CHAPTER 2

COAL MINING PRODUCTION TECHNOLOGY

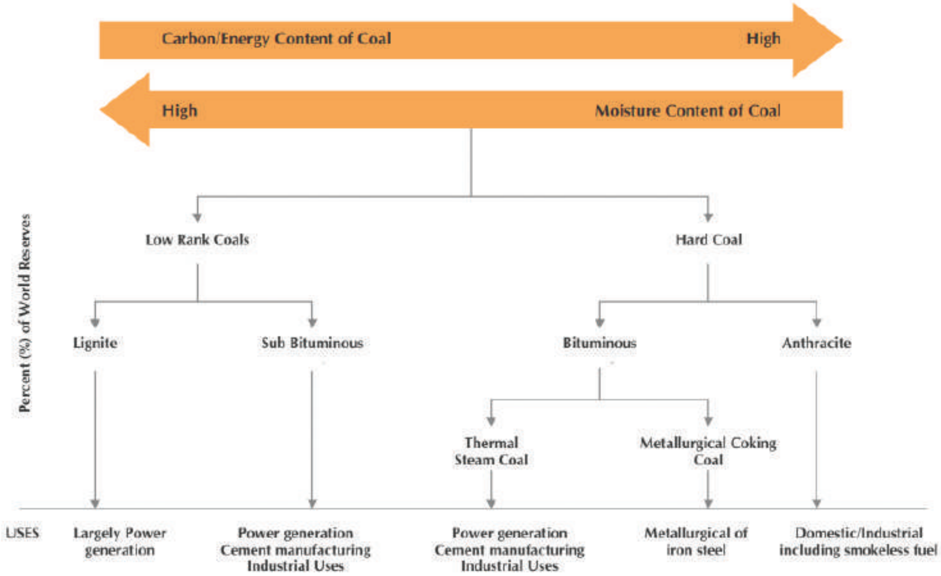
About Coal

Coal, the black diamond, is a combustible black or dark brown rock consisting chiefly of carbonized plant matter, found mainly in underground seams and used as fuel. Coal is containing more than 50 percent by weight of carbonaceous material, formed from compaction and induration of variously altered plants remain similar to those in peats.

- Peat is an unconsolidated deposit of plant remain from a water saturated environment such as a bog or a mire; structure of vegetal matter can be seen. Under the right conditions, peat transforms into coal through a process called carbonization. Carbonization takes place under incredible heat and pressure. About three meters (10 feet) of layered vegetation eventually compresses into a third of a meter (one foot) of coal.
- Coal exists in underground formations called “coal seams” or “coal beds” interstratified with shales, clays, sandstones and limestones (rarely). A coal seam can be as thick as 30 meters (90 feet) and stretch 1,500 km.
- Coal in India is found from two rock series from two geologic age. One, is Gondwana coal which was 200 million years ago mostly found in West Bengal-Jharkhand belt. Coal deposits are also present in the Godavari, Mahanadi, Son and Wardhya valleys. Tertiary coal which is about 55 million years deposition is mainly found in North-Eastern part of the country.

This fossil fuel is extracted from the ground by mining, either underground through the seams or in open pits. Coal is primarily used as input to generate electricity, manufacture steel, cement and liquid fuels. Coal is non-renewable in nature and the largest source of energy for the generation of electricity worldwide, as also the largest worldwide anthropogenic sources of carbon dioxide releases. Gross carbon dioxide emissions from coal usage are slightly more than those from petroleum and about double the amount from natural gas.

Types of Coal



Source: World Coal Association

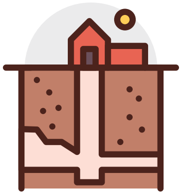
Coal Grade	Characteristics	Primary Use	Carbon Content	Calorific Value	Share of Global Reserve
Anthracite	The highest rank of coal. It is a hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter.	Domestic and industrial uses	High-86% and above	23,865 and above	14.06% (As of 2020)
Bituminous	Bituminous coal is a middle rank coal between subbituminous and anthracite. Bituminous coal usually has a high heating (Btu) value. Bituminous coal is blocky and appears shiny and smooth when you first see it, but look closer and you might see it has thin, alternating, shiny and dull layers.	Power generation, cement manufacture, iron and steel manufacture and industrial uses (Segmentation based on usage; Thermal (Steam) used for power generation, cement manufacture and industrial uses and Metallurgical (Coking) coal used in manufacturing of iron &steel)	Medium-45 to 86% and low moisture content	23,865 and above	
Subbituminous	Subbituminous coal is black in colour and is mainly dull (not shiny). Subbituminous coal has low-to-moderate heating values and is mainly used in electricity generation.	Power Generation, Cement Plants and various industrial uses	Low-35 to 45%, high moisture, low energy	17,435-23, 865	1.5% (As of 2020)
Lignite	Lignite coal, aka brown coal, is the lowest grade coal with the least concentration of carbon. Lignite has a low heating value and a high moisture content and is mainly used in electricity generation.	Power Generation	Low - 25 to 35%, high moisture content and low energy	23,865 and above	

Source: LSI Research, British Petroleum, and US Geological survey

Coal Extraction Methods

Generally, there are two methods of Coal Mining:

Surface or Opencast Mining



Underground or Deep Mining

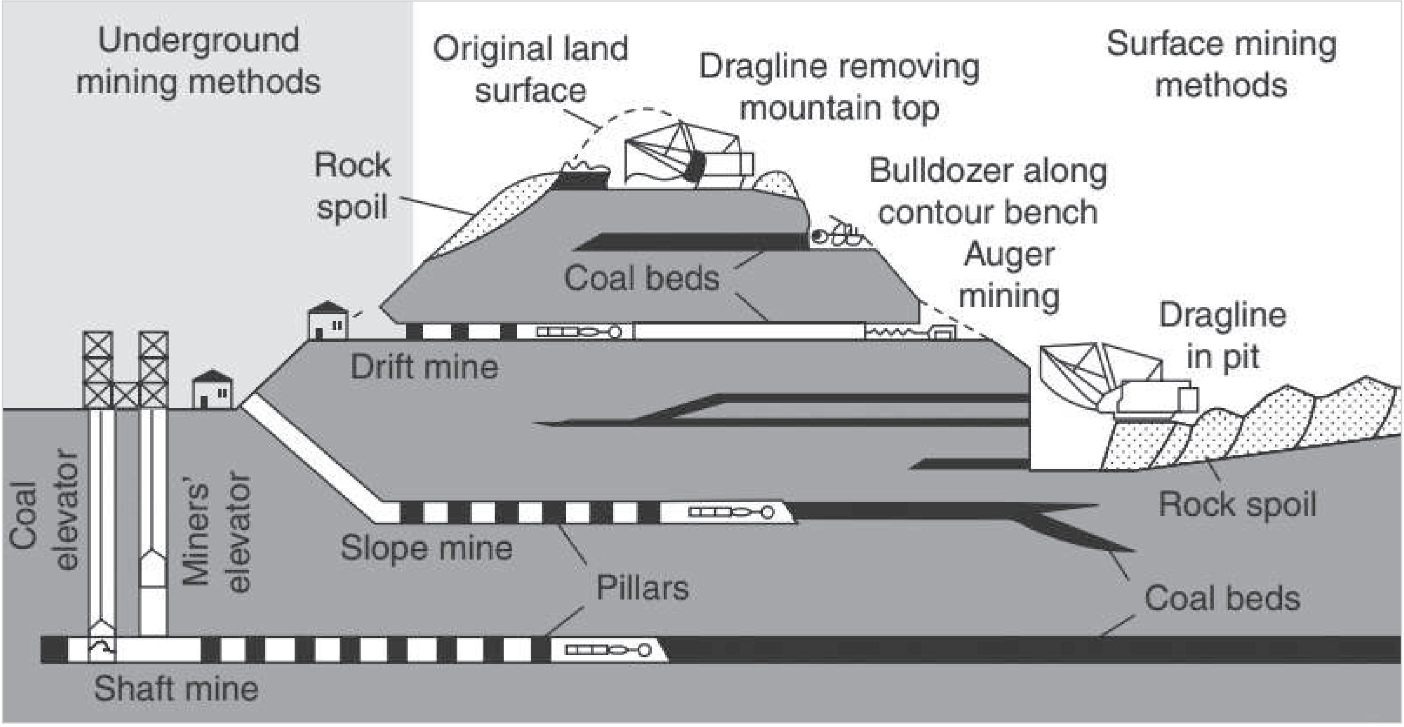
Coal exploration is done by studying the topography of the area. Geological characteristics of the proposed mine, location & thickness of the coal seams, density of overburden and environmental factors, are the important determining factors for selecting the best and economical type of mining. Globally, 60% of the coal mining is comprised of underground mining. Coal seams which are at approximately 50 meters depth are usually surfaced mined. Coal which is at depth of below 50 meters to 100 meters are deep-mined, but in some cases surface mining technique can be used. And in case where coal deposit is below 100 meters deep mining is always preferable.

Feasibility of Coal mining:

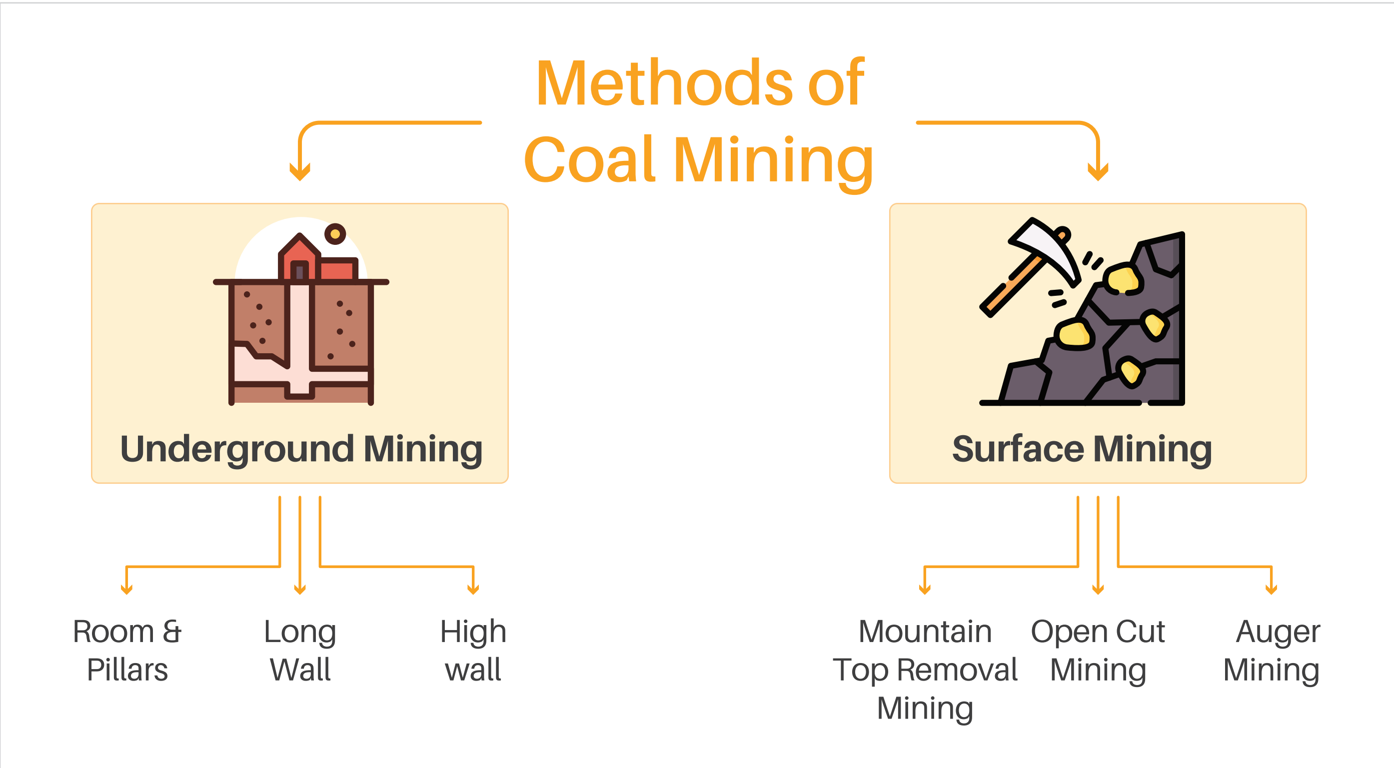
Evaluating parameters of technical and economic feasibility of coal mining are following:

- Geological condition of the specific mining location.
- Topographical characteristics.
- Characteristics of coal seam – continuity, depth, thickness and quality of coal.
- Overburden characteristics.
- Strength of materials above and below the coal seam for roof and floor condition.
- Availability of land and ownership status.
- Surface drainage system.
- Ground water condition.
- Availability of labour.
- Availability of proportionate capital investment required for coal mining.

Exhibit 2.1: Schematic diagram of coal Extraction



Source: EIA



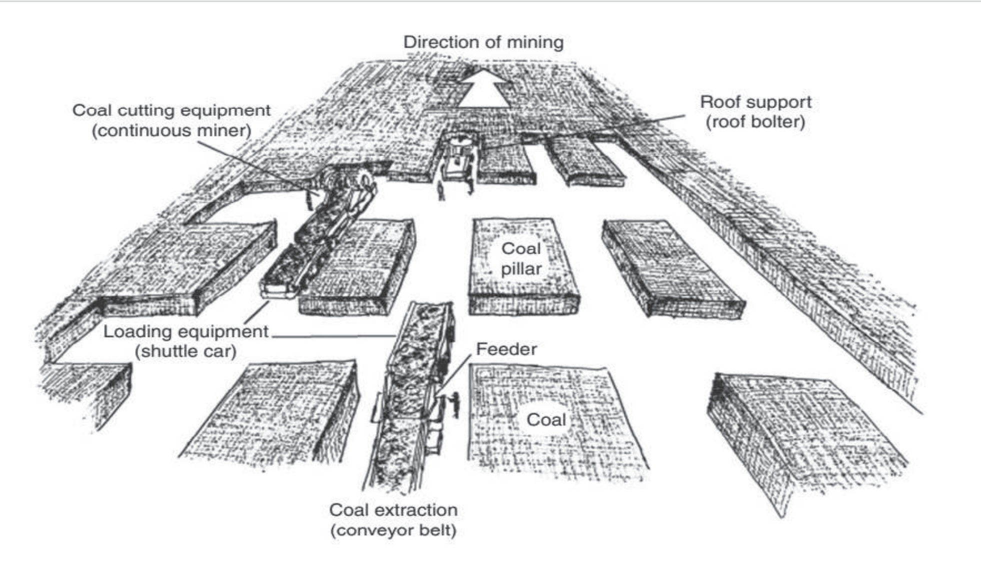
Underground and Deep Mining

Underground mining is classified based on according to how access to the coal is accomplished.

