Draft

Technology Roadmap for Coal Sector

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1. INTRODUCTION

Coal is the most important and abundant fossil fuel in India. Coal-fired power plantsmeet 72% of India's electricity demand. Presently India is the second largest producer of coalin the world after China. India had a total coal reserve of 344.02 billion tons the total lignite reserve stands on 46.02 billion tons. Commercial primary energy consumption in India has seen a rise of 700% over thelast four decades. The major factors for the increase in demand of energy sector areexpanding economy, rising population, moreover the improvement of quality of life.The limited potentiality of other energy sources will lead to the continuation of coal asthe primary resource in India's energy scenario for the next few decades. However,due to the high demand and poor average quality, India has to import coal of higherquality mainly to meet the requirements of its steel plants, cement plants, sponge ironplants etc.

Coal India has a target of achieving 1 billion tonnes by 2023-24. To reduce the dependencyon imports, it is critical for CIL to reach the 1 Bt target, therebyembarking on a technologicaltransformation journey. New technologies can have a number of impacts on mining operations, including safety andproductivity, environmental protection and opportunities for women. Safer workingconditions through improved underground communication, automation, moresophisticated mineral and metal transportation, and emergency response measuresare achieved by integrating technology into mining projects.Technological advancements in mining are alsomaking operations more productive.

The objective is to implementnew technologies and build digital infrastructure to support current and futureramp-up for the mines. This involves a strong, multi-speed backbone information technology and infrastructuresystem that allows rapid deployment of new technologies. Creation of such system wouldrequire access to new-age ecosystems (e.g., start-ups, established vendors, researchinstitutes, etc. The technological transformation will also entail creation of a new culture in theorganisation.

A new way of thinking will be inculcated in the entire organisation. A technology transformation team to be set in place to drive impact and sustain the program with establishedCentre of excellence. A robust tracking and change management mechanismto be deployed to ensure timely resolution and delivery.

The scope of this roadmap are as follows:

- Technology enablement in coal mines for transformation across business value chain.
- Leveraging 'Digital Technology' as an accelerator for demonstrating performanceenhancement from in the coal mines.
- Defining Coal sector's technology transformation ambition and prepare workforce in Coal Sector for Industry 4.0 Digital Technology.
- Increasing productivity, safety & sustainability while mean time reducing environmental impact by upgrading conventional technologies to new technologies.

2. UNDERGROUND COALMINING TECHNOLOGIES

2.1.Present Technologies

2.1.1 Semi Mechanized Methods:

Currently, most of CIL mines using Bord & Pillar removecoal from the face by blasting & deploy SDL or LHD forloading and transportation of coal in the active miningareas.Coal transportation to surface is either by a series of belt conveyors or rope haulage drawn coal tubs.

Side Discharge

Load Haul Dump

2.1.2. Continuous mining

In many of CIL new underground mines, bord & pillar mining is carried out using Continuous Miner method where geo-mining conditions permit.

Continuous Miner

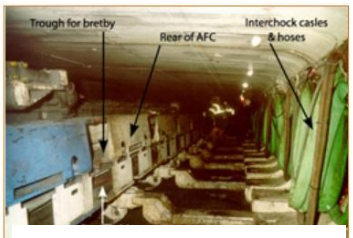
Shuttle Car

Quad Bolter

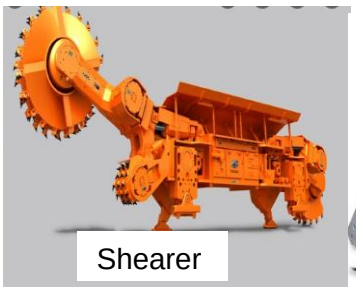
At present 17 Continuous Miners with a capacity of 7.46 Mt has been deployed in mines and another 41 mine CMs of 17.85 Mt capacity are under pipeline for future commissioning

2.1.3. Longwall

Fully mechanized underground mining method where the roof at the coal face issupported by self-advancing powered supports &the coal is mined by a shearer.



Armed face Conveyor



Shearer

Powered Support

Power Supported Longwall (PSLW) with 2.4 Mt capacity has been deployed in UG mines and further 6 nos. of PSLW 11.33 Mt capacity is under commissioning process.

2.2. Way Ahead for New Technologies

S. No	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
2.2.1.	Discontinuation of Drilling and blasting	✓ Drilling Blasting process for coal preparation shall be discontinued.	All profitable underground mines where geo mining conditions feasible				
2.2.2.	Longwall Mining	✓ Longwall mining has advantage of high recovery, lower operating cost, easier to supervise, works under weak roofs. ✓ Longwall is applicable in preferably flat and uniform (dip less than 12 degree) & Deposit size- large areal extent & uniform thickness	All new mines wherever suitable				
2.2.3.	Phasing out of SDL/LHD	✓ SDL/LHD to be phased out from all underground mines. ✓ Task force to oversee this in existing mines. ✓ PR revision if conditions favorable	All underground mineswhere geo mining conditions suitable				
2.2.4.	Continuous Miner	✓ Continuous miner/ Bolter miner /RH/LW/SW/HM shall be introduced in underground mine for cutting coal wherever applicable	All new mines wherever suitable geomining conditions				
2.2.5.	Amalgamation	✓ Small mines to be amalgamated to larger mines to make the mine profitable with high mechanization.	Implementation				
2.2.6.	R&D initiatives	✓ For liquidation of coal from deep UG mine R&D Initiatives (Coking coal) shall be taken up. ✓ For new Backfilling Technologies in	Implementation				
			Paste Fill technology (using Fly ash rejects of power plants) in 4 mines of ECL is under consideration				

		underground mines such paste fill, aqua fill etc.					
2.2.7.	Technology Transformation cell	✓ A dedicated team of persons having acceptability towards u/g mechanization culture positively need to be made from existing employees who are to carry the technology transformation at our u/g mines with sufficient coal reserve potentiality at the mine leasehold.	All Mines				
2.2.8.	Centralised control room	✓ Each mine shall be established for maintenance, monitoring, and supervision.	AllMines				

3. OPENCAST COAL MINING TECHNOLOGIES

Present Technologies

3.1 Cyclic Mining

3.1.1 Shovel Dumper:

- ✓ It is the most sought-after technology in opencast mining due to its inherent flexibility of operationIt also offers flexibility for easy transition to any other technology or equipment configuration.

Rope Shovel

Hydraulic Shovel

- ✓ CIL has fast tracking the process of procuring 360 high-capacity mining equipment valued at over Rs 7000 crore to bolster production after reviving the one billion tonne production target.
- ✓ 201 nos. new High Capacity HEMMs have been commissioned during 2020-21 (10 cum & higher bucket capacity Shovels – 14 nos., 150 T & 190 T Rear Dumpers – 144 nos. and 460 HP & 850 HP Dozers – 43 nos.).

3.1.2. Dragline:

- ✓ Dragline mining is the most cost-effective technology for the bedded deposits and is the first-choice technology for large opencast mining.Total of 32 draglines are in use in Coal India Ltd. of which maximum no. of 23 are in NCL.

Dragline

- ✓ Purchase Orders for 5 nos. 24/96 Dragline amounting to Rs 2400 Crores and 96 nos. 240T dumpers amounting to Rs 3200 Crores have been placed.

3.2.Continuous Mining

3.2.1. Surface Miner:

- ✓ They mine commodities selectively, ensuring a high quality and optimum exploitation of the deposit. Does not need drilling blasting. Total 30surface miners in CIL, of which 8 are in NCL and 22 are in MCL.

Surface Miner

Bucket Wheel Excavator

3.2.2. Bucket wheel excavator (BWE)**:**

- ✓ BWE's are continuous cutting machines for soft to semi hard materials like clay, sand, gravel, as well as lignite and hard coal. The BWE is a Continuous Mining Technology and works in conjunction with Conveyor belts & Spreaders.

3.3.In the Financial year 2021-22, it has been planned to procure High-Capacity Equipment of more than Rs 9000 Crores viz, 1 no. Dragline, 35 nos. Shovels, 112 nos. Dumpers and 43 nos. of Dozers for achieving the enhanced coal production target in the coming years.

Taking initiative for efficient and environmentally friendly evacuation of coal through rail, initiative has been taken for building rail infrastructure both on 'Deposit Basis' as well as by forming SPVs with Rail PSUs and the concerned State Govt.CIL plans to increase mechanized evacuation from 150 million tons to 665 million tons by FY24.

- ✓ 7 railway lines – estimated investment of INR 20,000 crore
- ✓ 21 railway sidings – estimated investment of INR 3,750 crore.
- ✓ 24 FMC Rail Connectivity Projects at an estimated INR 3,400 crore
- ✓ 33 coal trunk roads planned to be built by FY24

3.4. Way Ahead for New Technologies:

S. No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
3.4.1	In-pit crushing & conveying	✓ Should be introduced in phased manner in all big opencast mines with flatter gradients. ✓ In pit crushing of coal is generally found to be economical in high-capacity opencast mines where reasonable lead distance and lifts are involved. ✓ Depending on individual parameters, it can achieve full or partial replacement of trucks for material transport within and out of a mine.	All big opencast mines with favorable gradients wherever geomining conditions& economics permit.This would be increasing the efficiency as well as safety and help in fuel conservation.				
3.4.2.	Shovels & Dumpers	Size upgradation ✓ Further Upgradation of Dumper & Shovel sizes. The largest dumpers deployed internationally are 400T at present. ✓ 42 cum bucket capacity rope shovel at Gevra OCP (SECL) is the biggest rope shovels deployed in CIL & India. Internationally the largest Rope Shovel deployed is of 63cum bucket capacity. ✓ High Capacity HEMM has Less specific fuel and other resources consumption. less pollution, dusts etc. dispersion because of bulk handling and lessnumber of exposed people.	High capacity HEMM to be introduced in largemines with production more than 10 Mt or volumetric handling of more than 40 Mm3. Further large operating space, turning radius &pit size available.				
3.4.3	Highwall Mining	✓ Highwall mining to be introduced in mines where coal is blocked in batter existing opencast mines and which have reached their final limit due to uneconomic stripping ratio or due to local constraints (which limit further mining by normal surface/ opencast technology), by deploying remote operated equipment. ✓ This method relies upon the self-supporting capacity of	Ongoing as 2 sets of HW miners of 1MT are in operation at SECL. Future plan for 3 nos. of Highwall miners in ECL of 1.5 MT capacity.				

Further to be considered where geo mining conditions

S. No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		the strata above the series of parallel entries driven mechanically to a considerable depth without artificial roof support and ventilation in the seam horizon.					
3.4.4.	Dozer-Ripper	✓ Dozer ripper for blast free removal. Technology also helps in minimizing in air pollution. Started in MCL and further feasibility should be explored to other mines of CIL.	Wherever applicable possibilities to be explored				
3.4.5.	Rippers	✓ New technologies to cut overburden and coal by Impact energy accumulation. ✓ Few mines of CIL have started issuing contract with this technology. ✓ Full potential of this technology should be explored	Implementation				
3.4.6.	Alternative Fuel Technology	<u>Use of LNG in HEMM</u> ✓ LNG offers better fuel consumption efficiency, lower operating cost, Lower carbon emission (~ 22% less), higher energy density and no theft and adulteration. ✓ LNG hybrid operation in high-capacity mining dump trucks has been implemented in US, Canada, Mexico, Russia and Ghana. In India, 5 nos. 240T dumpers (Bucyrus make) converted to Diesel-LNG dual fuel system by Sasan coal mine. ✓ LNG engines emit almost 17% lower CO2 than Diesel engine. ✓ CIL has also taken initiatives to go for pilot project in collaboration with GAIL in one mine site of CIL before starting bulk use of LNG. A pilot project for use of LNG in HEMMs has been started in Lakhanpur OCP of MCL on 100 T BEML make dumpers. ✓ After completion of pilot project if found feasible this	Pilot project likely to completed by December 2021. Further Implementation if Trial successful				

S. No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		technology to be extended to other OC mines. <u>Use of Hydrogen</u> ✓ Some of the companies of world have started operating truck operating on hydrogen. The performance of the trucks is the same or better than the original diesel trucks, with the additional benefits of cleaner air, less noise and lower maintenance costs. ✓ Further linking this technology with recent coal to hydrogen initiative of MoC.	R & D towards this technology is needed for future prospects.			Implementation if found feasible	

4. TRANSPORTATION

4.1. Present Technologies

4.1.1. Opencast Mines

Presently in most of the mines of coal India Dumpers are used for transportation of coal. Conventional conveyors are in use in many mega mines. Conveyors that can handle coal up to 4500tph/hr has been planned in Coal India. Conventional conveyors are limited to inclined angles around 16 to 18 degrees.

4.1.2. Underground Mines

Coal/ Material

In Undergroundmines rope haulages and conveyor system is used for material transport. Further transportation of coal by shafts are prevalent in some of the mines of coal India.

Direct Rope Haulage: Consist of one pulling rope and one haulage drum for hauling minerals in tubs ormine cars up a gradient which is generally steeper than 1 in 10.

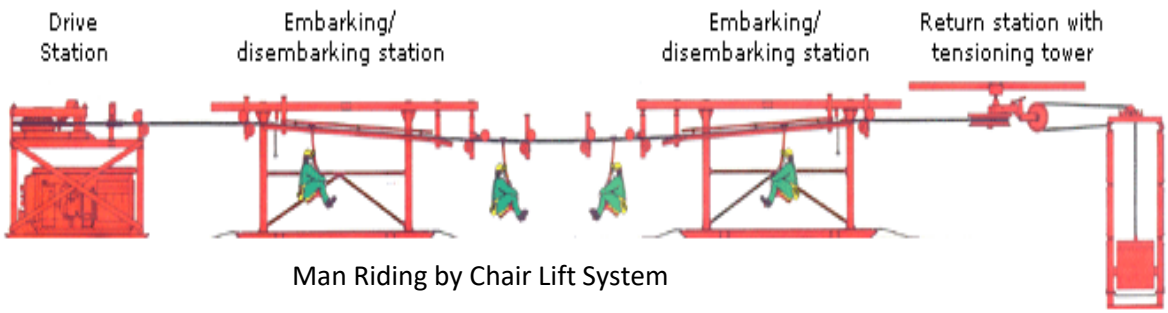
Endless Rope Haulage: In this system there are two parallel tracks side by side.One for loaded tubs and another for empty tubs and the endless rope passingfrom the driving drum located at out bye end of the haulage road to the in-bye endand back again via a tension bogey.

Conveyors: In coal mines and other mines of stratified deposits, where theunderground mineral if won by longwall method, the transportmedia often consists of conveyor.

Shuttle cars: A shuttle car is a pneumatic tire mounted, electrically driven and low-heighttransport vehicle of 5-7 te capacity with an open topped and open-ended body,used for transport of mineral from face to a central loading point.

Man Transportation

In most of the mines transportation of men via incline or either via shaft. Some of mines using man riding system for man transport.



Man Riding by Chair Lift System

4.2. Way aheadfor new technologies.

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
4.2.1. Transportation of Men Underground Mines							
1	Chair lift Man Riding System	✓ Man riding systems are the rapid, safe and comfortable solution when it comes to transporting persons fast, over long distances, including horizontal and vertical curves in underground mines. ✓ objective of reducing unproductive travelling time of mine workers.	Should be introduced in all UG Mines where mechanization permits				
2.	Winder shaft	✓ All steam winder shaft shall be replaced with electric winders.	AllMines				
3.	FSV	✓ Battery operated Free steered vehicle can be used for man transport in Underground mine.	All new mines where mechanization proposed				
4.2.2. Transportation of Coal from Underground Mines							
1.	Conveyors	✓ Coal transport by Haulage based system shall be discontinued and conveyor belt system of coal transport from face to surface shall be introduced. ✓ Considering the economic and environmental benefits of conveyor, it's use needs to be promoted wherever it is economical to use in CIL mines.	All new mines and present mines where mechanization & gradient permits				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
2.	MUV	✓ Battery operated Multi Utility Vehicle can be used for material transport.	All new mineswhere mechanization proposed				
4.2.3. Transportation of Men in Opencast Mines							
	Electric Infrastructure	✓ Electric Infrastructure to be developed in open cast mine. ✓ Battery operated portable man transport vehicles to introduced in OC mines.	Charging station for group of mines.				
4.2.4. Transportation of Coal from Opencast Mines							
1	High angle Conveyors	✓ A high angle conveyor can be defined as anyconveyor that transports material along a slopeexceeding the dynamic stability angle of the transported material. ✓ Implementation of High angle conveyors technology in opencast mines to be explored as early as possible. Though In some Project Reports prepared by CMPDIL, provisioning has been made for high angle conveyors.	Proposed to be introduced at all new mines where geomining condition permits. Reassessment to be done for ongoing mines				
2.	Pipe conveyors	✓ Used where spillage of materials,environmental	Proposed to be introduced at all new mines where geomining condition permits. Reassessment to be done for ongoing mines				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		issues and limitations in routing prevents the use of unconventional conveyingsystems. ✓ For transportation of coal can be considered where long distance is involved. In some of the Project reports of CMPDIL provisioning has been made for Pipe conveyors.					
3.	Rope conveyor	✓ Rope conveying system for difficult terrain such as rivers, buildings, deep valleys or roads without any problem.	Implementation wherever technoeconomic feasibility permits				
4.	First Mile connectivity	✓ Elimination of road transportation of coal in mines having capacity of 4 Mty and above. ✓ Creation of Mechanized conveyor system and computerized loading system (SILOs). in such a way that, wharf wall loading by pay loaders is eliminated by year 2023-24. ✓ Automation of Coal Evacuation and further adding a layer of IoT through Digitization would increase the efficiency and safety factor. ✓ 53 FMC Projects identified: 39 to be completed by FY 2024 (Ph-I)	Wharf wall loading by pay loaders is to be eliminated		Phase-1 (39 FMC projects)		

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		 Mechanised Evacuation of coal from the pithead to despatch point under FMC initiative					
5.	Autonomous Trucks	✓ This technology is already in use in some of mining companies. ✓ In coming years, with rising wage cost and demand for higher operational efficiencies, deployment of autonomous equipment will become a necessity.	Coal industry in India may plan a shift to autonomous Trucks in a phased manner				

5. COMMUNICATION

5.1 Present technologies

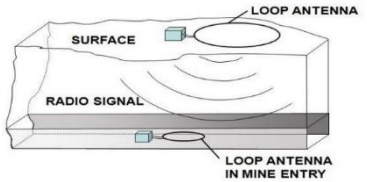
For communication in opencast mines supplied with walkie-talkie instruments from the central control room for interpersonal communication during the operations between different units/places of working.

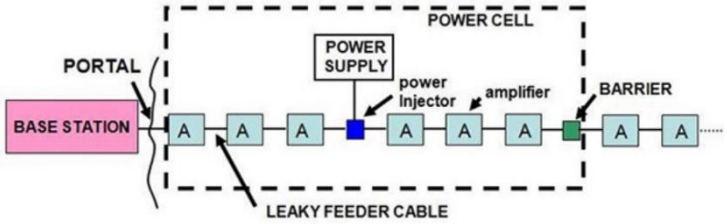
Further underground coal mines use wired telephonic communication as the primary means of communications between the surface and the underground miners. Conventional systems or the wired system is comprised of magnetophones, voice powered phones etc. This system is known as CDS system.

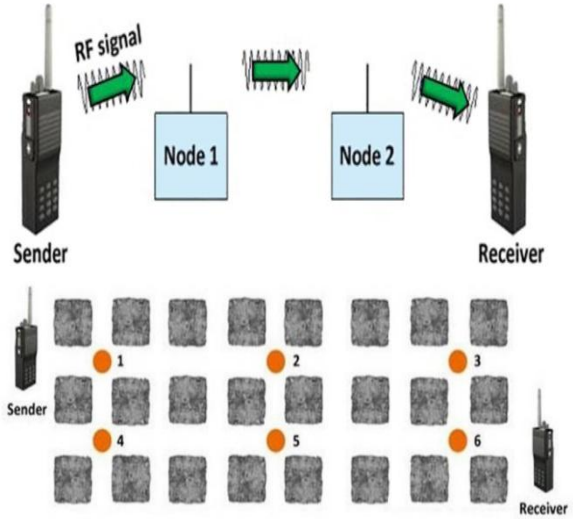
For communication related to transport of coal and material to underground and surface signaling system used for haulage, shafts is used. Audible and/or visual signaling systems are still widely used to communicate safety messages.

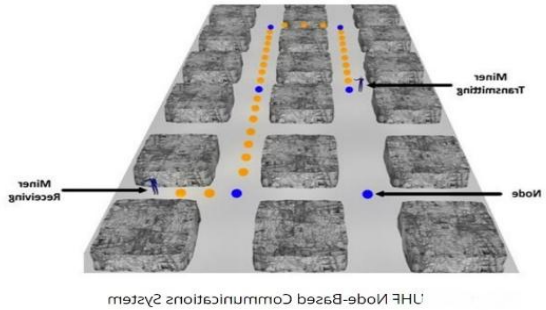
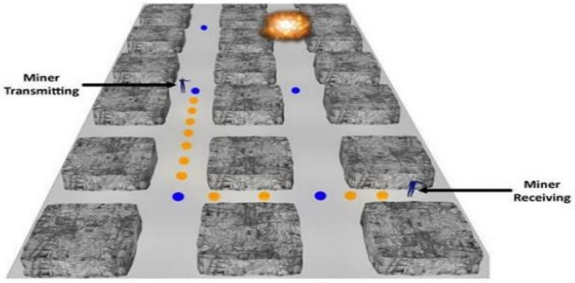
The use of longwalls led to the development of voice communications using speaker sets spaced across the face area.