- Where access to mine is bored horizontally from the surface to the deposit, such as the side of a mountain- it is called **'drift' mine**;
- Where the shaft angles downward, usually following the downward slope of the deposit – it is called a **'slope' mine**;

Room & Pillars Mining: Involves mining for coal deposits by cutting a network of rooms or panels into the coal seam and leaving behind pillars of coal to support the roof of the mine. Rooms of the coal deposit are mined usually with 'continuous miners. In this case, coal is mined from pillars when workers move out and then the mine is abandoned as the roof gets collapsed after extracting coal from those pillars.

Exhibit 2.2: **Schematic Diagram of Room & Pillars Mining**

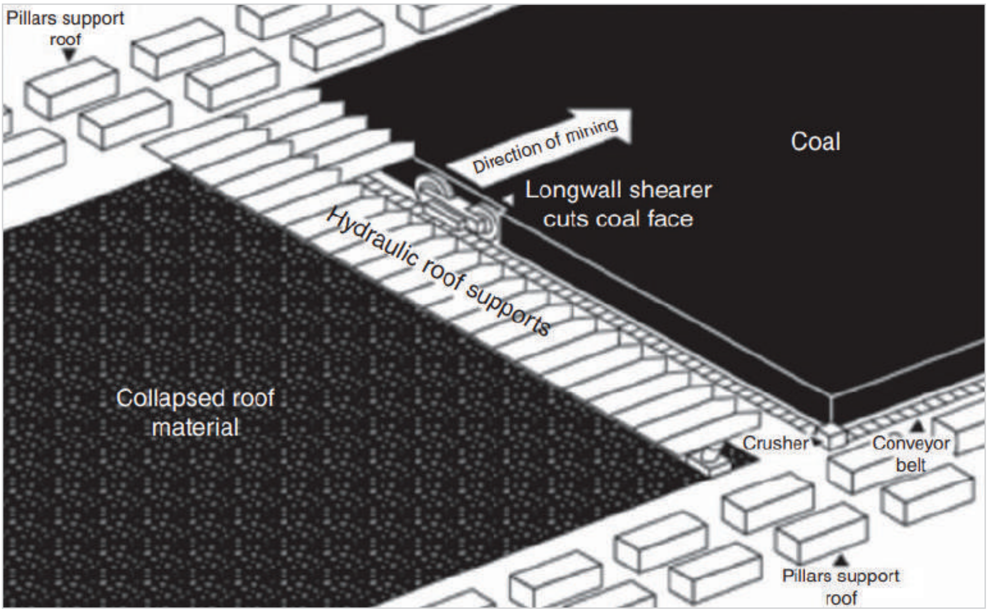


Source: EIA

Under favourable conditions, between 30 and 50 percent of the coal in an area can be recovered during development of the pillars. For recovering coal from the pillars, themselves, many methods are practiced, depending on the roof and floor conditions. The increased pressure created by pillar removal must be transferred in an orderly manner to the remaining pillars, so that there is no excessive accumulation of stress on them. Otherwise, the unrecovered pillars may start to fail, endangering the miners and mining equipment.

Long Wall Mining: 'Longwall' mining uses three basic system components: a cutting machine, usually a drum shearer, which moves back and forth across the coal face; an armoured face conveyor (AFC), which moves the coal to the belt conveyor in the gate road for removal from the mine; and moveable roof supports that both support the roof behind the cutting machine and conveyor and protect it This is a popular method of mining under which coal is extracted from a section of seam through the help of mechanical shearers. The shearers cut coal from a wall face which falls on a conveyor belt for further processing. As the face is mined, hydraulic supports hold up the roof of the mine after the shearer advances. The support is eventually moved forward towards the newly exposed coal face allowing the roof to collapse in the so-called goaf void behind the working face.

Exhibit 2.3: **Schematic Diagram of Long Wall Mining**



Source: EIA

Long wall mining is suitable for deep mining, generally with a depth of more than 300 meters. Hence, extraction of coal is much more efficient in this case with the recovery of more than 75% of coal deposits.

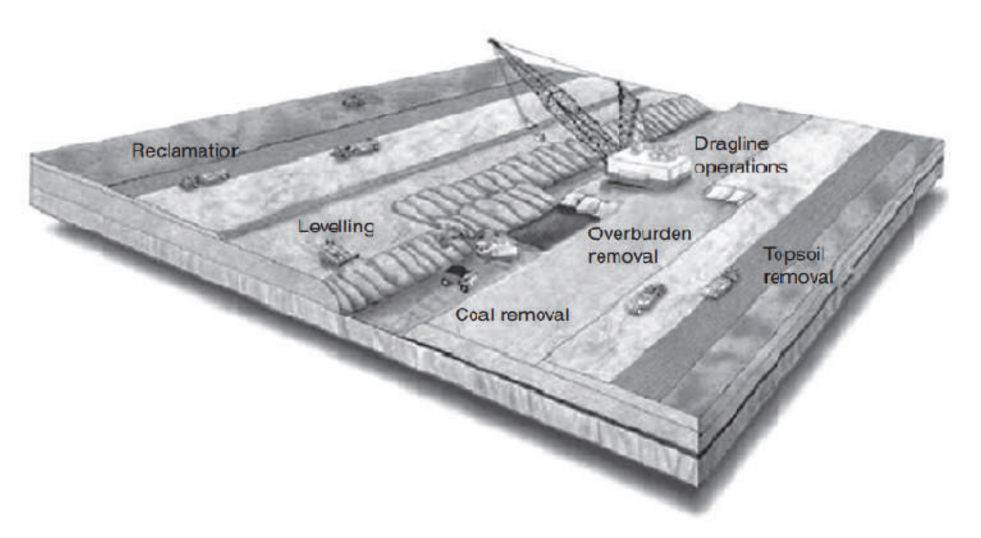
Initially, the coal panel must be prepared. This is done by using continuous miners to dig entries or passages on three sides of the panel, which is accomplished using a technique similar to that employed for room and pillar mining. After the blocking of the longwall panel, it is mined in either an 'advancing' or 'retreating' manner. Retreating' involves the development of the so-called gate-roads from the point of entry into the block to the far end of the panel, and then mining proceeds back towards the mine entrance. Retreating pre-explores the block, helping to identify any mining problems (faults, poor roof or gas) that might occur as the mining of the panel progresses. 'Advancing' begins at the entrance of the block and proceeds inward with the on-going development of the gate-roads. There are advantages and disadvantages to both methods. Advancing produces more coal from the onset, but introduces complications in continually advancing and maintaining the passages for coal conveying, movement of personnel and ventilation. However, the cost of equipment used in long wall mining is steeper than the capital cost of room-and-pillar mining and thus, it is more suitable for large-scale mining.

High Wall Mining: This is a hybrid technique between surface and underground mining in which while the machine is positioned on the surface, the cutter goes below the ground to extract coal without the need for manual entry into the coal mine. Being a safe mining technology, it is also versatile and can be applied to both opencast and underground mines that it may be otherwise economically unviable to mine. It therefore finds application in very thin layer seems lying at a shallow depth or exposed at the hill side.

Surface or Open Cast Mining

This form of mining is used in cases where coal bed is located close to the surface. This method is applied in case of coal seam being available at a depth of less than 200 feet. Coal extraction is highest in surface mining and 90% or more of the deposits can be recovered from the coal block. Surface mining is used when the economics of removal of 'overburden' to access the coal deposit is economically viable (i.e., increasing the profit margin). Coal seams with the greater depth require to remove a large amount of overburden, and the production cost of coal are higher. Nature of overburden is also crucial because hard and resistant overburden (for example, boulders,) requires blasting using efficient technology, which further increases the production cost. Here the understanding of stripping ratio is very important (Stripping Ratio = Unit Waste/ Unit ore cost of stripping overburden). Higher stripping ratio indicates a higher cost for overburden removal.

Exhibit 2.4: **Schematic Diagram of Surface Mining**



Source: EIA

Depending on the topography of the mining area there are several categories of surface mining:

Open cut mining: This method is used where the overburden is removed with 'draglines', large 'electric shovels and 'bucket wheel' excavators, after it has been drilled and blasted. The overburden is usually loaded into large trucks and removed to a waste area in the mine. The coal is then 'stripped,' usually after blasting, using hydraulic excavators or loaders, and removed from the mine using haulage trucks or conveyors.

Mountain top removal: This method is considered to be an alternative of drift mining or slope mining. The cases where the entire mountain top is considered to be the overburden and often removed to be used to fill in depressions nearby.

Auger Mining: This method is used where a trench is excavated and augers are used to extract the coal, usually in a narrow (thinner) seam, and often from 'high wall' mining where thicker seams are sheared or excavated with special machinery. Advantages of auger mining include higher productivity, greater safety, and lower cost. Different types of Auger mining:

- Add Car High Wall Mining Technology: It is a highly productive system that is capable of mining up to 1MT/year. However, it is constrained by the factor that it can be safely used only in mines with a strong roof as Add Car conveyers are open in design and if the roof of the mine collapses it is capable of damaging the conveying system.
- Auger High Wall Mining Technology: The auger high wall mining technology is considered less productive but safer than the Add Car technology as its augers (conveyer vehicles) are armoured and covered and can be safely applied under different conditions.

Advancement in Coal Mining:

Basic operational structure of all the coal mining companies remains the same- Across all the mines heavy mining equipment and machinery is used, productivity is measured in terms of ratio of hours worked and tonnes mined, the workers union structure almost remains the same and the knowledge endowment about mining i.e., engineering, geological and metallurgical education remains same. But the difference in productivities and efficiency in mining operations can be achieved by adopting modernization of mining in terms of adopting new technology and upskilling the existing workforce engaged in mining.

One aspect that dominates modern mining is increased uptake of robotics and automation. Automation and robotics are making much headway in mining due to the rapidly advancing state of communications, comprising cable and wireless, both within the mine, and between the mine and other entities.

In recent times two key developments have made adoption of automation and tele-operations jointly possible:

- Firstly, ability to construct a robust communication is considered to be most pivotal in the mine which is capable of handling data, voice, and video signals.
- Secondly, development of smart mining equipment, outfitted with onboard computers and a host of sensors

Bandwidth may be a somewhat limited commodity in surface mines, but the full radio frequency spectrum is available underground. International real-time communication connecting the mine site, regardless of how remote it is, to a centralized corporate office, to customers, to vendors and service providers is now a reality. Previously, communication on the mine site, both surface and underground, consisted solely of handheld radios and telephones. Today, the mine equipment can actually be used as communication nodes, with the mine site being transformed into a mesh communication system, rather than a point-to-point system. The system enables real-time vehicle diagnostics and payload data, automated traffic control, proximity detection, and remote centralized blast initiation.

Scope for Digitalisation in mining operation, control, safety management, KPI monitoring and MIS and its benefits after implementation

Sl. No.	Activity	Opportunity for Digitalization	Benefits from digitalisation
1	Safety	• Drone for surveillance • Virtual Reality (VR) based safety training • Ground-penetrating radar (GPR) • Collision avoidance systems • Intelligent injury response (Honeywell Intelligent Life Care) • Teleoperated mining equipment • Neural network technology based smart caps	• Drone with its analytics can improve mining safety on sites, by monitoring traffic, road conditions and hazards. • VR-Mine is based on the concepts of blended learning, gamification and flipped classroom, and focusses on the topics health and safety, and principles of underground mining. • GPR-Can provide real-time monitoring information to visualise potentially hazardous geological structures/ Dump. • warn operators with audio and visual indications of possible collisions, speeding or rollovers. • "The use of an intelligent life care system can provide faster and more accurate on-scene support and diagnosis until professional emergency services arrive at mine site. » They in turn can assess a patient's condition including the use of still images, video and vital signs, allowing the patient to receive diagnosis and treatment within minutes.

Sl. No.	Activity	Opportunity for Digitalization	Benefits from digitalisation
1	Safety		» The device can easily be used by non-medical personnel due to its easy-to-use interface, its step-by-step guidance and the comprehensive built-in medical and drugs database, therefore saving lives in difficult to reach mining operations." • Controlled by an operator at a remote location, teleoperated mining equipment can enhance safety by reducing the possibility of man-machine interactions. • BHP has used neural network technology based smart caps in 150 trucks which analyses driver brain waves to act according to the situation and thus accelerating productivity and safety.
2	Mine Planning	• Artificial Intelligence (AI) in Exploration • 3D Mapping • Face logging	• AI can eliminate time and money spent on detailed exploration as well as increasing discovery potential. • 3DP-improve mineral recovery by highlighting the most promising areas for excavation, reducing both time and operational costs. 3D images of the mining environment and topography are captured and analysed to evaluate plans such as targeting of drill holes, to zero in on high-quality ore in the least amount of time. • By face logging technology of Digit core software, better knowledge of deposit properties is possible.
3	Mining Operation	• Automated rock breakers and semi-autonomous crushers • Autonomous Trucks (AT) • Artificial Intelligence (AI)	• Cheaper running costs and flexibility to operate in different condition. • Improves safety by automatically identifying obstacles, and increases productivity by supporting autonomous operations • Throughput prediction: • Predict metal/mineral recovery at real time based on feed composition, concentration gradients across the process and material addition rates **Process modelling:** Create digital twins of mining processes that model the complex non-linear interactions between materials and mechanical parameters to run and evaluate various scenarios"
4	Data Analysis/ Quality Control	• Machine Learning • Data analytics and auto instructions	• Oversee operations and alert to abnormal situations • Observe product quality and specify issue causes without waiting for lab results • Notify equipment issues before unplanned downtime or catastrophic failure • Leverage all your data to increase capacity, reduce energy and improve quality
5	Survey	Drone for surveying	• Accurate topography, stockpile survey quicker and nearly real time volume handling.
6	MIS	• MIS • Truck despatch system	• "Automatic dispatching and truck reassignment in real-time, • In-pit blending, forecast of production and mine performance. Shift, equipment and drilling optimization. • Integrated Mine intelligence system to follow all the SOPs and alerts for non-compliance.
7	Transportation	• High Angle Conveyor (HAC)/ Rope way • Autonomous Trucks (AT), vehicles, Train	• HAC/ Rope way- Can save transportation time for transportation from hill top to ground level and complete control. • AT-Removing humans from hazardous environments or activities and eliminating 'human error'.