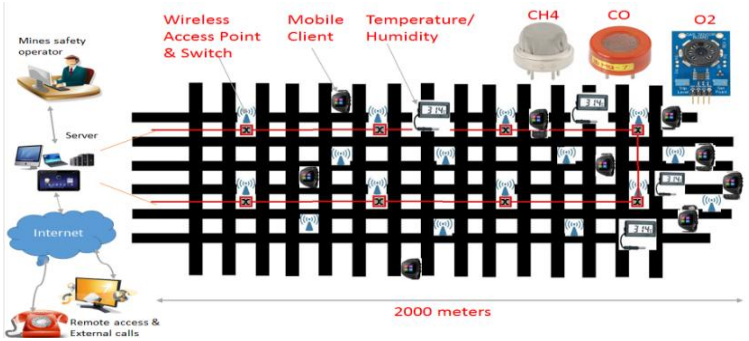
5.2. Way ahead for new Technologies

S.No.	Technology	Description	Timeline		
			FY 2022-23	FY 2023-24	FY 2024-25
5.2.1.	Through-the-earth mine communications	✓ Through-the-earth (TTE) and wireless radio systems are less common. ✓ Through-the-Earth (TTE) signaling is a type of radio signaling used in mines that uses low-frequency waves to penetrate dirt and rock, which are opaque to higher-frequency conventional radio signals.  Example of a TTE Communications System ✓ In mining, these lower-frequency signals can be relayed underground through various antennas, repeater or mesh configurations, but communication is restricted to line of sight to these antenna and repeaters systems. ✓ Except for TTE systems, most wireless systems require some wire-bound components, which are susceptible to failure during disasters as cable breakage interrupts communications.	Phase -1 Trial Period	Phase -2 Implementation	
5.2.2.	Leaky Feeder Systems	✓ A leaky feeder system used in an underground coal mine typically involves a single large transceiver on the surface that can communicate with all miners' radios along the length of the system. ✓ The transceiver on the surface, called a base station, connects to a DAS system. ✓ Leaky feeder systems operate at a frequency that is conventionally used by two-way voice radio communications, with the	Phase -1 Trial Period	Phase -2 Implementation	

		electromagnetic energy transmitted and received through radio frequencies (RF). ✓ This leaky feeder cable "leaks" the radio signal in or out along its length, thus creating a continuous coverage area along the tunnels in which the cable is strung. ✓ The coaxial cable has regular openings in the outer shield which permit RF energy to enter or leave the cable. It can receive and transmit signals down its entire length. Wherever a mine desires communications, it installs leaky feeder cable down the entries to the mine.  			
5.2.3.	Node-Based System	✓ Node-based systems refer to systems that use discrete antennas connected to small transceivers called "nodes." ✓ The nodes also contain small computers (microprocessors) that perform a variety of functions. ✓ In all node-based systems, the node can detect when a miner's radio is in range and provides an automatic connection to the network. ✓ Node-based communications systems for coal mines can be assembled from a number of different technologies. ✓ Wireless Fidelity (Wi-Fi), also referred to as wireless local area network (WLAN), is the foundation of one node-based system used for underground coal mines. ✓ Using UHF radios is another approach to node-based	Phase -1 Trial Period	Phase -2 Implementation	

		communications. In the underground coal mine environment, UHF radios can communicate directly with each other over significant distances, perhaps 1,000 feet. ✓ To extend the communications range, it is necessary to use repeaters (also called nodes) as intermediate components in the communications route. ✓ The communications connection between the sender and the receiver is generally from the transmitter to air, air to node, node to node to node (i.e. may possibly involve multiple nodes), and, finally, node to air to receiver. ✓ Note that the node-to-node link is also through the air. ✓ The manner in which a UHF radio wave travels through the air in a coal mine is different from through the air on the surface. ✓ In an underground mine, the UHF waves, which bounce off the walls, floor, and roof.  Node (Orange Dots) Based Communications System			

		✓ For a UHF network, fiber-optic cables or metallic conductors can connect the nodes in the entries to the mine. However, because the UHF nodes both receive and transmit UHF signals, a wireless connection is possible, with no cabling needed.   Node-Based Network Establishes Alternate Communications Path ✓ Orange dots indicate the RF signal route between the two miners. Should an incident occur that disables one of the nodes, it is possible for the node computers to recognize the loss and to determine a new route for reestablishing the communications link.			
5.2.4.	Wireless communication system approved by	✓ DGMS Permitted Underground Mines Wireless Network Communication System Is Successful at Moonidih Colliery, BCCL, Dhanbad, Jharkhand, India. ✓ Mobile client a wearable on wrist and it is connected to Wi-Fi mesh			

	DGMS for Underground	network infrastructure of underground mines. ✓ Automatically send signals to surface control room on location, man fall down, dangerous tunnel traversal by miners so that safety and rescue team can call back.  ✓ Introduction of this system may be considered in all underground mines and phasing put of ols communications system.	Phase-1 Trial for further extension to other UG mines	Phase -2 Implementation	

6. SAFETY IN UNDERGROUND & OPENCAST MINES

6.1. Present Technology

6.1.1. Personal Protective Equipment (PPE) :

Work Gloves, Footwear, Hearing Protection, helmet, Reflective clothing is in use for safety of individual in mines.

6.1.2. Support system in underground mines

Supports such as chock support, cog support, roofbolting, powered support in longwall mining etc.

6.1.3. Slope stability radar:

The “slope stability radar” has been developed to remotely scan a rock slope to continuously monitor the spatial deformation of the face. Currently in use in some of coal mines for safety related to dump failure.

6.1.4. Audio visual alarms:

In order to avoid accident, during reversing, Audio and Visual Alarm is required. To reduce such accidents DGMS made it compulsory to install Audio Visual Alarm (AVA) in every HEMM. & Surface Transportation Machineries used in Mines.

6.1.5. Flame safety lamps &Multigas detectors:

The flame is generally surrounded by a cylindrical covering of wire gauze. An explosive or flammable mixture of gas entering the lamp will be ignited by the flame. Further Multi Gas Detectors and monitors are used for the detection of flammable gases, oxygen depletion and an extensive range of toxic gases.

6.1.6. Safety Monitoring:

A Centralized Safety Information System portal is available to all concerned officers of CIL & Subsidiaries upto MineSafety Officer who enter relevant data on a daily basis. All important aspects of safety functions have been covered in this portal throughwhich informed decision can be taken by the management.

6.2. Way Aheadfor new technologies:

S. No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
6.2.1.	Personal Protective Equipment (PPE)	✓ Sensor based PPE (applicable for both OC & UG mines). ✓ By the use SMART PPE, it is quite easy to track vibrations to anticipate when motorized equipment might fail or need a check. ✓ SmartCap, a sensor-rigged PPE helmet, continually monitors common signs of fatigue and measures alertness to cut down on distraction-related incidents.	All mines both OC & UG				
6.2.2	Dust suppression	✓ Deployment of Mist spray canon for dust suppression in TOP 75 opencast mines. ✓ Fog canons are to be introduced in different mines which are deployed at coal stock yards and Railway siding which effectively suppress air borne dust. ✓ Truck mounted fog canons should be introduced in all mines of coal India for dust suppression in haul road. ✓ Wheel washing of trucks entering & Leaving mines. ✓ Deployment of mechanical road sweepers. ✓ Black topping of road transport roads&Plantation along road transport roads to minimize air pollution.	Ongoing technology and to be extended to all mines in phased manner				
6.2.3.	Tele-monitoring System (ETMS)	✓ Deployment of Tele-monitoring System (ETMS) to be installed in all UG mines.	To be extended to all UG mines				

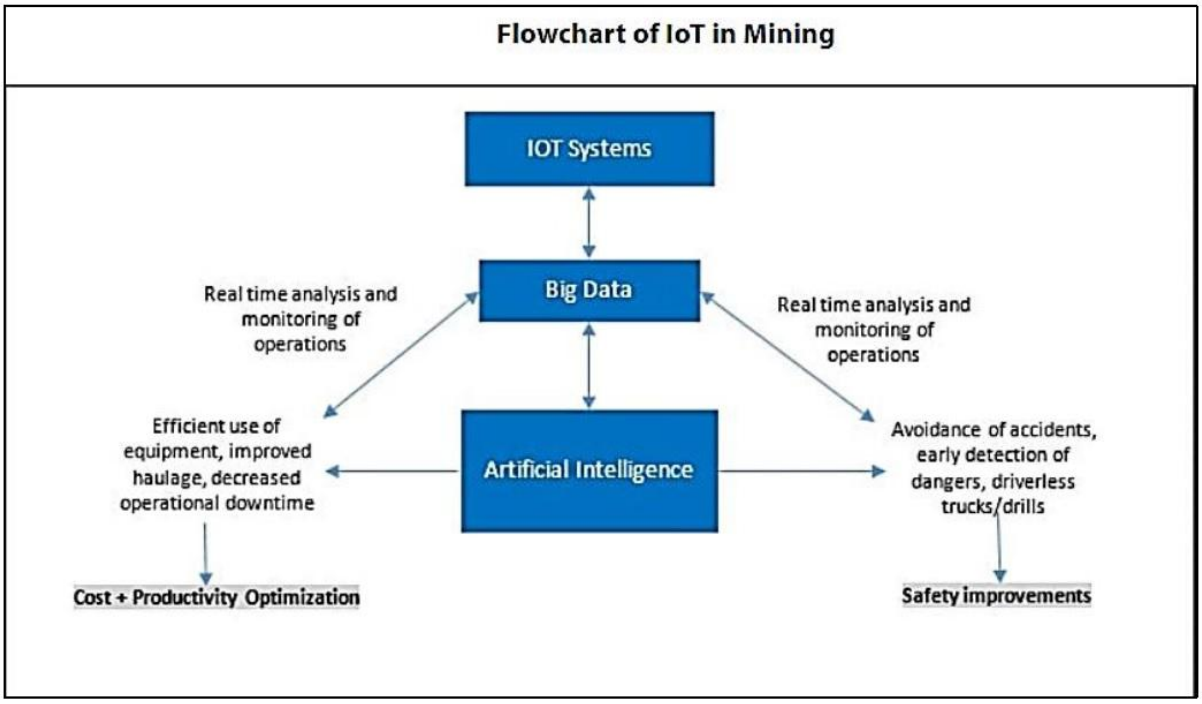
S. No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
6.2.4.	Digital Mine Collision Awareness System	✓ Introduction of Digital Mine Collision Awareness System ✓ Using a VLF magnetic system, the Collision Awareness System (CAS) enables detection around corners and through strata to provide alerts for potential collisions between people and heavy equipment before they happen. ✓ VLF (very low frequency) is used to generate a magnetic field – based on low frequency technology – around a vehicle, essentially an electric 'fence'	Trial Phase	All mines in phased manner			
6.2.5.	Digital Mine's Safety	✓ Digital Mine's Safety Solution in all mines for consistent, real-time detection. ✓ Digital Workplace Safety software processes multiple CCTV feeds simultaneously. ✓ Its ever-evolving machine learning filters (artificial intelligence) is trained to recognize – and get continuously better at recognizing: • Safety-zone violations • Hard hat violations • Safety vest violations • Protective eye wear violations Crowding & abnormal behaviour	All Mines				

S. No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
6.2.6.	SAGES (self-advanced goaf edge support):	✓ Medium duty 200t capacity remote controlled roof support system in underground coal mines. ✓ Implemented in RK-7 min of SCCL. 	Feasibility of Commercial usage & Further R&D for higher capacity				
6.2.7.	Strata monitoring	✓ Use of Underground mines strata monitoring by devices like convergence rods, tape extensometers, vibrating wire load cells in all underground mines for safety of persons working.		Implementation			
6.2.8.	Slope stability radar	✓ This technology should be extended to Top 35 mines for monitoring slope in OC mines.		Top 35 mines of CIL			
6.2.9.	CAAQMS	✓ CAAQMS facilitates in measuring a real time monitoring of Air Pollution, including particulate matter, all round the year.		For Group of 5 Mines			

7. INFORMATION TECHNOLOGY/ARTIFICAL INTELLIGENCE/IoT

Considering the numerous incentives it brings in Mining Sector, many large mining companies are planning and evaluating ways to start their digital journey and digitalization in mining industry to manage day-to-day mining operations.

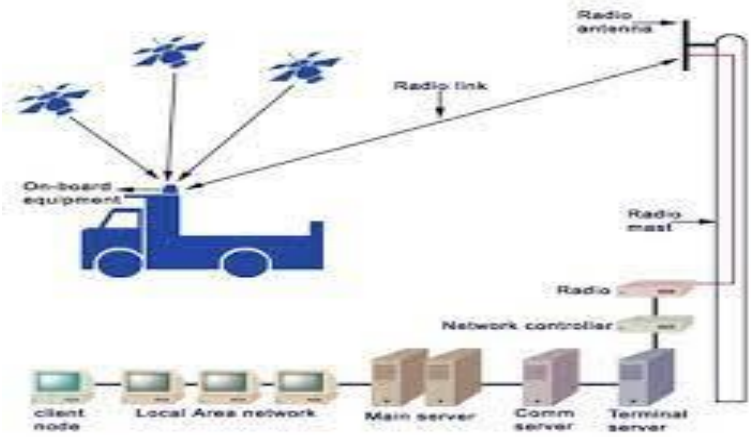
How IoT will work in mining industry?



7.1. Present Technologies

7.1.1. Online Truck Dispatch System (OITDS)-

A GPS - based, operator-independent truck dispatch system (OITDS) suitable for open cast mines has been installed and in operation at Mega mines of Coal India. This technology needs further upgradation compatible with the present and future requirements.



7.1.2. 3D Laser Scanner:

Currently 3D laser scanning is in use in surveying and volumetric measurements. A laser-scanning instrument works on the principle of LIDAR (light Detection & Ranging). The scanner emits laser rays, which hits the object to be captured I comes back to the scanner. Within a very short period, the scanner collects billions of points clouds), this point cloud data can be used to create 3D models for a wide variety of spatial volumetric tasks.

7.1.3. Geographic Information System:

Now a days maps are stored in layers of spatial information in a geographic information system (GIS) allowing manipulation, analysis. and display of spatial data.

7.1.4. Photogrammetry and Remote sensing:

Currently most of the jobs are being done based on satellite remote sensing such as land reclamation monitoring of all major opencast mines of CIL. Vegetation cover map of all major coalfields is also being done based on satellite data. In remote sensing.

7.1.5. Drones:

UAV equipped with a downward-facing RGB camera takes images of an open-pit mine or quarry from different points. Photogrammetry software uses these images to create geo-referenced 3D maps, contour lines, digital terrain models, or digital surface models of the site.

7.1.6. Enterprise Resource Planning

The primary objective of the project is to deploy a state-of-the-art ERP system across all aspects of the operation of CIL and its subsidiaries for the purpose of positioning the organization as an efficient and dynamic organization.

7.2. Way Aheadfor new technologies:

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
7.2.1	OITDS	✓ Full OITDS technology utilization such as automatic allocation of dumpers to shovels to reduce cycle time and cost instead of presently just tracking of vehicles in most of the mines. ✓ It should be implemented in Top 75 mines in phased manner. ✓ Integration OITDS with HEMM health monitoring sensors.	Top 35 mines of CIL		Other mines		
7.2.2	Dumper Truck Volume Analyzer	✓ Latest industrial high-resolution and wide dynamic range camera and laser technology for superior accuracy and robustness. ✓ Detection of overloading and uneven loading to avoid fleet damage and increased maintenance cycles ✓ Detection of under loading to avoid suboptimal fleet utilization and enable operator behavior improvement	All OC mines				
7.2.3.	Enterprise Resource Planning	Linking of ERP with all core functions such as should be done as early as possible ✓ Project Management ✓ Purchasing/ Procurement, Contracts and Materials Management ✓ Asset and Plant Maintenance Management	Phase -1		Phase -2		

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		✓ Finance & Management Accounting. ✓ Production and Planning ✓ Marketing and Sales Activities regarding real time monitoring outside the coverage of ERP to be integrated ✓ e-procurement and GeM based Procurement System ✓ e-auction ✓ Explosive Delivery Performance Monitoring System ✓ Centralized Safety Information System ✓ Coal Quality Monitoring System ✓ Weigh bridges /Road Dispatch ✓ Performance review and appraisal of Executives of CIL					
7.2.4.	RFID	✓ RFID provides automated solutions that monitor trips made by vehicles ✓ Real-time location tracking and monitoring, especially of moveable assets ✓ RFID-enabled weighbridges automate calculation of vehicle tare weight and laden weight, update databases at remote servers and transmit this data to the destination weighbridge for verification of trip made and delivered coal quantity. ✓ RFID based Automatic boom barriers are installed at all the entry and exit points of Mines and Railway Sidings so that only authorized vehicles/tippers can	All Mines				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		enter/exit into the mine premises which eliminate the possibility of any coal pilferage and helps to regulate vehicle traffic. ✓ RFID based sensor to be introduced in all mines of CIL in HEMMs, sidings, loading points etc.					
7.2.5.	Load Cells for Weighment	✓ Load cell can be installed below static weighbridges for accurate weight measurements ✓ In motion load cell to be installed in rail tracks.	All Mines				
7.2.6.	Mine Monitoring system	✓ Live feed CCTV system established at the weighbridges and coal heaps in some of coal mines of CIL to be extended to all areas and mines of coal India.	All Mines				
7.2.7.	Geo-fencing	✓ All mine boundaries, coal patches, unloading points like sidings, stocks,feeder breakers, crusher and bunker, internal coal transportation routes should be geo-fenced. ✓ Mine surveillance: Geo-referenced mining leases are superimposed on the latest satellite remote sensing scenes. System checks a defined region around the existing mining lease boundary to search for any unusual activity which is likely to be illegal mining. ✓ Periphery surveillance using virtual fencing for detecting intrusion of vehicles with the intention of illegal transportation of mineral through unauthorized routes as well as identifying human	All Mines				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		intrusion into an industrial area.					
7.2.8.	High Speed cameras	✓ Blast optimization study with the help of high-speed cameras. ✓ Stemming retention studies--effects of changing stemming type and height and the performance of stemming plugs. ✓ Face movement studies including front row burden, blowouts, hard toe problems, material trajectory, velocity, and casting range ✓ Timing studies, including detonator delay time quality, actual blast hole sequence, and blast delay times achieved, effects of timing changes, cutoffs, and misfires ✓ Environmental studies including fly-rock, air-blast noise from blowouts, vibration from choked blast, back-break, and noxious fumes	All Mines				
7.2.9.	Global Positioning System	✓ GPS to extended to all HEMMs ✓ Integration of drilling and blasting operations is GPS applied to drill positioning on individual blastholes. ✓ These systems allow the blast plan with hole locations to be downloaded to the drill. Through display the drill is guided onto the designed hole location.	All Mines				
7.2.10.	Conveyor Belt health check	✓ The Belt Condition Monitoring Solution will identify surface features on your conveyor belts, such as splices, tears and edge deformations. ✓ Real time belt integrity/rip monitoring and belt	All Mines				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		alignment detection. ✓ Fiber Optic Sensing measuring temperature and vibration of idlers along the length of the belt. ✓ System to introduced in all mines where conveyors are in use.					
7.2.11.	Simulator based training platform	✓ Simulators provide operators a safe environment to learn and practice their skills; Immersive Technologies' simulators allow the operator to practice for a range of possible emergency situations. Many of these situations are too dangerous, too difficult or too expensive to test in an actual mine. ✓ Within the often-hazardous mining industry, simulation training has quickly gained recognition as a significant method of increasing site safety and profitability through improved operator skill and knowledge. ✓ Simulator based training for operation of high capacity equipment has already been installed at NCL and training is being imparted to operators of NCL & other subsidiaries.	One training centre For each subsidiary company of CIL				
7.2.12	Fleet Management System	✓ **Improve Driver Behaviour:**Enforce safety behaviour and prevent over speeding. Instant alert devices allow employees in the field to call for help through GPS system. Operators kept on task with onscreen work details ✓ **Improves Vehicle Life:** Maintenance reminders based on engine hours. Observe machine	Introduction of Fleet Management System for mines producing more than 10MTPA.				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		performance with data direct from OEM systems ✓ **Reduced fuel budget:** Monitor excessive idling and unauthorized vehicle use, route optimization. Status of all shovels, trucks, drills, dozers and other equipment monitored ✓ **Streamline Operation:** Two-way communication helps to update the workers in the field with new assignments. Real-time views of location and activity for all equipment at the mine. ✓ FMS is deployed in Noamundi Iron ore mines of Tata Steel.					
7.2.13.	Behavior of Goaf	✓ Using the data analytics to predict the roof fall in underground mines. ✓ Periodic vetting of different type of data such as RMR ratings (Rating of rocks according to there quality), size of pillars, movement of strata (vertically and horizontally), magnitude and interval of different roof falls can be used to make system of prediction.	Further Research project in this is to be encouraged.				
7.2.14.	HEMM predictive maintenance monitoring.	✓ Maintaining & monitoring of HEMM such as Dumpers, Shovels, Surface Miners etc. before breakdown occurs. ✓ Predictive Maintenance focuses on failure events; therefore, it makes sense to start by collecting historical data about the machines' performance and maintenance records to form predictions about	CIL is procuring dump trucks with real-time monitoring interface facility compatible for GPS				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		future failures. ✓ Usage history data is an important indicator of equipment condition. ✓ Software modules for Prescriptive maintenance are also available where optimum solution is recommended by the software itself, in addition to prediction of failure of components etc.					
7.2.15.	Prediction of Fly rocks in OC mines	✓ By studying behavior of rocks in different type of blasting explosives, pattern of blasting, different rock qualities, delays detonators (detonator used to introduce a time lapse between the application of a firing signal and detonation) etc. we can develop a system of prediction to minimize fly rocks in opencast mines.	Further Research project in this is to be encouraged.				
7.2.16.	Rescue of Trapped workers in mine.	✓ Use of robotics for rescuing trapped miners in underground and hazardous places where rescue teams cannot reach. ✓ In situation when accidents take place in underground mine when it is impossible or dangerous to rescue persons to reach to rescue trapped miners then use of robotics can help. ✓ Research projects to be encourage in this field.	Further Research project in this is to be encouraged.				
7.2.17.	Mineral grades	✓ Image recognition used in identifying the reduces to negligible the error rate compared to employees doing the work.	Further Research project in this is to be encouraged.				