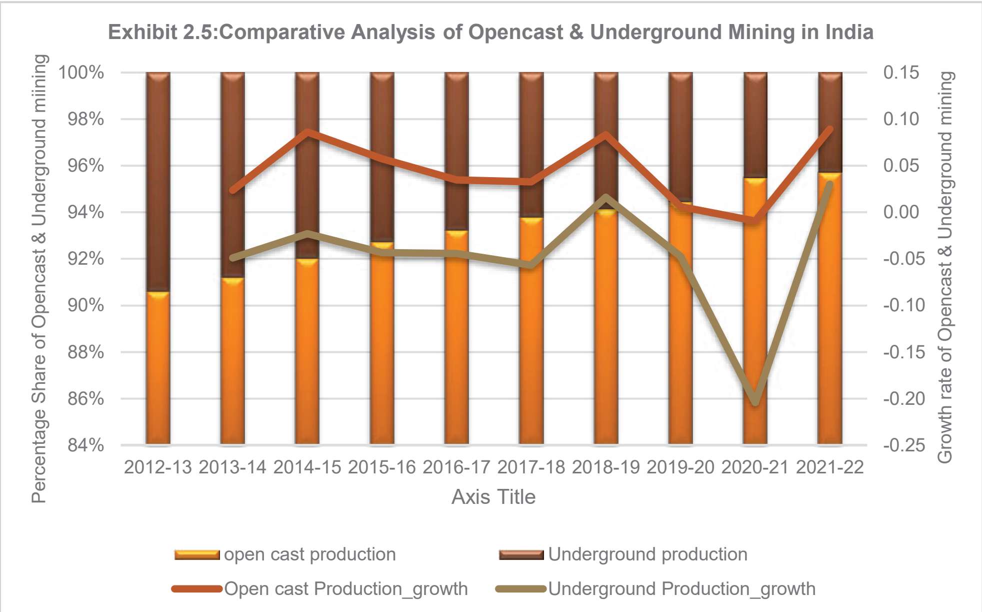
Sl. No.	Activity	Opportunity for Digitalization	Benefits from digitalisation
8	Maintenance	• Predictive Maintenance • 3D Printing	• Condition monitoring, data mining and machine learning can assist in predictive maintenance, auto fault diagnosis and automated parts ordering. Similarly, process optimisation can be automatically streamlined based on the mine data received. • 3DP has the potential to transform the maintenance supply chain for mines by offering quick access to a broad range of spare parts. • With 3DP, any item in the digital library can be replicated on site to suit the operations requirement. • Production of spare parts on-site and on-demand can reduce lead times and eliminate the cost-intensive process of transporting parts to remote sites in the event of equipment failure. • With spare parts stored digitally, warehousing and on-site storage costs could also stay at a minimum.

Summary:

1. Digitalisation in mines can be applied in many areas starting from exploration, planning to operation & monitoring measurement which are done manually today in most of the cases.
2. This improves the accuracy and provides a system for much improved predictability and real time monitoring & alerts etc to enable faster responsive implementation for safety, productivity and efficiency.
3. Enables Many fold increase in safety practices.
4. Reduces cost through manpower optimisation, preventive maintenance etc and make the mining operation more sustainable. A way to make Mining Industry more predictive and productive.

Status of Opencast and Underground Mining in India

Choice of mining method depends on various factors such as geological condition (depth, size, type, and quality of deposit), technological development and level of mechanisation. Besides these factors, production cost along with selling price, environmental and social aspects are also significant that should be taken into consideration before mining. Coal extraction in developed countries is mostly dominated by underground mining method over opencast mining method, and it comprises of 60% of world coal production. But in contrast to developed countries, practice of opencast mining is dominating over underground mining in developing countries due to lower cost of production and application of large mining equipment followed by higher productivity. India has a practice of both opencast and underground coal mining. Majority of the coal (approx. 84%) is mined by Coal India Limited (CIL) and its subsidiaries, and as of 2020 CIL has total of 352 coal mines and among them 174 mines are following completely opencast method of mining, 158 mines are following completely underground mining and 20 mines has mixed of practice i.e., both. During the time of nationalisation of coal mines in 1975 in India opencast had a share of 20% in coal mining. Then onwards the share of opencast has increased substantially and currently majority of coal in India is extracted by means of opencast mining methods, as on FY 2021-22 coal extracted from opencast mining is 96% and in contrary Underground mining is contributing 4% of coal extraction.



Source: LSI Research Calculation based on data from Ministry of Coal

In exhibit 2.5 comparative analysis of opencast and underground coal mining has been performed. It is clearly visible from the analysis that underground coal mining share has rapidly decreased over the years and is having a negative decadal CAGR of -4.43% of coal extraction. The decadal CAGR of coal extraction from opencast mining stands as 3.98% with an average extraction of 90% of total coal extraction. Exhibit 2.5 depicts a inter and intra analysis between opencast method and underground method of coal extraction. Firstly, between the two methods, opencast is dominating over the underground coal mining and the dominance has increased over time making underground method almost asymptotic. Secondly, the intra analysis within the method depicts the exponential rise in share of opencast method of coal mining year-on-year basis and falling share of underground coal mining.

Output Per Man shift (OMS) is a measure which is used to measure the efficiency and productivity of mine or particular mining method. It gives an idea about the efficiency and feasibility of a particular mining method. The higher value of OMS indicates the efficiency of mine, whereas the lower value indicates the unprofitable condition in mines. In India the opencast mines have much higher efficiency and productivity over the underground mines in terms of OMS. The extant technological efficiency of underground mining in India is not showing any significant progress and that is a critical reason for falling underground method of coal extraction. Reason for low OMS of underground mines is due to constraints in size, human resource, and technology. Opencast mines provide more enormous scope for applying modern, large and efficient machinery, which saves the labour cost and time. Due to the full exposure of coal strata, installation and operating the machinery is natural in opencast mines when compared to the underground mines. Equipment used in underground mines are expensive and can be used only for mining, whereas opencast mining equipment can also be used for building construction. But currently stripping Ratio for opencast mines in India is increasing at a faster rate, and with the increasing Stripping Ratio, the production cost has also been increasing for the opencast mines.

Advantages of Opencast coal mining:

- Extraction of coal over a large area.
- Less wastage.
- The benefit of using modern and large machinery.
- Less production cost of coal compared to the UG mining.
- Lesser Risk of Accidents.

Advantage of underground coal mining:

- Lesser Environmental Impacts.
- Extraction of Deeper Coal Seams.
- Can Avoid the Problem of Land Acquisition.
- Lesser Waste Generation.
- Involves greater man power generating more employment especially in developing countries

Disadvantage of Opencast coal mining:

- Alteration of topography- Land Degradation and land use, land cover change
- Removal of topsoil, contamination of soil and deforestation.
- Acid mine drainage and contamination of surface and sub-surface water.
  - Sedimentation within the river bed and lowering the groundwater table.
  - Displacement of people and land loss, damages of infrastructures, social instability, and unrest. Destruction of local ecosystem and habitat of species.

Disadvantage of underground coal mining:

- Land Subsidence and Damages to Property and Infrastructures due to Depillaring and Blasting.
- Over exploitation of Groundwater because of dewatering
- Damages to the Aquifer.
- Pollution of Land, Water, and Atmosphere.
- Health Issues to Mine Workers.
- Accidents and Deaths of Mine Workers arising because of flooding, subsidence, and outgassing within the underground mines.

CHAPTER 3

MARKET SCENARIO ANALYSIS OF COAL IN INDIA

Scope of the Study

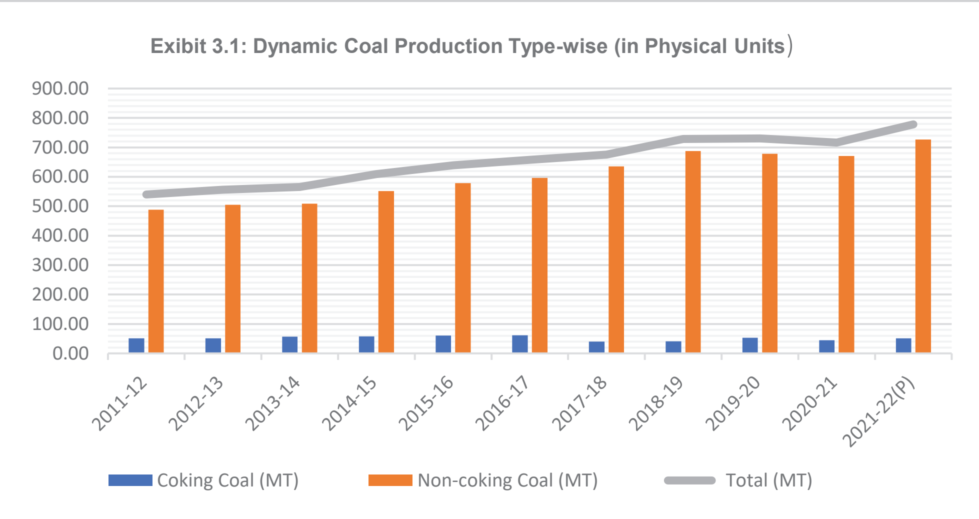
India is the fifth largest economy in the world with a realised growth rate of 6.2% in 2022 and the major primary energy support to the economic growth is provided by coal. The current share of India in global primary energy consumption is 6.1% and is likely to increase to about 9.8% under stated policies scenario by 2050. Though India has the fifth highest coal reserve globally, nonetheless, demand-supply imbalance of coal has steadily increased in recent years. India mitigates the demand-supply gap by importing coal heavily from Australia, Indonesia, South Africa. For an emerging economy like India coal is a double-edged sword for the growing economy it is like black gold, and at the same time it is like a black cloud for an environment friendly economy complying to guidelines of Paris Agreement. India is facing a twin challenge of high sustainable growth and simultaneously meeting the environmental compliances. India has been actively implementing world class technology in coal-fired power plants. The development of technology in the domestic market and adoption from international sources form part of the industrial policies with high priority. In this backdrop it is crucial to study the market scenario of coal in India.

The data-driven study is unique in detailing specifications by incorporating a coal-to-energy-usage efficiency indicator along with other influencing factors, into the demand–supply framework to understand the market scenario of coal. The study uses the annual the data from 2011 to 2021 of coal production and consumption and their respective influencing parameters corresponding to the same period. A **time series exploration** is performed by means of **regression analysis** to understand the **mean effect of the change in influencing variable on the dependent variables i.e., coal production and coal consumption**. The effect would be obtained in the form of estimates. In order to work with a balanced data-set (data-set for which data are available for all variables for each time point) the empirical exercise is limited within the mentioned timeframe. Following the regression analysis, a forecasting exercise for coal production and consumption is performed conditioned upon the behaviour of its influencing variable.

Note: Regression analysis includes many techniques for modelling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed.

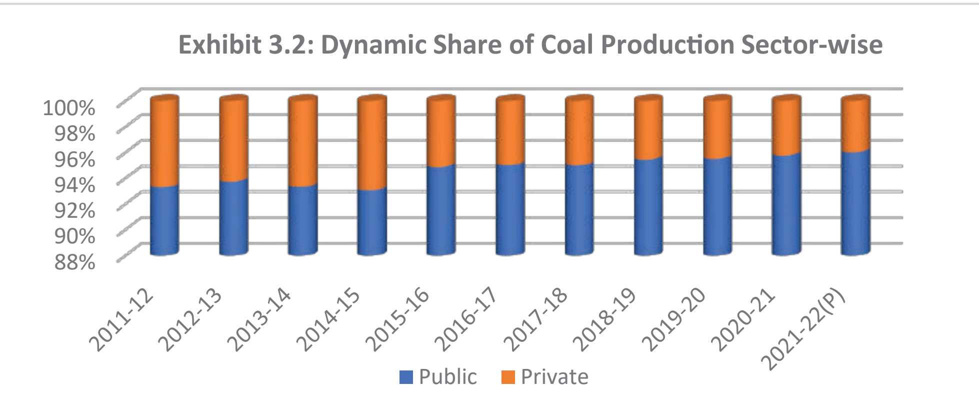
Coal Production Analysis

India's ongoing burgeoning economic activities is inducing high energy demand and India is in constant effort to supply secured form of energy to meet that respective demand. India stands in the third position with respect to coal consumption. The objective of secured energy supply is complimented with the target of reduced import demand of energy and to substitute that with the domestic supply. From the period of 2011 to 2021 CAGR of total coal production is 3.80%. Type-wise, coking coal production is 0.03% and non-coking coal production is 4.13%. India's coal production rose from 6.3% (805 Mt year-on-year) in 2021 to a stronger 11% (893 Mt) in 2022. Non-coking coal is dominating the production share and since domestic Coking Coal production is not adequate, the unmet demand is catered by import.



Source: LSI Research Calculation based on data from Ministry of Coal

Coal availability in India has improved significantly in India and historical shortage of coal has ameliorated. Nevertheless, even with increased domestic coal production there has been short-run disruption in the supply of coal from August 2021, against the backdrop of economic recovery followed by surging demand after the pandemic, and since then the shortage of supply has been seasonal till August 2023. Coal supply were disrupted by heavy monsoons in major mining regions domestically and high prices of imported coal led to liquidity problems resulting in insufficient stock build-up at power plants relying on imports. All combined created an acute supply shortage.



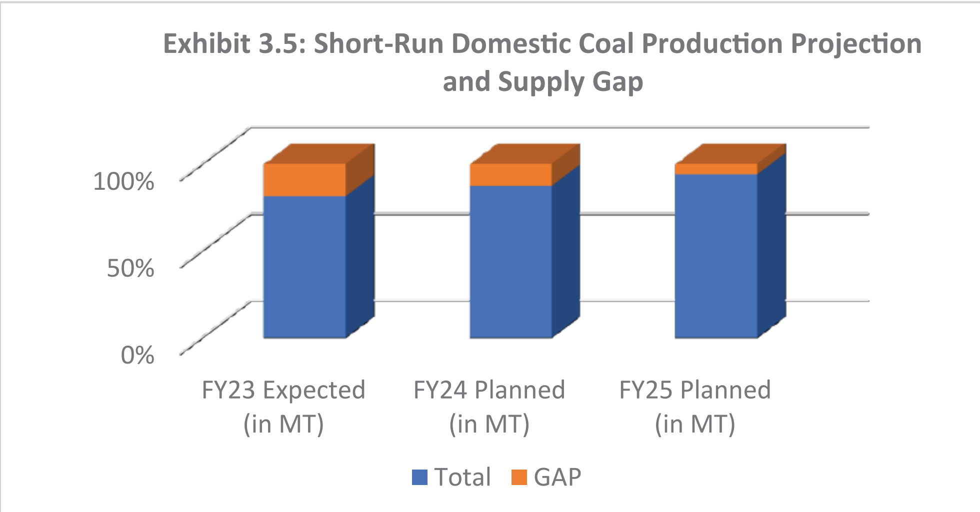
Source: LSI Research Calculation based on data from Ministry of Coal

India's coal mining has both public and private enterprise participation. Sector-wise CAGR from 2012-13 to 2021-22 is 4.08% for Public Sector and for Private Sector is -1.33%. Public sector has dominated the share of Coal Production historically but from 2011 to 2014 private sector has increased its share, and again since 2015 public sector has increased its dominance till present.

Further subdividing there are three kind of coal mines in India – Public, Captive, and Commercial.

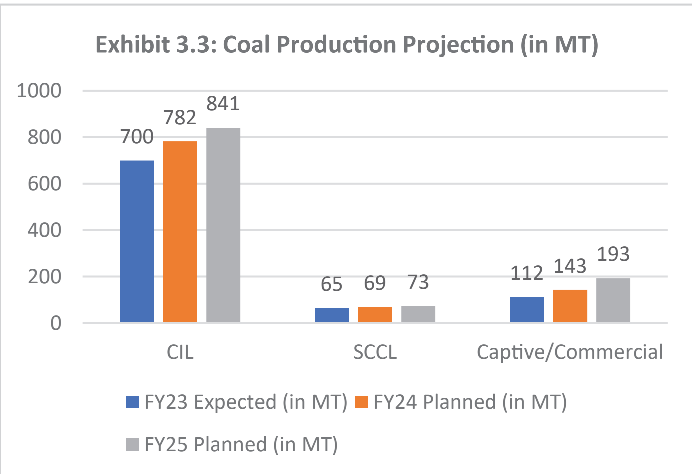
- Three state-owned coal mining companies - Coal India Ltd (CIL), Singareni Collieries Company Ltd (SCCL) and NLC - conduct public mining. CIL, the largest coal mining company in the world, accounted for ~77% of the country's production in 2021, and SCCL, the second-largest producer in India, for another 8%.
- Captive blocks are industry-owned mines to meet companies' self-consumption.
- Commercial coal blocks are auctioned by the government to private mining firms for commercial coal sale.

In very near future the production of coal from captive mining and commercial mining is about to rise. And in 2022 coal supply from these two respective categories has increased by 50% in combined manner.



Source: LSI Research Calculation based on data from Ministry of Coal & CIL

Every year demand for electricity grows by 4.7% on average. And in current times due to unprecedented rise in temperature there is an unanticipated surge in demand for electricity every summer, and during April-July, 2022, coal-based power generation witnessed an increase of 16.13% compared to 2021. Government of India in a bid to ensure secured supply of energy is striving hard to drive domestic coal production, and simultaneously reducing the import dependency of coal. Ministry of Coal is constantly engaging with all coal production companies and regularly monitoring their production to ensure adequate supply of coal to meet the surge in demand of coal due to increased power generation.



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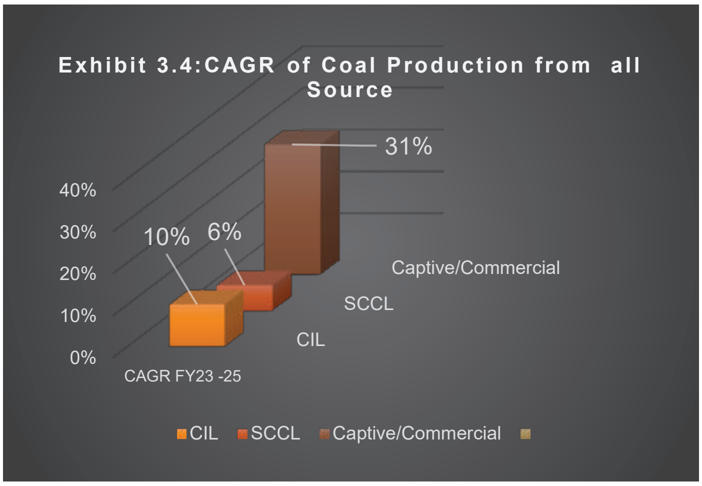
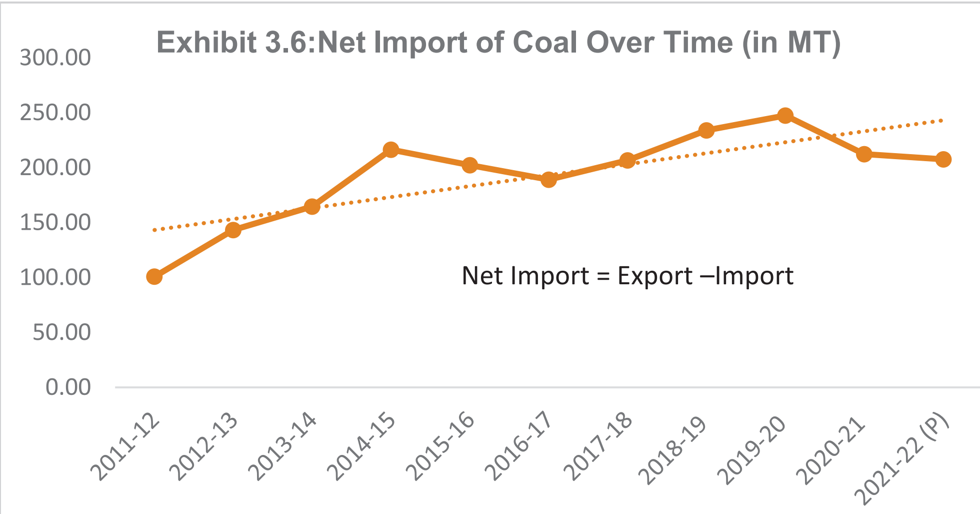


Source: LSI Research Calculation based on data from Ministry of Coal & CIL

The total coal production and despatch in the country have increased to 265.65 million tonnes (MT) and 291.32 MT respectively during Apr-July 2022 registering an impressive growth of 26.44 % and 13.05% respectively on year-on-year basis. The total coal despatches to power plants (including non CIL coal producing units) have been 250.51MT during Apr-July 2022, registering a growth of 21.31 % as compared to the same period of FY 22. Coal India Limited (CIL) has played an important role in augmenting production of coal and shows a growth of 24.33% and despatch growth of 10.06% during April-July 2022.



Source: LSI Research Calculation based on data from Ministry of Coal & CIL

To plug the shortfall in domestic coal supplies, coal can be freely imported under Open General Licence by the consumers themselves as per the present import policy. Coking Coal is imported by Steel Authority of India Ltd. (SAIL) while non-coking coal is imported by coal-based plants, cement plants, captive power plants, sponge iron plants, industrial consumers and coal traders. From the year 2012-13 to 2021-22 CAGR of Net Import of Coal in India is 4.21%. The government's intention is to reduce import dependency to drive coal production growth for which the government has issued a blend of push and pull measures in recent years. On the one side, the Government inflicts a penalty on underperforming power plants and specifying their fixed inventory levels. On the other side, the government permits captive mines to sell up to 50% of their production and to blend up to 30% of imported coal. To avoid the increasing import prices, the government has implemented directives to improve the liquidity of power plant owners indicating the diminishing supply gap in the above figure. Moreover, it is imperative to have a cost efficient, sustainable and resilient logistics ecosystem for making India's domestically manufactured coal globally competitive and for achieving the USD 2.5 trillion EXIM target by 2030.

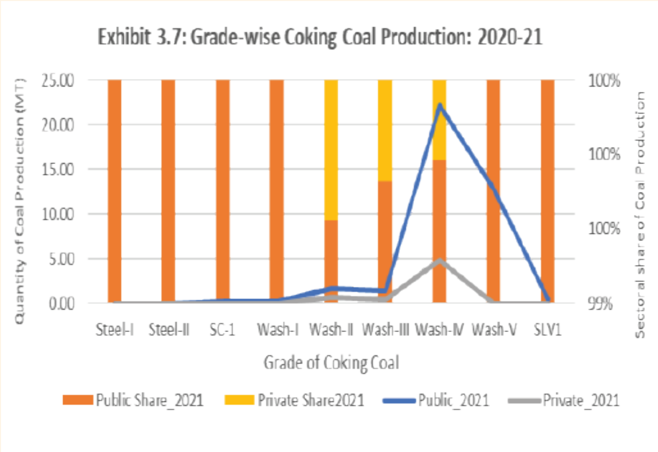
Commercial Mining- A Special Focus

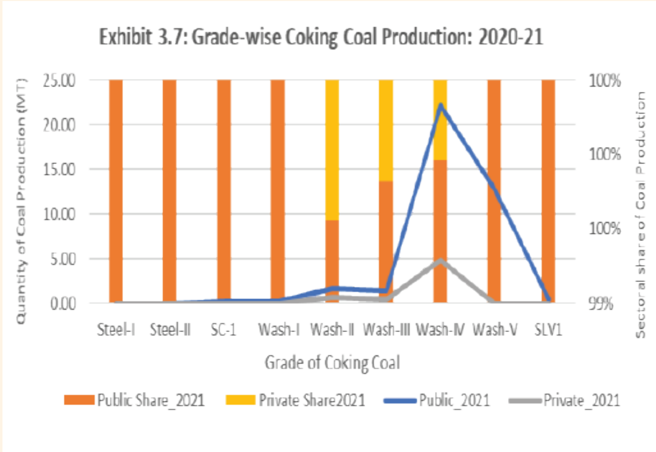
Government has given a major thrust in commercialization of coal mines, in its strategy towards boosting the domestic coal production. A special provision to reform the Mining Act in 2015 paved the way for the private sector to produce coal to be sold in the free market out of the monopoly of Coal India. Since November 2020 several coal blocks have been auctioned, allocating an estimated cumulated capacity of 156 Mtpa thermal coal and 6 Mtpa coking coal for commercial mining. In November, 2022 sixth round coal block auctioning (including 141 coal mines, of which 71 are new mines, 62 are ones not awarded in previous auctions, and 8 are ones for which single bids were received in the 5th auction) took place for initiation of commercial mining.

Captive mining has increased its production approximately by 30% in the year 2021-22. Currently 48 captive and commercial mines are in state to be operational and 5 coal mines located in Jharkhand are dedicated specifically towards supplying coal to power generation companies like NTPC DVC and Punjab Electricity Board. Captive and Commercial mining is expected to increase its 112 Mt in FY23 and from exhibit 3.4 it is observed that projected CAGR of captive and commercial mining in FY23-25 is expected to be 31% which is way ahead than CIL and SCCL.

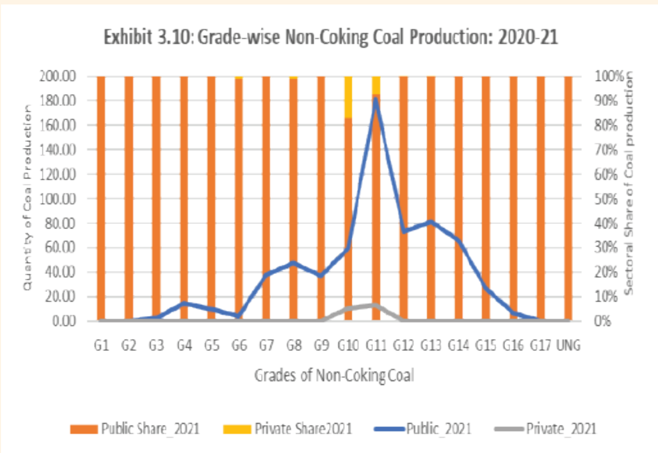
Snapshot of Coal Production Based on Grades

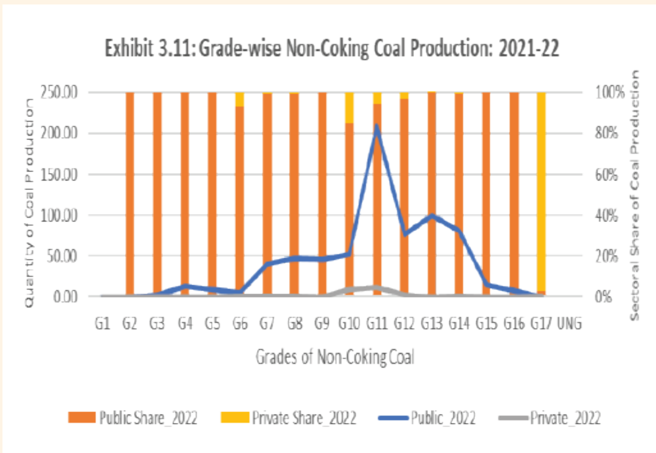
Grades of Coking Coal is based on ash content for semi coking /weakly coking coal it is based on ash plus moisture content. The gradation of non-coking coal is based on Gross Calorific Value (GCV)





- In case of Coking-Coal there are Nine Grades.
- Wash-IV &Wash-V are the highest producing grades
- Public Sector has dominated in production of coking coal in all grades.
- In the year 2020-21 Wash-II grade Private sector has more share over the public, and for Wash III, & IV grades, Private sector has shared the production space unlike the other Grades.
- Interestingly, in 2021-22 production in Steel-I, II is NIL and Private sector production share in Wash-I, II & III has completely become ZERO.