S.No.	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
		✓ Research projects in this field to be encouraged.					
7.2.18.	Big Data Management and Intelligent Analytics software.	✓ CMPDIL is in the process of software procurement of Big Data Management and Intelligent Analytics software. ✓ The tender has been floated in GeM Portal and final stage of Reverse Auction is completed.	2 pilot projects by March 2022.				
7.2.19.	Real Time Rake Tracking	✓ The turnaround time for rakes in India is a critical area on which the dispatch of raw coal and other mined materials depend. ✓ Tata SteelLtd. deployed real-time tracking of rakes to ensure minimum delays due to rake unavailability and lower inventory lying with the mine and siding.		Implementation			

8. SURVEY/MAPPING

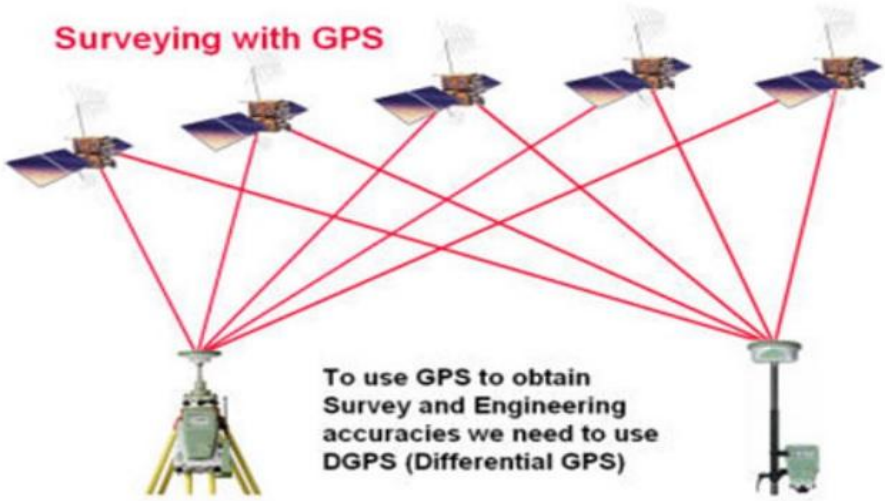
8.1. Present Technologies

8.1.1. Volumetric Measurement

The major job of survey is volumetric measurement and boundary demarcation. In volumetric measurement, LiDAR technology is in use since 2008. It is the latest technology for terrestrial volumetric measurement wherein 3D Terrestrial Laser Scanner is used for creating a point cloud based DTM through which volume is computed.

8.1.2. Boundary demarcation

For boundary demarcation, high-end DGPS instruments are in use.A Differential Global Positioning System (DGPS) is an enhancement to the Global Positioning System (GPS) which provides improved location accuracy, in the range of operations of each system, from the 15-meter nominal GPS accuracy to about 1-3 cm in case of the best implementations.



Principle of DGPS Survey using two receivers at the same time

8.1.3. Remote Sensing

Currently most of the jobs are being done based on satellite remote sensing. Major jobs are land reclamation monitoring of all major opencast mines of CIL. Vegetation cover map of all major coalfields is also being done based on satellite data

8.2. Way Ahead for New Technologies

S.No.	Technology	Description	Timeline		
			FY 2021-22	FY 2022-23	FY 2023-24
8.2.1.	Drones	✓ In future drones will be used for generating DTM. ✓ CMPDI has procured two drones which are currently in use and benchmarking is being done to establish the variance between volumetric measurement by 3D TLS and drone-based photogrammetry survey. ✓ Once successfully established, gradual technological shift. ✓ Equipped of drones with LiDAR, Optical and Thermal Sensors ✓ Volumetric measurement of Overburden Removal ✓ Monitoring of plantations/afforestation for assessment of their survival and growth. ✓ Mine closure monitoring ✓ Thermal mapping of mine fire zones. ✓ Haul road monitoring by drones helps accounting of haul fleet and safe conditions will ensure savings in fuel costs and higher productivity of workers. ✓ Generation of digital terrain models for mine operational planning ✓ Detect hot spots in coal stockpiles to assess potential spontaneous combustion areas and enable personnel take pre-emptive measures. ✓ Security of mine and coal stockyard. ✓ Almost 7X to 10X reduction in total survey time, including on ground survey and data analysis	Implementation already started		
8.2.2.	Remote Sensing	✓ To be used for generation of high-resolution imagery for jobs like settlement mapping, monitoring of plantation and mine closure monitoring.	Already in Operation		

9. EXPLORATION

9.1. Present Scenario and Technologies:

The present standard procedure for exploration is as follows:

- ✓ In the initial stage, reconnaissance survey is mainly done by GSI (scientific agency under the Government of India)
- ✓ Then regional/promotional and detailed exploration are done by public sector agencies like CMPDI, MECL to further increase the confidence level to prove the resources mainly through drilling coupled with geophysical logging and 2D & 3D seismic survey to enhance the productivity with simultaneous reduction in cost and time.

9.1.1. Drilling:

- ✓ Mostly mechanical rigs are used for drilling, but nowadays more hydrostatic rigs are getting deployed which are more competent and faster.
- ✓ Introduction of more hydrostatic rigs for it's easy and fast hydrostatic operational system with higher depth capacity to enhance the pace of exploration.

9.1.2. Geo-physical Survey:

- ✓ The conventional methods for geophysical logging are used currently. The newly introduced method of 2D/3D seismic survey for both Promotional and detailed exploration will increase the productivity with simultaneous reduction in cost and time.
- ✓ Paradigm software is currently used for the processing of geophysical data for exploration.
- ✓ Aero-magnetic survey using aircraft is being done for gaining better and faster spectral resolution for the terrains where the feasibility of drilling and other conventional techniques is less

9.1.3. Software used for Geological Report preparation:

- ✓ The software used for the preparation of Geological reports are ArcGIS, AutoCAD, MINEX, Paradigm etc. The introduction of modern software like these has contributed for the faster processing and storage of geological data.

9.1.4. Online System for Geo-data base:

- ✓ SCCL has indigenously developed a web enabled programme named as SIDEX (Singareni Integrated Data on Exploration) which aims to help the Exploration Division and Management to query about various aspects of exploration data with a provision to automatically update / upload with the data of Drilling, Chemical, Geophysical, Hydrogeological, Geotechnical & in obtaining required graphic output etc.

9.2. Way Ahead for New Technologies

S. No	Technology	Description	Timeline				
			FY 2022-23	FY 2023-24	FY 2024-25	FY 2025-26	FY 2029-30
9.2.1.	Drilling	✓ Introduction of more hydrostatic rigs for it's easy and fast hydrostatic operational system with higher depth capacity to enhance the pace of exploration. ✓ Do away with all the Conventional Mechanical Rigs				All of the mechanical rigs can be replaced by hydrostatic drills by the year 2026-27	
9.2.2.	Geo-physical Survey	✓ Vast use of 2D/3D seismic survey for both Promotional and Detailed exploration ✓	Implementation has already been started				
9.2.3.	Software	✓ Integration of Minex and Paradigm Software for Resource evaluation and Mine Planning; Synergising the capability of Geology, Geo-Physics and Mining.	Implementation				
9.2.4.	Geo-physical technology	✓ Extensive use of Geophysical logging of boreholes to partly replace the Coal characteristic study including Physico-mechanical study. (Pilot project in SCCL)Ex: Sonic Probe can be used to obtain the data for the Physico-mechanical study of a rock strata.	Phase 1: Pilot project			Phase 2: Implementation (if Phase 1 is successful)	
9.2.5.	Online System for Exploration work of CMSP and MMDR blocks	✓ Presently grant of PL and GR formulation and approval process is in manual mode. A module is being developed under SWCS under which all the process related to exploration of CMSP and MMDR blocks will be brought on digital platform. For which, presently, System Requirement Gathering is under process.	Imple-mentat-ion				

10. MINE PLANNING & SCHEDULING

10.1. Present Technologies:

Today the mining industry use the software for exploration, geological resource modelling, mine optimization, mine design, reserve calculations, mine scheduling, operational efficiencies, equipment analysis, project management and financial modelling. The various types of software packages available in the market are MAPTEK VULCAN, GEOVIA SURPAC, DATAMINE, GEOVIA MINEX, CARLSON, SLOPE STABILITY SOFTWARES, SIMULATION SOFTWARES etc.

10.2. Way Ahead:

S.No.	Technology	Description	Timeline	
			FY 2022-23	FY 2025-26
10.2.2	CAD design software	✓ Use of CAD design software in all coal mines. ✓ Do away of physical preparation of plans.	Implementation	
10.2.3.	MIS/ Dashboard	✓ Dashboard of each subsidiary for regular updation of plans related to each mine.	Implementation	
10.2.4.	Mine Scheduling	✓ Short term and long term mine scheduling to be done using Mine Planning software.	Implementation	
10.2.5.	Optimization	✓ Simulating the mine operations to optimize the production and fleet of HEMM etc. ✓ In coal India the use of software is limited to preparation of Project report. Use should be further percolated up to individual coal mines.	Implementation	
10.2.6.	Outsourcing Proposal	✓ Preparing of outsourcing proposals in very short time using planning software.	Implementation	
10.2.7.	Blasting	✓ Software such as Wipfrag, fragblast etc. are used in blasting fragmentation analysis to extended to all mines.	Implementation	

11. NEW INITIATIVES

11.1. Surface Coal gasification:

S.No.	Technology	Description	Timeline
1.	Surface Coal gasification	✓ Alternate use of coal &lesser carbon footprint than direct burning. ✓ Setting up of Coal to Methanol plant at Dankuni Coal Complex (DCC) is anothermaiden initiative, CIL is exploring the possibilities to venture into Coal-toChemical's sector on stand-alone basis by setting up a Coal to-Methanol plantat Dankuni Coal Complex (DCC). ✓ JSPL is operating a plant in Angul district of odisha for steel making through gas based DRI by domestic coal.	CIL to gassify 100 million tonnes (MT) coal by 2030.

11.2. Coal Bed Methane:

S.No.	Technology	Description	Timeline
1.	CBM/CMM	✓ Technology to be adopted for the purpose is under evolving stage in India and an international cooperation in this field was felt essential ✓ 3 CBM blocks in Jharia, Raniganj&Sohagpur Coalfields	Operationalization under progress (Work awarded for Jharia)

11.3. System improvement in project monitoring:

S.No.	Technology	Description	Timeline
1.	WEB Based Online Monitoring System	✓ CIL had developed WEB Based Online Monitoring System for monitoring implementation of coal projects. ✓ The portal has all important information related to salient features, Land, R&R, EC, Production, financial information, Milestones etc. which is updated regularly. ✓ Apart from this portal, the progress of implementation of all the ongoing projects costing more than 20 Crores. are being monitored through Master Control Networks (MCNs), developed in MS project software	Ongoing

		and uploaded in project server.	