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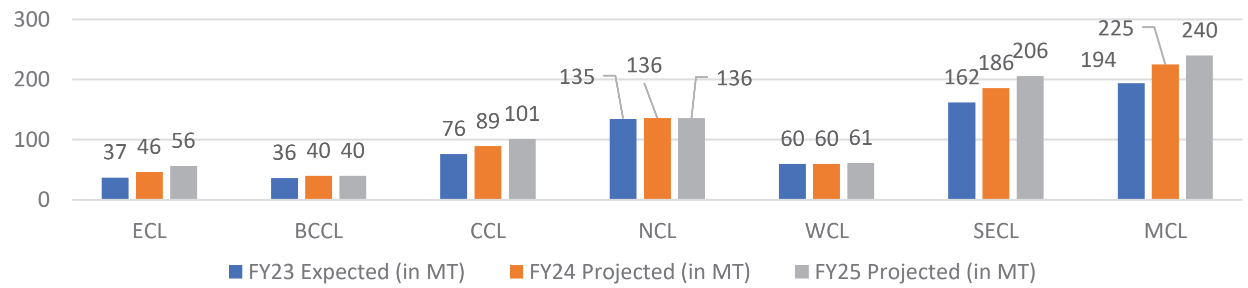
- Interestingly, in 2021-22 production in Steel-I, II is NIL and Private sector production share in Wash-I, II & III has completely become ZERO.

Grades of Coking Coal	
Grade	**Ash Content**
Steel Grade - I	Not exceeding 15%
Steel Grade -II	Exceeding 15% but not exceeding 18%
Washery Grade -I	Exceeding 18% but not exceeding 21%
Washery Grade -II	Exceeding 21% but not exceeding 24%
Washery Grade -III	Exceeding 24% but not exceeding 28%
Washery Grade -IV	Exceeding 28% but not exceeding 35%
Washery Grade – V	Exceeding 35% but not exceeding 42%
Washery Grade -VI	Exceeding 42% but not exceeding 49%
Grades of Semi-Coking Coal	
Grade	**Ash + Moisture**
Semi Coking Grade -I	Not exceeding 19%
Semi Coking Grade -II	Exceeding 19% but not exceeding 24%
Grades of Non-Coking Coal	
Grade	**Ash Content**
G-1	Exceeding 7000
G-2	Exceeding 6700 and not exceeding 7000
G-3	Exceeding 6400 and not exceeding 6700
G-4	Exceeding 6100 and not exceeding 6400
G-5	Exceeding 5800 and not exceeding 6100
G-6	Exceeding 5500 and not exceeding 5800
G-7	Exceeding 5200 and not exceeding 5500
G-8	Exceeding 4900 and not exceeding 5200
G-9	Exceeding 4600 and not exceeding 4900
G-10	Exceeding 4300 and not exceeding 4600
G-11	Exceeding 4000 and not exceeding 4300
G-12	Exceeding 3700 and not exceeding 4000
G-13	Exceeding 3400 and not exceeding 3700
G-14	Exceeding 3100 and not exceeding 3400
G-15	Exceeding 2800 and not exceeding 3100
G-16	Exceeding 2500 and not exceeding 2800
G-17	Exceeding 2200 and not exceeding 2500

Exhibit 3.12: CIL Subsidiary Coal Production Projection



Source: LSI Research Calculation based on data from CIL Annual Reports

Towards a Production-side Model: Considering Coal as a Major Source of Energy

Objective of the Study:

This section deals with the analytical part of the empirical model of production of coal. We develop an econometric approach to understand in what manner the significant parameters are influencing the production of coal and hence the supply. During the journey of economic growth of India, non-renewable source of energy (in our case coal) has a pivotal role, and in the entire process technology plays an important part maintaining a steady growth process and balancing demand-supply situation. Therefore, technology advancement in the coal mining sector and coal-based utility sector acts as a catalyst in reducing carbon emission. The role of coal technology and associated measures in reducing CO_2 intensity from coal is treated as endogenous in our production (aka supply-side) model.

Assuming a standard production function with respect to coal production, we incorporate a technology index (coal-to-energy usage efficiency indicator), which is endogenous into the production process. The aggregate output of coal is Y(t)

Y(t) = f (Net Import(t), Ultimate Coal Consumption(t), Coal Inventory(t), Coal Reserve(t), Manshift(t), Change in Capital Employed(t), Technology Index(t)).

The objective of the study is to estimate the above-mentioned functional relationship by means of Multiple Linear Regression Model (MLRM)- an econometric approach, to understand the impact of the influencing variables on the domestic coal production. The study will provide key insights related to the sector for all the stakeholders: policymakers, business world and to the investors, on specific points that are responsible for stimulating the domestic coal production side.

Description of Influencing Variable and Data- Coal Production:

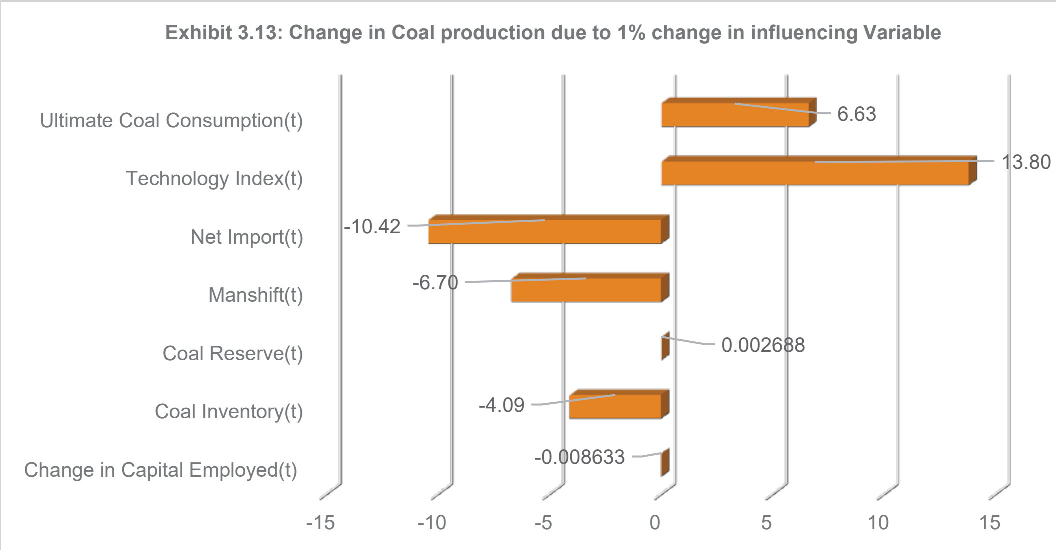
In the functional relationship mentioned above, important determinants of coal production are the factor of production- capital and labor. '**Change in capital employed**' is considered in the model which accounts year-on-year change in capital employed for- land, R&R and CSR, Mine infrastructure, HEMM, Railway Siding, Coal Handling Plant. 'Change in capital employed' is taken as the proxy for change in capital, assuming capital stock reflects changes in investment. And change in capital employed accounts for the constant depreciation rate in plant and machinery. '**Manshift**' is considered, which represents- a unit of work output equal to that of one man working through one shift. Another important variable '**coal reserve**' is considered in the model, which stands as the initial physical endowment of production. Depletion of fossil fuel reserve is an important yard stick to decide for the quantity of the fuel to be extracted because of its non-renewable characteristics and hence production optimization of coal given the resource constraint is performed every time. '**Ultimate coal consumption**' in lag period is considered as a crucial determinant for production in the current year because it is rational to expect the demand for coal from observing its previous periods trend, and following that optimal coal production can be decided upon. '**Inventory**' accumulation adds on to the overhead cost and is considered to be a negative factor, hence given the expected coal demand, production amount in the current period can only be decided upon after accounting for the inventory. Another crucial factor, '**net import**' (import- export) is accounted for in the model because domestic coal production is always function off its international trade. Last but not the least an important parameter, '**technology index**'- captures the effect of advanced coal technology (in combination of new advanced design unit) has been endogenized in the model. It has been strongly believed that the role of this technology-index captures the advancement of coal use into the growth process, and is significant in an increasing energy demand environment in India. We measure Technology index as CO_2 emissions from coal in generating per unit of energy measured in in India relative to that in Japan. Faster implementation of technology in India relative to the frontier leads to a faster reduction in CO_2 emissions in energy usage process. The underlying assumption here is that faster diffusion of technology is driving growth towards sustainable development along with other factors of production. In the absence of any composite measure, we define technology index (as **Atc**). The dependent variable coal production along with the independent variables ultimate coal consumption, inventory, coal reserve and net import are measured in tons.

Atc = (CO_2 emissions per unit of energy from coal)India / (CO_2 emissions per unit of energy from coal)Japan

Japan has been considered in the baseline since it has been in the forefront for adopting and diffusion of carbon reducing technology across coal-based utilities and especially in power plants.

Empirical Result and Analysis:

This section deals with the reporting and analysis of the results based on the statistical significance of the regression model of production of coal.



Source: LSI Research Calculation

Set of positive Influencing variable of Coal Production:

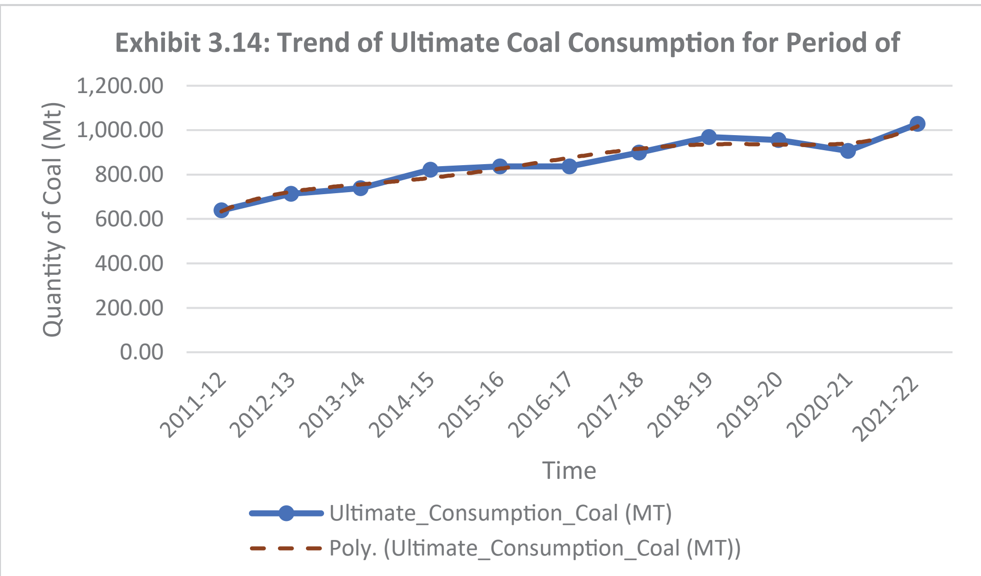
- We hypothesised that the variable Ultimate Coal Consumption is going to positively affect the dependent variable Coal production. And the regression model analysis conforms the hypothesis i.e., a positive change in the coal consumption in the previous periods will be leading to an increase in the coal production in the current period, since the current period coal production is decided by forming an expectation on last period consumption. While setting the expectation over the demand if any systematic mistake is occurred then that respective expectational error would be internalized in the next period coal demand expectation process, and in due course this rational expectation process will ultimately lead towards the optimal coal production based on demand in the long run. To account for the systematic mistake in short run we incorporate error correction model of timeseries econometrics. Error correction model confirms that though in short run there is disequilibrium but in long run the model indicates to be in equilibrium.
- **Coal reserve** plays an important factor in the coal production process. From the empirical model it is observed that increase in coal reserve is positively affecting the coal production, because coal being a non-renewable resource has to be extracted judiciously. Growth of coal reserve happens organically but with a very slow pace. But coal is required constantly to fuel the economic growth, hence a natural increase in coal reserve is going to positively influence the coal production.
- **Technology index** is hypothesised to have a positive relationship with the coal production and the regression model also conforms the same and is the most dominant positive influencing parameter. As mentioned above, the technology index is capturing the advancement of coal technology in coal production process in terms of clean coal, as well as the carbon reducing technology of coal-based utilities. Hence improvement in technology parameter is going to positively affect the coal production to cater the growing energy demand, because in the extant energy portfolio, coal in India is relatively abundant in supply and available at relatively cheaper price. Thus, it can be concluded that with the available clean technology of coal in both at the production end and at the usage end would increase the coal demand and correspondingly the supply.

Set of Negative Influencer of Coal Production:

- **Coal inventory** is hypothesised to have a negative relationship with coal production and the result of the regression model has been in conformity with hypothesis. Accumulation of inventory is perceived negatively in the production decision by the coal plants. Principle decision rule for the coal plant will be to first clear off the existing stock before extraction of fresh coal from the mines.
- From the result of the regression model, it is observed that increase in **Net import** has a negative impact on the domestic coal production. Though government is taking lot import substitution policy in regard to the coal, but quality of coal is poor and not fit for producing steel since ash content is very high. Coal fired power plants in the western part of the India sometimes imports the coal as their primal input, firstly to reduce carbon emission because of high ash content in coal, and secondly, since majority of the coal is found in eastern coal fields, the transport cost or railway freight charge cost them very high.
- **Manshift** a crucial influencing variable is hypothesised to have negative relation with respect to coal production, and the same is in conformity with the regression result. Manshift plays an important role in deciding the productivity or OMS (output per manshift) and therefore should be optimized to improve the productivity of a mine. Mathematically, the OMS is given by the ratio of production to the manshift in a mine. Therefore, for a given production, if the manshift is decreased, the OMS will be increased.
- **Change in capital employed** is an influencing variable to coal production hypothesized to have positive relation with the dependent variable. But the result from the estimated regression model shows the other way round, i.e., change in capital employed has negative relation with the coal production. The result is implying that marginal productivity of capital has become negative and the operation of coal mining is not enjoying the return to scale. To increase the efficiency of the production system the cost of capital has to be reduced and improvement in technology can have a trajectory shift in the production process towards a positive quadrant.