11.4. Improve Mine Operations

S.No.	Technology	Description	Timeline
1.	Digital Transformation at Mine Level	✓ Coal India Ltd (CIL) has identified seven opencast mines for digitalization of mine process to accelerate performance and enhance output. The initiative shall witness the implementation of digitalization and process excellence with a goal of an increased coal output of 100 million tonnes from the identified mines. ✓ The seven identified mines are Kusmunda, Gevra&Dipka projects of the South Eastern Coalfields Ltd (SECL) and Nigahi, Jayant, Dudhichua&Khadia projects of the Northern Coalfields Ltd (NCL). ✓ The roadmap adopted by CIL aims to use available data from the sites to analyse mine productivity and efficiency through planning, project and dynamic monitoring. As part of data flow into the interconnected system, the project envisages to deploy digital sensors in the HEMMs to monitor the asset health, fuel consumption and other key factors responsible for the optimal utilization of assets at site.	Ongoing

12. RESEARCH & DEVELOPMENT

12.1 Ongoing Projects

Sl No.	Projects	Brief Details
1.	On-line coal dust suppressionsystem for opencast mines.	Implementing agencies are Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram & CMPDI, Ranchi. The objectives of the project is to identify air pollutants present in opencast coal mines and provide centralised online monitoring of inventory of the pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO) based on National Ambient Air Quality Standard (NAAQS) and to develop an automatic dust suppression system for thedust generated during transportation activities in opencast coal mines for regulating the amount of particulate matter PM_{10} and $PM_{2.5}$ present in the air based on NAAQS standard bysprinkling of adequate quantity of water.
2.	Indigenous development of early warning radar system for predicting failures/slopeinstabilities in open cast mines.	Implementing agencies are Society for Applied Microwave Electronics Engineering & Research (SAMEER), Mumbai, Armament Research & Development Establishment (ARDE), Pune, Centre of Studies in Resources Engineering (CSRE), Indian Institute of Technology (IIT), Mumbai and Central Mine Planning & Design Limited (CMPDI), Ranchi. The objectives are development of a prototype instrument of SSR system based on GB-SAR principle and an Interferometric Information Generation System (IIGS). It will also help to develop a Control Logic, Archiving and Prediction System (CLAPS) and the Displacement Map Generation System (DMGS) of the SAR processed time series data.
3.	Development and Field Trial of 500 T Capacity SAGES-III for Use with Continuous Miners (Phase-III)	Implementing agencies are IIT-ISM, Dhanbad, SECL, Bilaspur, M/s Andhra Pradesh Heavy Machinery & Engineering Limited (APHMEL), Vijayawada and M/s Jaya Bharat Equipment Pvt. Ltd. (JBEPL), Hyderabad. The objectives are to design, develop and manufacture of 4 nos. of 500 t capacity Self Advancing Goaf Edge Supports (SAGES) compatible with continuous miners in extraction of coal pillars and field trial of developed SAGES in depillaring operation with continuous miner at one of the underground mines of SECL and to study the techno-economic of deployed SAGES (500 T) with

		Continuous miner.
4.	Indigenous Development of IoT Enabled Technology for Monitoring, Analysis and Interpretation of Longwall Shield Pressures for Improving Safety and Productivity	Implementing agencies are CMPDI, Ranchi, IIT Kharagpur & Eastern Coalfields Limited (ECL), Sanctoria. The objective of the project is the indigenous development of IoT Enabled Technology for Monitoring, Analysis and Interpretation of Longwall Shield Pressures for Improving Safety and Productivity.
5.	Design & Development of Drone Mounted Optical Sensor for continuous monitoring of PM2.5 & PM10 in railway siding before, during & after loading operation	Implementing agencies are IIT-BHU, Varanasi and NCL, Singrauli. Objectives are to design and develop a device for real-time monitoring of $PM_{2.5}$ & PM_{10} concentration at railway siding before, during, and after loading of coal on rail wagons and to predict Air quality & measure the heat, humidity and pressure in a non-contact manner.
6.	Development of Coal Quality Exploration Technique based on Convolutional Neural Network and Hyperspectral Images	Implementing agencies are CIMFR, Nagpur and Department of Computer Science & Engineering, ShriRamdeobaba College of Engineering & Management, Nagpur. The objective is to develop a new coal quality identification and classification equipment and a technique to predict coal quality data by using Hyper-spectral imaging.
7.	Development of Virtual Reality Mine Simulator (VRMS) for improving safety and productivity in coal mines	For improving safety and productivity in coal mines" has been taken up by IIT-ISM, Dhanbad. After the completion of project, necessary training programmes will be run by IIT-ISM, Dhanbad for CIL to build the capacity in mining technologies and mines safety with active participation from subsidiaries of CIL on mutually agreed cost basis. Schedule date of completion of the above project is 31st May 2022.

12.2. <u>Projects completed in last 5 years:</u>

Sl No.	Projects	Brief Details
1.	Enhancing life of de-watering pipes in coal/lignite mines by prevention of erosion-corrosion with nano-crystalline surface engineering treatments	Implementing agencies are NLCIL and NIT, Tiruchirappalli. Under this project poly-urea coatings are indigenously developed to increase the life of the pipes with great cost savings. Developed coatings are under implementation at Mine No. I, IA & II of NLCIL.
2.	Designand development of	Implementing agencies are CSIR-CIMFR,

	truck mounted mobile coal sampler for instant coal ash & moisture analyser at site from railway wagon/truck	Dhanbad and M/s Pranay Enterprises Pvt. Ltd., Hyderabad. Nuclear technique was established with dual gamma-ray transmission for analysis of coal ash and moisture contents. This project is implemented at SCCL.
3.	Blastdesignand fragmentation control-key to productivity	Implementing agency is CSIR-CIMFR Dhanbad. This helps in achieving optimal explosive energy utilisation in rock fragmentation and improvement in productivity. This is implemented at Kusmunda OCP, SECL, SonepurBazari OCP, ECL, Nigahi OCP, NCL and Samleswari OCP, MCL.
4.	Optimization of various parameters of lab scale Coal Winnowing System (Phase-II)	Implementing agencies are CIMFR Nagpur unit and CMPDI, Ranchi. Under this project various parameters of lab scale 'Coaal winnowing system' were optimized for consistency in product yield and ash of various coal samples. This is a developed lab scale technology and is required to be tried in a pilot scale.
5.	Development of an on-line coal wash ability analyser	Implementing agencies are CSIR-CIMFR, Dhanbad and M/s ArdeeHitechPvt. Ltd., Vishakhapatnam. In this an x-ray based instant online coal washability analyser is developed which can save time as compared to traditional float-sink tests. It has already been installed at CSIR-CIMFR, Digwadih campus, Dhanbad.
6.	Techno-economicevaluation and performance behaviour of self-advancing (mobile) Goaf Edge Supports (SAGES) (Phase-II)	Implementing agencies are IIT-ISM Dhanbadamd M/s Jaya Bharat Equipment Pvt. Ltd. (JBEPL), Hyderabad. SAGES developed for safe, economic and efficient extraction of locked coal in pillars in UG coal mines. It is implemented at RK-7 mines of SRP area, SCCL and the provisioning of SAGES is recommended by CMPDI in the project report for depillaring at Parej East UG mine, CCL.
7.	Assessment of horizontal stress fields in deeper horizons and development of roof hazard maps of coal resources in SCCL	Implementing agencies are NIRM, Bengaluru & SCCL, Kothagudem. Under this project horizontal stress fields are assessed in deeper horizon in the mines of Godavari coalfield and suitable support systems are devised for coal mining blocks of SCCL. This is implemented at Mandamari Shaft block and RKNT dip side block, SCCL.
8.	Design of water network to	Implementing agencies are IIT, Roorkee,

	optimize water consumption in coal washeries for removal of impurities from coal	CMPDI, Ranchi and CCL Ranchi. An optimum water network is suggested for washeries, which is required to be modified for closed water circuit operation with zero discharge of effluent to the surrounding. The implementation of outcome of the project is under consideration at Kedla&PiparwarWashery, CCL.
9.	Shale gas potentiality evaluation of Damodar basin of India	Implementing agencies are NGRI, Hyderabad, CIMFR, Dhanbad & CMPDI, Ranchi. 3D seismic survey was conducted for different blocks and estimation for shale gas resources were done.
10.	Electronification of Ground Water Control and Conveyor System in Mines	Implementing agencies are NLCIL, Neyveli& NITT, Tamil Nadu. A real time automation of Ground Water Control (GWC) system has been developed and continuous monitoring of parameters like vibration, temperature, energy of the conveyor drives in the mines through Internet of Things. It is already under operation in the Mine No.-II of NLCIL and work order is placed for replication of the developed system in other mines of NLCIL.
12.	Seismicdata processing, interpretation and identification of thin coal seams using Inverse Continuous Wavelet Transform Deconvolution (ICWT-Decon) for resource estimation	Implementing agencies are Gujarat Energy Research and Management Institute (GERMI), Gandhi Nagar & CMPDI, Ranchi. Under this project a software is developed for Spectral Enhancement (SPE) that will help in identifying thin coal seams under the earth crust and improving the assessment of resources of fossil fuel using seismic survey during exploration process. The developed SPE software is being used in CMPDI for resource estimation.
13.	Integrated geo-physical approach for tectonic study in Main coal basin of Singrauli coalfield using 3D inverse modelling of Gravity, Magnetic and AMT data.	Implementing agencies are IIT-ISM, Dhanbad & CMPDI, Ranchi. An integrated geophysical approach is adopted for demarcation of coal seams, tectonic features (faults, fractures etc.) in main coal basin of Singrauli coalfield without exploration in that area.
14.	Development of the robotics and remote operation technology for underground coal mines	Project has been completed in March 2021. The developed robot is capable of monitoring environmental parameters in UG viz % of Co2, CH4, O2, and also humidity & temperature.

13. ENVIRONMENT&SUSTAINABILITY

13.1. Mine Water Utilization in sync with National Water Mission

In the process of coal mining, huge volume of mine water gets collected in mine sumps and subsequently pumped out to surface. By application of appropriate treatment methods, the available mine water may be used for drinking/irrigation purposes.Coal companies are doing commendable job in gainful utilization of mine water – both from active and abandoned mines.This endeavour is in line with the Jal Shakti Abhiyan for water conservation campaign initiated by Government of India.