Coal Consumption Analysis:

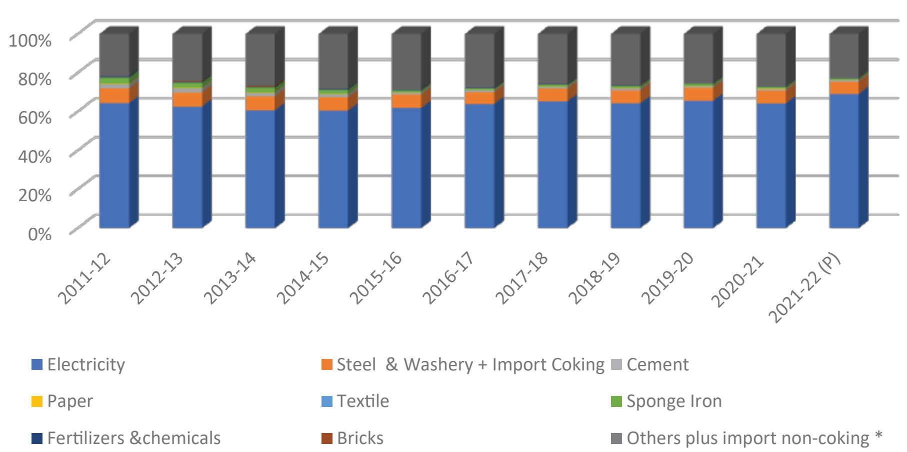
Indian economy has always been heavily coal dependent for its economic growth. Dependency on coal happens due to the abundancy of the resource availability and relatively cheap price than its other competitive fossil fuel sources. IEA states that per-capita coal demand has increased from 25% in 1990 to 60% in 2019 in India. Coal consumption is expected to remain high in India in the near to medium future. For the period of 2011 to 2021 CAGR of ultimate coal consumption has been 3.71% and the estimated trend of coal consumption is upward rising as depicted in exhibit 3.14.



Source: LSI Research Calculation based on data from Ministry of Coal

Coal-based thermal power started rapidly growing in India since 1970, which lead to the rise in demand for non-coking or thermal coal. In 1970 electricity generation consumed only 20% of the coal produced, and with due course of time as Indian economy progressed, penetration of electricity both at the production process and at the consumer utility-level happened more rigorously, which lead to increase in the electricity's share of consumption in coal up to 70% in 2021. Since the early 1970s, indigenous coal has primarily fuelled the Indian power sector and, concurrently, most of the coal produced in the country has been used by the power sector The use of coal for power generation was accelerated by the creation of National Thermal Power Corporation (NTPC) centrally-owned public sector corporation that focused on installing of pithead coal power plants to provide additional thermal power to the regional grids. Locating coal-based power at pithead locations was considered optimal as it was more economical to locate power plants near coal mines rather than transporting the coal to power plants located near load centres. Power plant manufacturing capability in the county was also consolidated with the formation of the Bharat Heavy Electricals Limited (BHEL), which began to supply indigenously manufactured power plants in 1970 Along with the industrial expansion, the other two significant reason behind the increase in the consumption share has been massive electrification of railways and rural India.

Exhibit 3.15: Dynamic share of Consumption of Industry-wise



Other consumers for coal include the **iron and steel industry, cement manufacturers**, and industries such as **fertilizers, textiles, paper, brick-making**, etc. In the history of coal consumption railways in the second half of the nineteenth century had the entire dominance over it, but from the railway's share of coal consumption lowered down to 20% only in 1970, and direct coal consumption by the railways ended by the mid-1990s, as the railways became entirely based on electricity and diesel

The iron and steel industry, which primarily consumes coking coal and some high-grade non-coking coal, is the second largest consumer of domestic coal. Domestic coking coal supply has reduced since the mid-1990s, as coking coal reserves in the country are quite limited; hence, the steel industry accounts for much of India's coal imports. For the entire period of 2011-2021, Electricity (Power sector) has dominated the consumption share of coal followed by Cement, and Steel & Washery sector consecutively. **CAGR** (2011-12 to 2021-22) of **Coal consumption** in **electricity** has been **5.28%** and for **cement** and **steel & washery sector** has been **-6.32%** and **2.64%** respectively. In the same period, **consumption of coal** in **brick sector** has been the **lowest** with a **CAGR** of **-39.43%**, followed by **textile** and **sponge iron** having CAGR of **-13.5%** & **-9.31%** respectively.

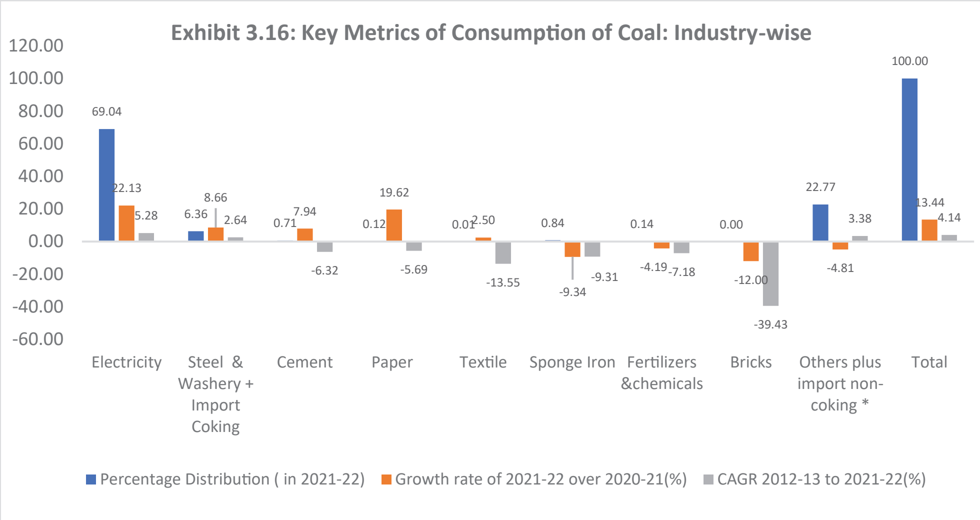


Exhibit 3.16: Key Metrics of Consumption of Coal: Industry-wise

Source: LSI Research Calculation based on data from Ministry of Coal

Coal demand is expected to rise near to 1.8 BT in most optimistic scenario, however correspondingly supply of coal is going to rise near to 1.5 BT. Hence the inadequate supply of coal has to be substituted with either the imported coal or the production has to be increased by means of advanced coal technology. Therefore, meeting the expected coal demand would require greater investments in domestic production and also importing greater quantities of coal

Challenges and scope in coal-based power sector:

- The poor quality of coal is an important issue that affects the power sector in several ways. The designs of the coal-handling systems, pulverisers, boilers, economizers and electrostatic precipitators (ESPs) have to be altered to account for the high ash and low calorific value of Indian coals. The use of low-quality coal increases auxiliary consumption, operation and maintenance costs and time, and reduces overall efficiency. The high silica and alumina content in Indian coal ash is another problem, as it increases ash resistivity that reduces the collection efficiency of electrostatic precipitators and increases emissions.
- The high ash content in Indian coals implies that at least one acre of land is needed for one MW of installed capacity, and hence there are many large power plants with more than 1000 acres of land dedicated simply for ash storage. Over the past decade, 1.4–1.5 million tons of ash was produced annually per GW of installed capacity, with the number increasing slightly over time because of increasing ash content in coal and increasing PLF. In order to increase ash utilization, MoEF in 1999 mandated a 100% utilization of fly ash in a phased manner by 2013–14.
- Supercritical pulverized coal (SCPC) technology is well suited for the Indian coal power sector, especially in the near term. SCPC technologies, including flue gas desulfurizers, would be at least 5% more efficient than current 500 MW subcritical units and the use of washed coal would increase the efficiency by another 1% hence, the overall coal consumption (if using washed coal) could reduce by at least 6%. While washing of coal does result in some loss of coal in fines, the gain in efficiency in coal transportation and power-plant operations as well as ease in coal handling and operation and maintenance of power plants underline the need for using washed coal in supercritical PC plants. Moreover, it has been noted that in the Indian case, a simple deshaling and supplying plants with a uniformly-sized coal would be sufficient in improving power plant performance. Technological advances and greater operational experience through these programs will lead to a better understanding of the technical and cost trajectories as well as the feasibility for large-scale deployment of new technologies that will increase efficient use of coal and help reduce positively.

Towards a Consumption-side Model: Considering the Robust Usage of Coal

Objective of the Study:

This section deals with the analytical part of the empirical model of coal consumption in India. Here a similar sort of analysis like the coal-production will be performed to understand the market scenario from the demand side perspective of coal in India. Coal is a dominant source of energy historically in India, but currently with the pledge to reduce carbon emission downstream industries are devising new strategies to employ non-renewable sources of energy in their energy portfolio mix. But still coal demand is expected to remain high given the most reliable source, based on the regularity of supply. Hence it is of utmost importance to understand the crucial parameters on which the demand of coal depends, so that relevant production decision (including planning and stream lining the logistical arrangement for supplying coal) can be taken promptly to supply optimal amount of coal in due time.

We assume a standard coal consumption function. The aggregate coal consumption is represented as C(t):

C(t) = f (Coal Price(t), GDP(t), Manufacturing Index(t), Electricity Index(t), Trade-openness Index(t)).

By means of a **Multiple Linear Regression Model (MLRM)**- an **Econometric approach** here in this study we try to estimate the above functional relationship for understanding the impact of the change in influencing variable on the coal demand in terms of magnitude and direction.

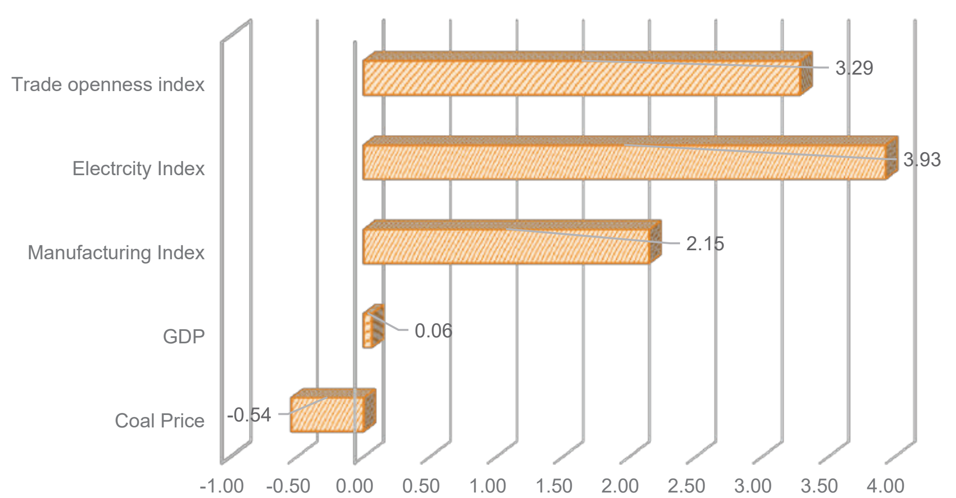
Description of Influencing Variable and Data- Coal consumption:

Dependent variable coal consumption (the demand variable) is represented by the "**Ultimate Coal Consumption**" measured in tons. In the functional relationship above determinant of coal consumption is considered is "**coal price**", and the WPI for coal is used as the price measurement in the analysis. Since 2000 coal price reform happened in India but coal prices in India is semi-regulated. Stimulated by increasing demand, the increasing trend in price has created intense bargaining between coal companies and power plants. Another important variable "**GDP**" is considered in the consumption analysis, since demand for coal (as the primary source of energy in India) is going to increase more with the rising economic growth and the prediction of demand for coal is directly function on the trend of economic growth. Trade exposure of India has been a significant factor in raising coal consumption in India, hence openness of the economy, which reflect the effects of trade liberalisation, is considered in the model as "**Trade Openness**" variable. Trade Openness is measured as share of exports and imports in GDP. "**Electricity index**" representing the power sector performance is a crucial influencing parameter in the model, because power-sector has the highest consumption share in coal consumption currently and hence the performance of the respective sector is directly going to affect the demand for coal. "**Manufacturing Index**" has been considered in the model as representation of performance of overall manufacturing sector- since coal is used by many heavy manufacturing industries and their respective performance is going to directly affect the consumption of coal.

Empirical Result and Analysis:

This section deals with the reporting and analysis of the results based on the statistical significance of the regression model of Consumption of coal.

EXHIBIT 3.17: PERCENTAGE CHANGE IN COAL CONSUMPTION DUE TO 1% CHANGE IN INFLUENCING VARIABLE



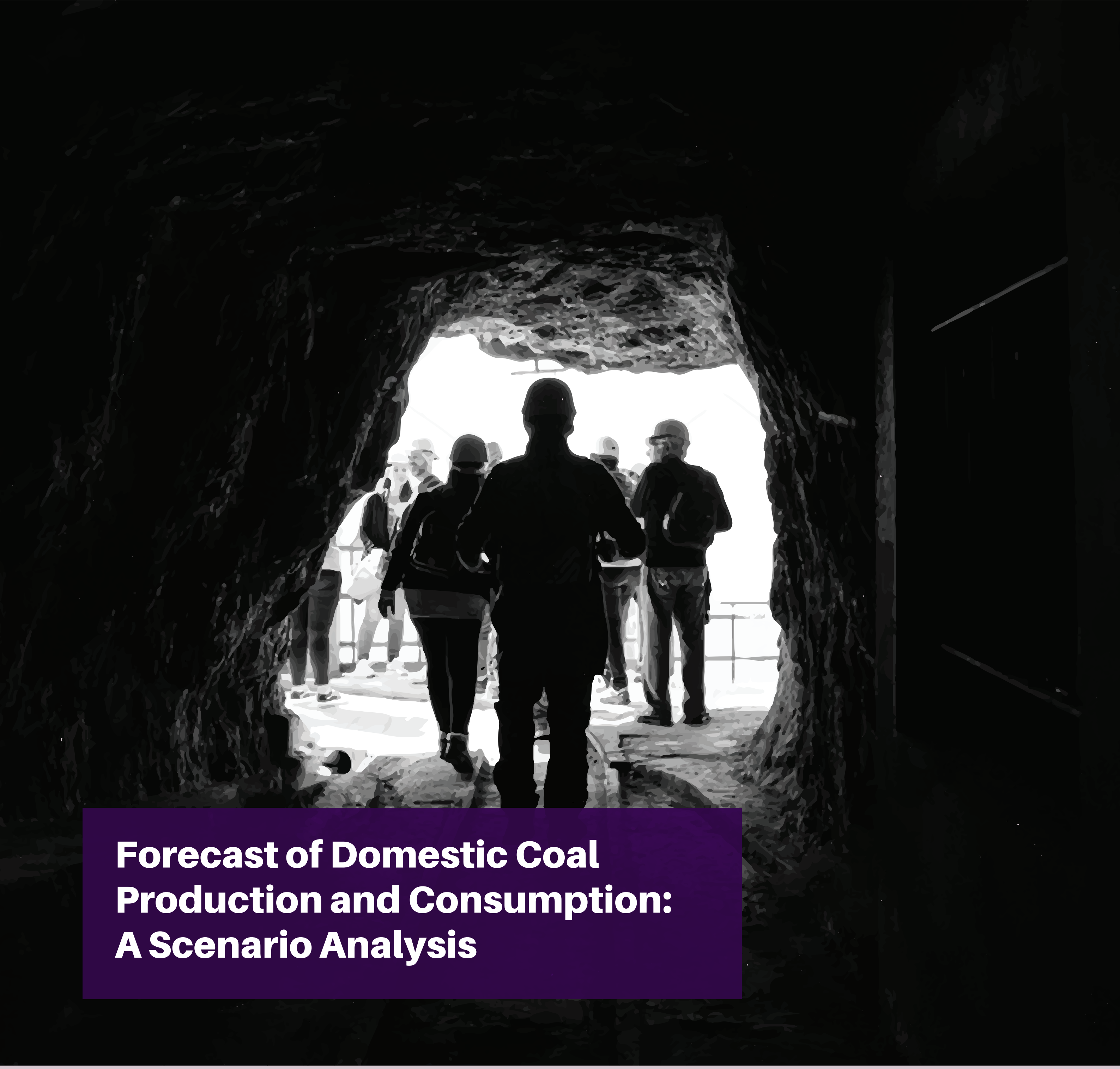
Source: LSI Research Calculation

Set of Positively Influencing Variable of Coal Consumption:

- From the regression model coal consumption is found to have a directly proportional relationship with the Trade Openness of the economy. Export growth of manufacturing has increased with due course of time which have direct impact on the coal consumption by the manufacturing industries. Along with this, shift in the service sector trade in India from the developed part of the world has made India the leading economy exporting services. Growth of the service sector lead income has an important impact on the domestic manufacturing sector in the form of linkage and multiplier effect, causing more demand of coal by the manufacturing industries due to an indirect impact of trade openness.
- Along the line of expectation, increase in the performance of the Electricity Index is having a positive impact on the demand for coal. The parameter is affecting coal demand to the highest compare to the other parameters because currently thermal power has the majority share in generation of electricity and following that power sector has highest consumption share in coal produced in India.
- Manufacturing Index is observed to have a directly proportional relationship with the coal consumption. Many industries such as iron and steel industry, cement manufacturers, and industries such as fertilizers, textiles, paper, brick-making uses coal as the major input in their production process. Implying with the growth of these industries coal consumption is going to increase.
- GDP is hypothesised to have positive relationship with coal consumption and the result from the regression model is in in conformity with it. Increase in the economic activity by means of any sector (manufacturing, service and agriculture) is going to have direct impact on the primary energy consumption both at the production and household end. And spill-over effect of income is going to generate demand in manufacturing sector and the power sector, significantly rising the coal consumption.

Set of Negatively Influencing Variable of Coal Consumption:

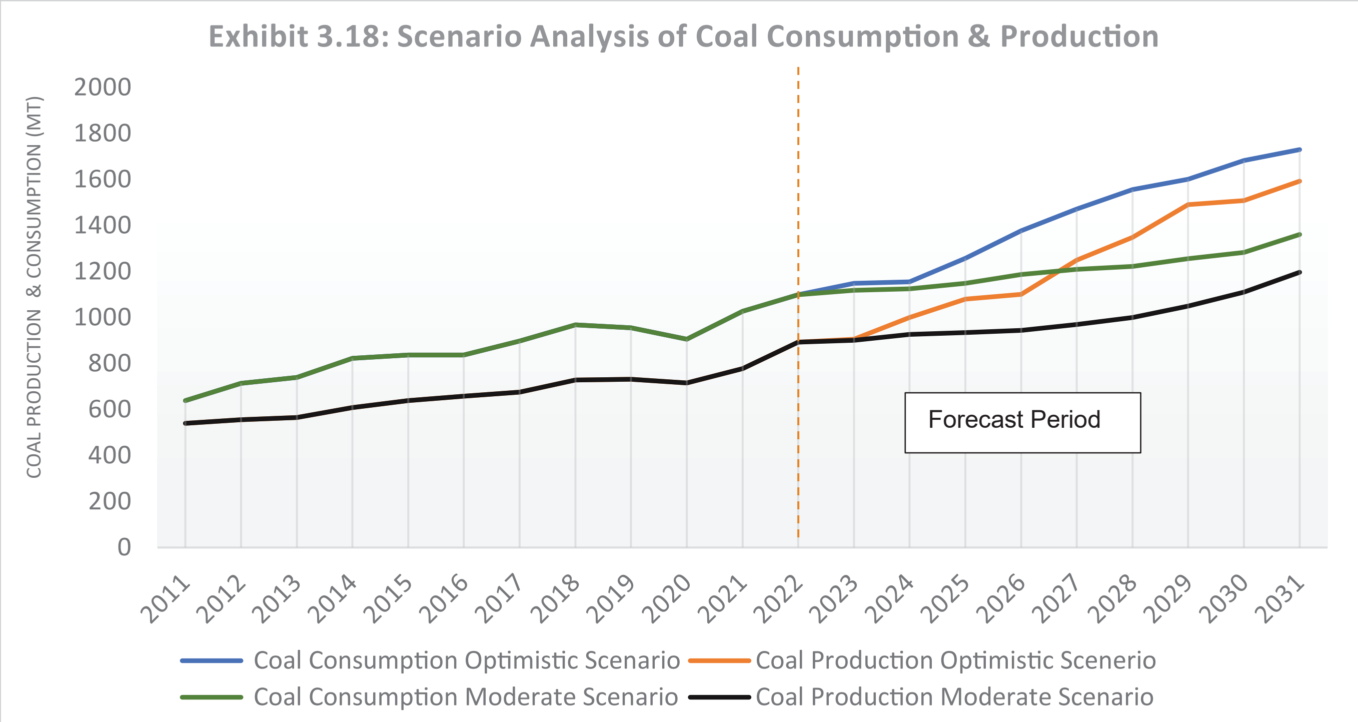
- Coal Price is the only variable having negative influence on the dependent variable coal consumption. But the estimated price impact is not significantly affecting the coal demand, implying the nature of coal demand to be inelastic. From the inelastic demand for coal, it is deducible that coal is still the dominant form energy in terms of availability, reliability and usability among all the other competitive sources.



Forecast of Domestic Coal Production and Consumption: A Scenario Analysis

Estimated time series regression model result of coal production and consumption has been utilised further to conditional forecast of the domestic coal production and consumption. Statistical test has been performed to verify the long run equilibrium relationship among the set independent/influencing variables and the dependent variables i.e., coal production and coal consumption. The long run relationship is established since the set of influencing variables are cointegrated with the coal production and consumption respectively. After confirming the long run equilibrium relationship, the forecasting of the coal production and consumption has been done for the period of 2022-2031.

While forecasting the coal production two scenarios have been considered – an **Optimistic Scenario (S1) and a moderate scenario (S2)**. Two scenarios have been considered based on the **coal demand situation (forecasted) and technology index**



Source: LSI Research Calculation

- **Optimistic Scenario (S1)** states the situation where there will be towering energy demand to maintain high economic growth, and correspondingly the coal demand. In this scenario the coal is considered to be the most reliable and secured source of energy supply compared to its competitive sources- renewables, whose supply flow is bleak. The situation also conditioned upon the fact of current renewable deployment rate, the capacity utilization rate and other limitations of renewable energy supply. The scenario is also based on the postulate that technology index representing advancement in coal technology in terms of clean coal at both production and coal-based utility consumption end is going to improve further and hence demand for clean coal. The CAGR of forecasted coal production in S1 is found to be 5.9% and forecasted coal consumption is 4.6%
- **Moderate Scenario (S2)**, a moderate situation is considered where the coal demand by the downstream industries majorly power sector is going to slow down with the objective of reducing carbon emission. The CAGR of forecasted coal production case of S2 is 2.6% and forecasted coal consumption is 2.1%. the situation also can arise due to non-progression on the part of technology index of coal. The scenario is also like to be realised if the deployment growth of renewables happens at a faster rate compare to the current rate, given the renewable expansion target of Indian government.
- **In both the scenarios** it is observed that there will be a rise in the forecasted coal production. Coal production forecast in S1 has a steep rise compared to the rise in S2, and rate of increase of coal production is higher compared to S2. Another significant observation from the exhibit 3.18 is there will be always a demand-supply imbalance in both the scenario. In Scenario-1, though CAGR forecasted coal production is more than the forecasted coal consumption, still there is existence of demand supply imbalance, because the base level of coal production is significantly less than the base level of coal consumption in absolute terms. But in case of scenario-1, (as shown in exhibit 3.18), an accelerating growth rate of coal production due to the possible increase in the efficiency of the mine and some pro-coal government policies like commercial mining and the mandate to increase the coal production from the captive plant, is narrowing the gap between the forecasted demand supply scenario, suggesting a possible convergence between them in the long run. In case of Scenario-2 the forecasted CAGR of coal production is less than the coal consumption, implying a less chance of convergence.

Domestic Supply of coal is constrained by certain factors creating the gap between demand and supply. This demand-supply imbalance needs to be minimized, addressed by increasing domestic coal production and maintaining its growth in following ways-

a) Better understanding of coal resources

The Indian Coal industry is based on geological evaluations without assessing the quality and mine ability and the coal resource inventory includes reserves that are already depleted and cannot be mined further due to geotechnical constraints. Hence resolution of uncertainties and significant improvements in the assessment and classification procedures and restructuring of institutional responsibilities to ensure the collection and reporting of better data on the availability of resources and their extraction potential is necessary for sustained growth in the coal sector.

b) Improved coal extraction

Over the past decade, underground mining has essentially stagnated over the past decade with annual production decreasing to below 65MT in recent years. The economic extraction of coal reserves to seams located within 300-400 meters below ground has been limited by the lack of mechanized longwall technology. Hence large increase in both underground opencast mines can be achieved by better adaptation of foreign technologies and building up manufacturing and design capability in longwall mining technology and providing incentives for mining companies to take up advanced extraction technologies.

c) Improving coal quality and transport

The quality of the Indian coal is poor which has the general properties of Southern Hemisphere Gondwana coal whose seams are inter-banded with mineral sediments. Because of increased opencast mining and production of coal from inherently inferior grades of resources, the ash content in Indian coals have been increasing over the past decades. Coal washing and coal beneficiation for thermal power applications are increasingly needed. Washing coal improves thermal efficiency by reducing mineral content and also reduces cost of transporting coal for a given requirement at the power plant. Coal transport is heavily relied on railways but high levels of railway tariff for coal are used to offset costs of passenger transport. Hence, continuous review of railway tariff and a well thought out railway-cum-sea route to southern and western ports would help improve coal transportation.

CHAPTER 4

ENVIRONMENTAL, SOCIAL, & GOVERNANCE (ESG) OF COAL MINING

The Concept of ESG and Sustainable Mining:

Presently, ESG (Environmental, Social and Governance) factors have become the minimum operating standard in the mining industry where investors and consumers increasingly recognize the industry as not only a first source of emissions in the value chain but also as a provider of critical raw materials needed for the global energy transition.

ESG

ENVIRONMENTAL

Environmental responsibility

a) Energy Consumption and Efficiency.
b) Carbon footprints and climate change
c) Waste Management
d) Renewable energy
e) Clean Technology
f) Forest management
g) Recycling process

SOCIAL

Social Responsibility

a) Community relations
b) Diversity, equity and inclusion programs.
c) Workplace safety
d) Fair treatment of customers and suppliers
e) Human rights and labour standards
f) Employee relations and benefits.

GOVERNANCE

Corporate Governance

a) Company leadership and management
b) Business Ethics and integrity
c) Transparency
d) Shareholder rights and structure
e) Board independence
f) Rules on bribery, corruption, conflicts of interest and political donations and lobbying.
g) Risk management initiatives

Mining has a direct impact on the environment and acts as a strong nexus with the community. Recently, the term "Circular Economy" is gaining ground and contributes to combating climate changes. As the starting point of all finished products is largely commenced with the mining activities, hence ESG in mining becomes more important that characterize a sustainable, responsible or ethical investment.

Environmental Stewardship	Avoid, minimize and mitigate any potential negative impact of mining operations on environment
Social Performance Leadership	Improve well-being and enhance prosperity and resilience of mining communities
Governance Excellence	Strong internal systems and controls to measure and report performance

Environmental and Social Impacts of Coal Mining:

As a result of the large scale of mining activities and the significant expansion and dominance of open cast mining, Coal mining is associated with significant social and environmental impacts.

The major impacts include-

1. **Air Pollution**- The release of total suspended particulates from fugitive dusts during open-cast mining and transportation operations often exceed air pollution standards for human health and affect plant life. It calls for higher maintenance costs of the mining equipment. Coal mines are often affected by fire which leads not only to safety issues for mine workers but also to economic losses as well as a source of air pollution for neighbouring areas.
2. **Greenhouse Gas** - Methane, an important greenhouse gas is released into the atmosphere during coal mining which causes an adverse effect on the environment.
3. **Effect on water resources**- Many of the coal mines are in regions with water scarcity, hence coal mining, washing and associated activities affect water resources adversely. Groundwater aquifers are affected by Opencast mines, runoff from mines and coal washeries. Moreover, in the North Eastern Coalfields where sulphur content is very high, acid mine drainage results in significant impacts on local water bodies.
4. **Land degradation and deforestation**- About 0.25% of the total land area of India is under mining. Unless proper planning and management are made for the restoration of the mined area to a status better than what it was before the commencement of mining operations, a mine that produces 40 MT of coal over a period of 15 years, could result in a scar of 25 sq. kms. Coal mining also results in deforestation with a concomitant effect on biodiversity and wildlife corridors. Underground mining results in land subsidence which can damage engineering structures in neighbouring areas.

ESG opportunities in Mining-The Path forward:

- Miners are increasingly incorporating environmental, social and governance factors into their decision making, corporate strategies and stakeholder reporting since ESG becomes a more important factor for shareholders, investors and a wider group of stakeholders. Miners will have to develop better and progressive mining plans to meet expectations of the stakeholders based on biodiversity and water management.
- Through Scenario modelling and reviewing funding, technology and assets, companies can achieve net-zero and differentiate themselves with a flexible path to decarbonization.

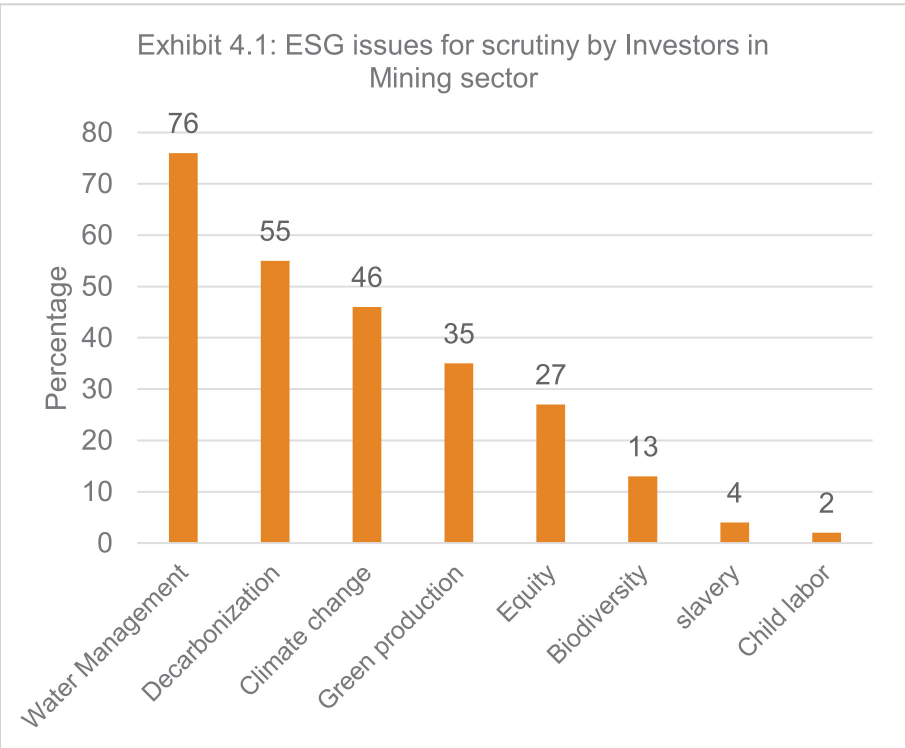
License to operate (LTO) is needed to be stronger through relationships with Traditional owners, strengthening the brand and a commitment to drive value for shareholders and communities. The LTO requirement is changing rapidly as the expectations on mining's contribution to communities, economy and preservation of heritage sites change.

Better policies to achieve sustainability:

Sustainable development of the Indian Coal sector can be better achieved with good policies like - improving the efficiency of all elements of the country's existing power system, deploying high efficiency technologies in the short term, and devising a long-term strategy for developing and deploying advanced coal power technologies. Since, there is a lack of emphasis on efficiency during operations and maintenance, it is of utmost importance for all power plants to carry out energy-audits and measure efficiencies routinely.

The main challenges to sustainable development of the coal sector relate to - systems of coal exploration, extraction and processing, developing environmental and social concerns and meeting high demand for coal in the power sector. Rigorous and continuous assessment, systematic planning, policy development in a transparent manner and resolution of relevant technical, economic and institutional issues can help overcome these challenges.

Supercritical pulverized coal (SCPC) and other emerging technologies may become important for the long-term future of the coal industry which should include advanced fluidized combustion, oxy-fuel combustion, carbon capture and storage. Greater operational experience through research, development, demonstration and deployment will lead to a better understanding of the technical and cost trajectories as well as the feasibility for large-scale deployment of new technologies that will increase efficient use of coal and help reduce environmental impacts.



Source: EY Knowledge analysis of business risks and opportunities survey 2023

CHAPTER 5

RISK OF FINANCING IN COAL MINING

Introduction

The availability of finance for a Coal mining project is generally dependent on the economic robustness of the project, the requirements of the lender and the overall risk profile of the individual project and/or corporate entity.

Bank financing is a funding mechanism of coal mining business, that relies on a future stream of cash flow from a project as the main source of repayment, and uses the project's assets, contracts, rights and interests as security for the loan. In order to determine the certainty of the project cash flows, a detailed due diligence exercise should be undertaken to identify the risks that could potentially impact on the robustness of these cash flows.

The purpose of any lenders' due diligence exercise can be broadly categorized under the following:

I. To identify and mitigate the risks,

II. To develop the appropriate funding and legal structure, and

III. To determine the risk-reward relationship in order to correctly price the Loan financing

This section of the report will focus in exploring the risk factors in mining business to have an in-depth assessment of the risk exposure the financial institution can have while lending the money.

1. Geological Assessment Risk:

The orebody is the only real asset in a mining project and that will generate revenue. If this respective asset fails to deliver up to the expected potential output, there is a downside risk of non-repayment to the lenders, and shareholders will not receive an adequate return. Creating representative geological model of the orebody and its classification which will comprise of quantum of various reserves, metallurgical properties and physical structure are immensely critical for asset valuation. Exploration of core input data is crucial for any mining project, which need to be validated. Geological data is used as the primary data for mine design, method selection, technology selection, cost estimation etc. Any mistake in the data exploration process will lead to error in forecasting. Resource estimation with advance tool, classification and codification need to be undertaken to all mining and economic aspect towards its viability.

Risk Mitigation:

- Proper study of - geological & mining model, including mineralogy, structure,
- To have the pre-feasibility study completed with clear indication on economic benefits.
- Mine life cycle plan with likely quality variations etc.
- To take extensive mine exploration programs and the results have to be vetted by appropriate independent parties.

2. Resource Scarcity & Quality Risk:

One of the major challenges facing the mining industry today is that there are less high-quality ore deposits left to be developed. New deposits exist mostly in remote and difficult-to-access areas. Declining ore grades significantly increases the production costs for each ounce or ton. Consequently, the extraction & hauling cost per unit of energy increases proportionately – leading to financial risks associated with developing and operating new mines. In such cases, proper assessment of upgradation with a better technology becomes very critical as the scope of technology risk can be extremely wide, in relation to beneficiation, mining risk and equipment selection. This factor raises a key concern for the marketability of the product.

Risk Mitigation:

- Proper geological modelling, mine modelling, not only rely on data but also geology and mineralogy
- Technology selection for upgradation / beneficiation of the ore
- By doing multiple tests and increasing the severity of the completion tests.
- Market study for segmentized selling potential

3. Mining Plan Risk:

Mine design and dump design- this gives complete material handling, cost, etc. - inefficient design impacts heavily on project economics.

Appropriate & experienced working of the following has a significant implication on the business plan (otherwise in case of wrong assumptions/assessments may lead to pre-mature closure of mine):

- Commitment towards mine closure obligations, both progressive and final closure, remains critical for statutory purpose
- Mine schedule, ramp up, equipment mobilization etc.
- Selection of equipment, size, specification, make – technology
- Operating cost estimation - direct impact on profit
- MDO scope, investment, terms & condition, rates

Risk Mitigation:

- Proper life of mine plan along with a clear focus on maximisation of extraction and technology for quality control.
- Hauling optimization through appropriate waste handling design.
- To have Skilled manpower and subject matter expert engagement.

4. Ownership Risk – LAND & R/R:

Acquisition of Land is a major risk in the mining sector as there are multiple stakeholders involved. Delay in land acquisition will affect the project viability. Potential delay is expected in overall land acquisition due to encroachment of Govt. Land & discrepancies or unavailability of land records with land-owners / possessors. taking possession of Govt land due to procedural issue which is linked to obtaining FC Stage II before cabinet approval

Private land acquisition is adversely impacted due to slow administrative processes and. Prolong negotiation for private land acquisition impacts the timely mine operationalization.

Lack of Strategy for the development of R&R colony and actual displacement of people. Non-acceptance of proposed R&R site (Tribal & non-tribal issue) & package. Delay on the acquisition of land parcels which are required for the initial development of Mine Infrastructure including evacuation route, affects the project economics.

Influence of land compensation offered by nearby coal block allottees can result in increase in land acquisition capex due to higher expectation from landowners in line with nearby coal blocks

Risk Mitigation:

- Clear and transparent policy for land acquisition.
- Closely maintain the liaise with State for speedy implementation
- Stakeholder consultation along with strong site presence for CSR activities from beginning of operation.

5. Environment & Forest Approval Risk:

The mining industry has a significant impact on the environment, and mining companies are under increasing pressure to reduce their environmental footprint and minimize the negative impact of their operations. This includes reducing greenhouse gas emissions, managing waste and water resources, and preserving biodiversity. Timely approval of Statutory clearances is extremely critical to the success of mining project and the business plan.

Environmental & Forest risk are much broader discipline and cover issues such as compliance to:

- Strict prescribed norms,
- Forest diversion and equivalent growth
- Long drawn process engaging multiple agencies (State. Center and Site)
- Tailings/waste disposal, water recycling
- Social and cultural implications – stake holders' engagement

Another major issue for any mining project is delay in Environment and Forest clearance process– impacting deliverables and financial loss like PBG appropriation, increase and increasing the gestation cost.

Risk Mitigation:

- Fast tracking the transfer of land, acquired by the Prior Allottee, (CMSP mines), and by paying the value and Stamp Duty to State.
- Management's focus to work closely with State Govt on fast tracking the time lines even by ssetting up a PMC for liasoning with the State to assists in obtaining Statutory Clearances including EC/FC
- Long term Sustainability plan along with ESG initiatives on Biodiversity, decarbonization, water management.

6. Project Implementation Risk:

Implementation and execution of mining project is very complicated as it involves number of activities related to technical, statutory, stake holders and construction and the steps have to be completed within budget and time frame. Any abnormal delay in planned project schedule, in terms of following key areas, may lead to significant cost overrun and revenue loss:

- All technical studies and statutory clearance time taking and involved multiple stockholders.
- MDO mobilization
- Ordering of long lead items/equipment
- EPCM (engineering, procurement, construction management) is a commonly used investment project implementation model where the EPCM supplier, i.e., the engineering contractor, does all the technical design necessary for the investment and co-ordinates the implementation with the owner.

A lack of proper project management team affects faster decision-making process and the project's progress.

Risk Mitigation:

- Define the scope of work for a project in detail.
- Proactively Identify the risks as early as possible.
- Designing strategies to combat the risk.
- Engaging independent Engineer or PMC.

7. Cash Flow Risk:

Mining projects are long gestation projects where mine opening takes place in about 5-6 years, followed by 3-5 years for ramping up of coal production to peak levels from any coal mine. The projects are capital intensive and so there is always a possibility of cost and time overrun. Estimation of total project capex includes:

- Equipment (@ 50-60%),
- Land and R&R cost (@ 25-30%)
- Mine Infra and P&M cost (@ 15-20%)

(Incorrect assumptions/estimations impacts IRR, Cashflow, NPV projection significantly)

Defaulting efficiency parameter has very high-cost impact, and phasing of capex has impact on cash flow from equity and loan. Ultimately, they have direct impact on NPV and IRR.

Risk Mitigation:

- After award of mine, the successful bidders get a technical DPR prepared as per the geo-mining conditions and the prevalent rate of equipment, manpower in the industry to arrive at realistic estimates.
- Lenders may get the technical reports and the resource estimates vetted by independent engineers/ mining engineer, at the time of project appraisal.
- Adapting to an evolving market in addition to meet investors' expectations around ESG performance

8. Risks of Visibility of Regular Offtake

Offtake of Coal is critical based on future of coal is to be assessed. With the prevalent evacuation infrastructure issues and dominance of CIL in the market, mitigation to the offtake risk is critical. Improper benchmarking of imported coal price with respect to the product grade may severely impact the bottom line.

Revenue estimates which are based on foreseeable ground realities in the region rather than considering CIL spot auction premiums for 100% of the sales for large mines. Cost structure of commercial mines should be competitive against the cost structure of CIL subsidiary in the region

Offtake uncertainty - Consider of having ~50-60% of the production tied up with a long term off-take agreement/arrangement as hedge against price uncertainty to lower the market risk.

Varying scale of production year on year may impact revenue without proportionately reducing cost – in this regard not having the right MDO partner with enforcing contractual terms (e.g., equipment stranding risk etc) can impact the business

Risk Mitigation:

- There are regional pockets which are not serviced well by Coal India Limited, the successful bidder may look at serving the unmet demand and may fetch good price at par with market. Further, with the implementation of Coal Exchange, this risk will further get mitigated.
- Also, Ministry of Coal is preparing the National Coal Evacuation Infrastructure Plan in consultation with various stakeholders to address the evacuation constraints in the country.
- Miners are considering more innovative, sophisticated approaches to mitigating supply chain risk, including through stronger relationships with suppliers and collaborative contracting. to balance supply chain resilience with costs.
- Imported coal pricing over a long enough tenure (say 5 years) to set the right alternative benchmark instead of spot
- Lenders may stipulate Market Assessment Study from independent agencies with focus on the catchment area of the bidder where captive requirement of coal is low.
- Medium/long term offtake arrangements may be sought prior to disbursement.

9. Regulatory Risk:

Resource nationalism refers to the policies and regulations imposed by a country's government to maximize the benefits gained from the natural resources of a country. However, this resource nationalism sometimes seems to be detrimental for private companies. In Mining industry, this can range from rising taxes, permitting fees, export duties, etc. Although this is not a new phenomenon for the mining industry, but can impact the business during economic slowdown.

The mining industry is exposed to economic and geopolitical risks, as global economic conditions and geopolitical events can affect the demand for resources and the commodity prices. As mining companies operate globally, sudden shifts in any of these factors can greatly impact their operation. Another important dimension of Regulatory Risk is- Performance Bank Guarantee for non-compliance

Risk Mitigation:

- Regular monitoring of the policy changes and amendments.
- Establishing a process of continuous review by the Risk Management cell.

10. Market Volatility & Price Risk:

Market risk in a broad sense is the potential risk of a project failing to sell its commodities into the market, at the actual prices that are forecasted in the budget. Every commodity has unique market dynamics that are influenced by supply and demand forces, price volatility, announcements of new capacity coming on-stream, or capacity being taken off stream. Changing market conditions and sluggish demand growth has resulted in a steep decline in profits in the mining industry. Cyclic demand of Commodities, has huge impact on top and bottom line;

Risk Mitigation:

- Planning early ramp up, to ensure recovery of cash flow.
- Timing the project well to ensure not face the cut down of prices.
- Dynamic optimisation and strategic management of the project.
- Long term hedging programs.

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