Mine Water is used for own consumption (industrial and domestic) and surplus water supplied for community use for domestic and irrigation purposes and also for ground water recharge. During the year 2020-21, coal/lignite PSUs had utilized 3800 LKL for own use and supplied 3165 LKL to nearby community for irrigation (1934 LKL) and domestic use (1231 LKL) benefitting 15.34 lakh people and creating substantial irrigation potential. Balance water helps ground water recharge and part of that will be covered in future mine water utilization schemes. The envisaged community mine water supply target for next 5 years is:

PSUs		2021-22	2022-23	2023-24	2024-25	2025-26
Community Use (in Lakh Cu. Meter)						
CIL	Domestic	780	900	950	1000	1050
	Irrigation	1770	2100	2300	2350	2400
	Total	**2550**	**3000**	**3250**	**3350**	**3450**
SCCL	Domestic	30	35	50	50	50
	Irrigation	600	615	630	650	700
	Total	**630**	**650**	**680**	**700**	**750**
NLCIL	Domestic	100	100	100	100	100
	Irrigation	220	250	270	300	300
	Total	**320**	**350**	**370**	**400**	**400**
Total	Domestic	910	1035	1100	1150	1200
	Irrigation	2590	2965	3200	3300	3400
	Total	**3500**	**4000**	**4300**	**4450**	**4600**

Expenditure and Impact

	CIL	SCCL	NLCIL	Total
Estimated Expenditure during 5 Years (Rs. Crore)	66	10	40	116
Villages to be covered in 5 years (Nos.)	700	120	40	860

13.2 Gainful Utilization of OB to extract sand for supporting PM AwasYojna

Up till now, the linear 'take-make-waste' model of growth has created the climate crisis, driven biodiversity loss and left behind mountains of waste in the environment. Time has come to adopt the circular economy with reduced consumption, reuse of resources and minimum waste generation. Coal companies are also promoting principles of circular economy by ensuring optimal use of various natural resources that are handled in course of mining.

Extraction of sand from Over Burden (OB) for use as construction & stowing material is another unique initiative promoting sustainable development. This not only helps in availability of cheaper sand for construction and other usage but also minimizes the land required for OB dump. More so, this initiative also lowers the adverse footprint of river bed mining of sand. Besides extraction of sand, OB may also be utilized in road construction or in laying of Railway track.

As on 31.03.2021, three (3) OB processing plants for providing sand for construction purpose and 3 for providing UG stowing material is already in operation. These plants have handled more than 30 lakh Cu.m of OB during last 5 years. Further CMPDI has prepared a document to facilitate OB to Sand tenders by subsidiary companies.Coal companies have planned to take up more such projects in coming 5 years:

Extraction of Sand from OB					
PSUs	**Years**	**Nos. of Operating Plants**	**Total Volume of OB to be handled (Cu.m)**	**Total Sand generation (Cu.m)**	**Avenues of sand Utilization**
CIL	**2021-22**	9	598000	272000	UG Stowing Construction
	2022-23	11 (9+2)	3495000	1592000	
	2023-24	12 (11+1)	3860000	1775000	

	2024-25	14 (12+2)	4075000	1859000	(Own and Commercial use)
	2025-26	15 (14+1)	4780000	2142000	
	Total	**15**	**1,68,08,000**	**76,40,000**	
SCCL	**2021-22**	3	723625	434175	3 Plants already in operation for UG sand stowing, 1 plant will be added for Construction Sand
	2022-23	4 (3+1)	844172	506503	
	2023-24	4	865968	519581	
	2024-25	4	784982	470989	
	2025-26	4	742317	445390	
	Total	**4**	39,61,063	**23,76,638**	
NLCIL (Neyvelli Mines)	**2021-22**	--	--	--	Construction
	2022-23	2	796000	524000	
	2023-24	3 (2+1)	1195000	786000	
	2024-25	3	1195000	786000	
	2025-26	3	1195000	786000	
	Total	**3**	**43,81,000**	**28,82,000**	

Expenditure and Impact

	CIL	**SCCL**	**NLCIL**
Estimated number of local people likely to be engaged (In Nos.)	160	200	30
Estimated Capital (In Rs. Crore)	HoE basis		1.8

13.3. Promoting Renewable in Sync with National Solar Mission

In order to minimize the carbon footprints of mining, coal/lignite companies are keen on promoting renewables. Coal companies are going for both roof top solar and ground mounted solar projects. It has also been envisaged to develop solar parks in some of the reclaimed mining areas.

As on 31.03.2021, Coal/lignite PSUs have installed solar capacity of about 1445 MW (including roof top solar of ~ 4 MW) and wind mills of 51 MW thereby creating carbon offset potential of about 2 Million Ton Per annum. During next 5 years it is planned to install additional 5560 MW of renewable capacity. Coal India has planned to install 3 GW of solar Power in next 5 years.

Comp.	**Target for renewables (MW)**						**Capital (Rs. Crore)**
	2021-22	2022-23	2023-24	2024-25	2025-26	Total	
CIL	470	1315	1215	*	*	3000	5648

SCCL	200	100	100	100	100	600	2680
NLCIL JV			1200			1200	2820
NLCIL		250	510			760	3919
Total	**670**	**1665**	**3025**	**100**	**100**	**5560**	**15067**

**** CIL will be participating in tenders of SECI. Will firm up the targets after award of tender**

The estimated carbon offset potential by the targeted projects would be around 7 Million Ton of CO2 e per Year.

13.4. Electric Vehicle Charging Stations

S.No.	Technology	Description	Timeline		
			FY 2022-23	FY 2023-24	FY 2025-26
1.	Electric Vehicle Charging Stations	✓ Electric vehicles that use exclusively chemical energy stored in rechargeable battery packs, with no secondary source of propulsion. ✓ To cut overall C02 emissions and mitigate the risks of diesel-powered vehicles on the health and wellbeing of their employees, the market for EVs within the mining sector has proliferated.	Charging Station for Group of Mines		

13.5. Use of Geo-Textiles for Dump Management

S.No.	Technology	Description	Timeline		
			FY 2022-23	FY 2023-24	FY 2024-25
1.	Geotextiles	A new approach Geotextile –for controlling erosion of the dump surface has been explored few years back. Geotextile are thin, bio-degradable, permeable material made up of coir, cotton, jute, interwoven with nylon filaments.Geotextiles are laid on dump slope before onset of monsoon, which reduces impacts of rain on dump surface thus preventing erosion and also	Trial	Implementation if trial Successful	

S.No.	Technology	Description	Timeline		
			FY 2022-23	FY 2023-24	FY 2024-25
		conserving moisture by acting as mulch for the better growth of the plant. Geotextiles decomposes within three years by the time dump is stabilized with vegetation.			

13.6. Use of Dumps for installing solar panels.

S.No.	Technology	Description	Timeline
			FY 2022-23
1.	Solar Panel on Dumps	While most post-mining plans, especially for surface mines, calls for pits to be redeveloped into lakes or farm land, an increasing body of research and evidence shows that these ripped-up landscapes can be successfully transformed into clean energy. Reservation of at least 30 percent can be considered in OB dump for installation of solar panels.	Feasibility Check

13.7. Energy Efficiency measures in sync with National Mission on EnhanceEnergyEfficiency

Efficient use of energy resources and their conservation assume tremendous significance as one unit of energy saved at the consumption level reduces the need for fresh capacity creation by 2 times to 2.5 times. Further, such saving through efficient use of energy can be achieved at less than one-fifth the cost of fresh capacity creation. Most importantly, energy conservation also translates into reduction of carbon footprint. Coal companies also have several areas for implementing energy efficiency measures:

- Colonies, buildings, offices, industrial establishments, rest houses etc.
- Various mining activities – HEMM, Transport, Ventilation, Pumping etc.
- Efficient Power Supply Management and many other avenues

Coal companies have been taking various energy conservation and efficiency measures over the years. The details of various efficiency measures taken during last 5 years are:

PSU	Energy efficiency measures taken/implemented (2016-17 to 2020-21)							
	Use of LED lights	Energy efficient AC	Super Fan	E-Vehicle	Efficient water heaters	Energy efficient motors for pumps	Auto-timer in street lights	Capacitor Bank
	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.
CIL	4,56,262	2,499	2,674	--	91	31	996	849
SCCL	7676	749	22,920	--	284	--	803	89
NLCIL	23,500	110	145	2	12	4	152	60
Total	**4,87,438**	**3,358**	**25,739**	**2**	**387**	**35**	**1,951**	**998**

The aforementioned energy efficiency measures have resulted in estimated carbon offset potential of about 60000 Ton/annum.

Future Targets

Coal/lignite PSUs have set targets for implementing various energy efficient appliances and measures for improving energy efficiency:

PSU	Energy efficiency measures to be taken in (2021-22& 2022-23)							
	Use of LED lights	Energy efficient AC	Super Fan	E-Vehicle	Efficient water heaters	Energy efficient motors for pumps	Auto-timer in street lights	Capacitor Bank
	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.	Nos.
CIL	1724	3499	84855	390	1020	977	3511	160
SCCL	2480	1093	13800	--	--	--	--	13
NLCIL	8400	40	1100	5	5	5	25	40
Total	2056	4632	99755	395	1025	982	3536	213

By implementing various energy efficiency measures, Coal/lignite PSUs have envisaged to create additional carbon offset potential of 1 Lakh Ton/annum.

CIL has signed MOU with EESL to implement Energy Efficiency Programs at CIL and Subsidiaries. This shall cover Building Energy Efficiency Projects (BEEP), Replacement of old fans, ACs and conventional light fittings, motors, adoption of e-vehicle, installation of distributed and rooftop solar projects.

14. WORLDWIDE NEW TECHNOLOGIES

14.1 Digital Mine Collision Awareness System

Using a VLF magnetic system, the Collision Awareness System (CAS) enables detection around corners and through strata to provide alerts for potential collisions between people and heavy equipment before they happen. The high-integrity CAS-Surface can be deployed with a variety of proximity detection methods including GPS, radio frequency (RF), VLF magnetic, and cameras. With the CAS reporting and analytics tools, you can monitor and manage operator behaviour, as well as help improve safety culture and compliance at your mine site. VLF (very low frequency) is used to generate a magnetic field – based on low frequency technology – around a vehicle, essentially an electric 'fence' which is independent of the material present in the immediate environment. "In other words, VLF technology allows this magnetic field to travel through obstacles like rock and water, maintaining the 'fence' at a constant distance from the vehicle. This means that the shape of the fence around the vehicle remains exactly the same, whether the vehicle is underground or on surface.

- CAS-CAM – Camera system for blind spot vision

Proximity Detection:

- CAS-RF – Radio Frequency (RF)-based proximity solution for heavy and light vehicles
- CAS-GPS – GPS-based proximity solution for heavy and light vehicles
- CAS-WEB – Web-based reporting system
- Personnel Tag – Personnel solution
- Self-Test – Real-time system health monitoring.
- CAS Extensions

Advisory Controls (level 8) and intervention Controls (level 9) – global EMESRT / ICMM initiative using industry standard PDS-OEM interface (ISO 21815)

Driver Fatigue Monitoring – integration with third party systems

Fleet Management System and Dispatch – integration with third party system

Most important of these is the creation of detection ‘zones’ within the magnetic field which trigger specific greater operator warnings and subsequent actions. This technology allows us to define the accuracy of these zones to within very low deviation tolerances. For instance, our first zone of safety may be 20 m from the moving vehicle – and this is accurate to within 10 cm.”

ZONE 1: When a miner – equipped with a VLF receiver and buzzer unit – enters this zone, the system sends a warning through a flashing light and buzzing sound, to alert them to the fact that they are entering a dangerous area. Importantly, the behavior of the VLF waves will allow the miner to be alerted even if they are behind a corner or otherwise out of sight of the vehicle operator, when within the detection range.

ZONE 2: A second zone, closer to the vehicle, is also set up in the PDS to warn the vehicle operator that there is a pedestrian in the proximity. If the pedestrian does not respond to the warnings and gets even closer, they will enter a third zone which could now trigger the mechanical intervention: switching the vehicle automatically to ‘creep’ mode.

ZONE 3: Should the pedestrian enter the last zone defined by the PDS – even closer to the vehicle – then a second intervention comes into play, stopping the machine in its tracks to avoid any possible collision or injury.

14.2. Autonomous Drilling in mines

Potential benefits:

- ✓ Integrating the technology into the current systems with real time data
- ✓ Increased productivity of the mines
- ✓ Higher safety

While global practices show that in Rio Tinto it has piloted two autonomous electric drills at Iron Ore Company of Canada (IOC) in Newfoundland & Labrador and a single operator to monitor multiple drills from IOC’s Integrated Operations Centre in Labrador City.

14.3. Real time data visualisation

In Fushun West Open Pit Mine the roads of Open Pit roads are divided into two types: Fixed and Temporary link Roads. Using Machine learning prediction accuracy of 15.79% is obtained for link road.

Glencore'sMatagami Zinc mine – Canada: understanding of operations with essential data from interconnected assets and equipment has helped better understand how their equipment works in order to improve productivity. The company has reported that average tonnage of ore hauled in each trip has risen from 55 to 60 tonnes.

14.4. Use of AI in Preventive Maintenance

Benefits:

- ✓ Improvement in machine health (involves wear and tears detection of vital parts of equipment when maintenance or repairs are needed)
- ✓ Improves overall equipment efficiency
- ✓ Reduces cost of operations
- ✓ improves work environment with higher safety standards

Hecla Mining Company -Casa Berardi mine – Canada: With real-time equipment diagnostics, Hecla has been able to use data to determine optimal ways to utilize machines and make immediate diagnoses of equipment issues in order to decrease downtime. Since its implementation, the mine has quantified an increase of an hour per day of operations.

14.5. Automatically adjust underground ventilation

Goldcorp - Porcupine Gold Mine's Borden site – Canada: With a Ventilation on Demand system, Goldcorp can automatically adjust underground ventilation by controlling fans remotely through a centralized digital interface on the surface. This allows for a more efficient use of energy and can better control for potential operational stoppages due to a lack of ventilation. This project has cut the operation's electrical consumption in half and significantly reduced cost.

14.6. Digital Mine's Safety Solution

Wabtec's Digital Mine's Safety Solution combined with Stone Three Solutions provides for safety monitoring system that allow for consistent, real-time detection. Digital Workplace Safety software processes multiple CCTV feeds simultaneously. Its ever-evolving machine learning filters (artificial intelligence) is trained to recognize – and get continuously better at recognizing:

- ✓ Safety-zone violations
- ✓ Hard hat violations
- ✓ Safety vest violations
- ✓ Protective eye wear violations
- ✓ Crowding & abnormal behaviour

14.7. Volume Analyser

Analyzer system is a reliable and robust machine vision-based solution. Used to measure the volume and tonnage of bulk material such as mineral ore on haul trucks. This system makes use of the latest industrial high-resolution and wide dynamic range camera and laser technology for superior accuracy and robustness. The Digital solution now utilizes the latest deep learning detection technology. This allows for automatic identification of different truck types, e.g. Cat 777 vs Komatsu 785 and accurate detection of the truck bucket. The deep learning models are robust against the presence of sunlight, shadows and dust on the imaging area. Machine vision technology is used for detailed truck motion tracking to compensate for non-linear motion, e.g. curved parking at crusher.

Key Benefits

The system automatically identifies and scans each truck to provide high accuracy data on the ore received and has the following benefits:

- ✓ It is automated, real-time and statistically representative
- ✓ High accuracy volumetric measurement. Inferred tonnage using bulk density factor
- ✓ Detection of overloading and uneven loading to avoid fleet damage and increased maintenance cycles • Detection of under loading to avoid suboptimal fleet utilization and enable operator behavior improvement
- ✓ Ideal for totalizing material received during a period (shift, day, week, month) and comparing with mining plan or fleet contractor obligation
- ✓ More cost effective than truck load cells, simplified calibration.
- ✓ Can be deployed within 2 months after hardware installation.
- ✓ The machine vision-based measurement is non-contact and therefore robust and low maintenance.
- ✓ Can also incorporate a Particle Size Analysis Solution to provide detailed data on the ore received.

14.8. Advanced GPS System in Mining

The GNSS guidance systems are applied to many aspects of mining operation including:

Blasthole Drilling: GNSS based blasthole drill systems provide drill monitoring, control and guidance. The prime objective of GNSS positioning for drilling is to navigate the drill rig over the designed collar position, eliminating the need for manual survey.

Shovels, Loaders, Dozers and Graders: The planned design of the mines, ore blocks, pits and roads, is overlapped with the vehicle's current positions providing the operator with the assistance required to mine the pit and ore block to the intended mine design. The on-board display provides required assistance by providing visual cues to where are located the ore blocks and whether the current floor grade is below or above the design floor grade.

Vehicle Tracking and Dispatch: The dump trucks positions obtained are sent to the central control station, where is carried the dumping scheduling management. This application determines which material is loaded and sends information and instructions to be followed by the truck drivers, in order to guarantee that the assignments are followed and the materials are correctly collected from the correct ore block and dumped in the correct dumping location.

GNSS Surveying: The advantage of using GNSS for surveying in open pit mining is that only a single surveyor is required, in opposition to the conventional methods.

Monitor Drivers and Vehicles: The sensors in the vehicle provide monitoring information of equipment's, like for instance air pressures. These systems also provide sensors to analyze the operator's well-being, by measuring key body parameters such as heart rate and skin temperature. This information is combined

with GNSS information and is sent to a central control station. This information will allow for rapid intervention in case of problems

14.9. Barracuda - compact bucket wheel excavator to enhance operational efficiency

The barracuda compact bucket wheel excavator vastly extends the application range of bucket wheel excavators as it can dig or cut materials with average uniaxial compressive strengths of up to 50 MPa. In other words, the barracuda® is a genuine alternative to the conventional drilling and blasting methods used in mining coal, phosphate, ore and potash or the corresponding overburden and waste removal. But the barracuda® is not just a smart interesting alternative to drill and blast or surface miner; it has more to offer.

The combined extracting and loading process within a single machine eliminates hazardous and ecologically harmful blasting as well as additional loading activities. That is why health and safety standards at the highest level can be ensured. Since the new bucket wheel excavators are able to produce throughputs of over 3,000 t/h, and less vehicles and manpower are required, so operational expenditures can be reduced significantly.

14.10. GPS for Underground

The inability to access satellite-based global positioning data in underground environments has created many challenges for the mining sector, particularly in terms of miners' safety, materials tracking, fleet management, autonomous-truck deployment and drill automation.

The LiDAR- and UGPS-based underground tunnel positioning (LUTP) system performs mine scanning, mapping and positioning. The portable mobile mapping unit pinpoints the exact location of miners, drillers, surveyors, and autonomous truck or robotic drills, and allows users to plan their routes precisely according to tunnel maps.

14.11. Hydrogen powered Dumpers

Anglo American’s innovation-led approach to sustainable mining, Future Smart Mining, which applies innovative thinking and technological advances to address mining’s major sustainability challenges. This collaboration with ENGIE, in which ENGIE is providing the hydrogen generation solutions and Anglo American is developing the truck, marks the first time a truck of this size and load capacity has been converted to run on hydrogen. Operational performance of the converted trucks is the same or better than the original diesel trucks, with the additional benefits of cleaner air, less noise and lower maintenance costs. A lithium-ion battery will replace the diesel engine, allowing the FCEV haul truck to be powered by both a battery and hydrogen fuel cell technology. The truck will also have regenerative braking, allowing the vehicle to conserve and recuperate energy while going downhill.

14.12. Process Health: Sensors (A Digital Mine Solution from Stone Three andWabtec’s Digital Mine)

Crushing: A healthy mineral extraction process relies on optimal crusher performance – and complications like improper gap settings, irregular feed size and unpredictable liner wear can compromise this. Leveraging machine vision Crusher Diagnostics and Analytics Solutions, one will be able to continuously monitor the feed and product size distribution in real time, while improving your maintenance planning, increasing your crusher uptime, and optimizing your crusher control at the same time.

Truck Particle Size Measurement Solutions:

A working primary crusher is of key importance in the mining industry serving as a vital link between the mine and plant for managing ore size. If rocks or other materials are oversized when entering the crusher, they can cause significant damage, which can be costly to repair. The Truck Particle Size Measurement Solution uses machine vision laser-based sensors to measure and monitor the particle size distribution of ore as it goes into the crusher, improving uptime, increasing efficiency and providing actionable feedback.

14.13. High Fidelity Fiber Sensing&Asset Performance Management in Conveyor Belt

Managing the key assets is always vital to keeping costs down on site, particularly when it comes to conveyor belts. Belt failures can be dangerous, disruptive and costly – but can be prevented. The Belt Condition Monitoring Solution will identify surface features on your conveyor belts, such as splices, tears and edge deformations, while detecting belt drift at the same time. Wabtec corporation's enhanced early detection helps to simplify the belt inspection process, resulting in improved maintenance scheduling and helping to keep costs and downtime at a minimum.

Belt Integrity and Operation

Real time belt integrity/rip monitoring and belt alignment detection. PSA and volumetric measurement.

- ✓ Reduce damage on belt
- ✓ Reduction in safety risks
- ✓ Proactively detect potential belt failures

Idler temperature and vibration profile monitoring:

Fiber Optic Sensing measuring temperature and vibration of idlers along the length of the belt

- ✓ Real time visibility on idler health
- ✓ Alarm location along length of belt
- ✓ Reduce engineering cost in troubleshooting
- ✓ Prevent unplanned downtime.

Predictive Analytics

Pre-emptive detection of eminent failures on the drive and gearbox using digital twins.

- ✓ Reduce unplanned downtime
- ✓ Remote monitoring augmenting engineering team

Asset Centric Application

Unified analytics and visibility of operational performance and how the conveyor system relates to the up- & downstream operation with Value Stream Mapping, KPI Driver Trees and Bottleneck Identification

- ✓ Continuous improvement on production capability
- ✓ Operational performance improvement

14.14. Drone-based Subsidence Monitoring

Measure Australia's drones can take precise measurements of an area of land, on average, five times faster than traditional methods of land surveying. Rather than needing a whole team of surveyors, in most cases, there is just one person piloting the drone. Not only is drone-based subsidence monitoring faster, but it's also extremely accurate and much more affordable compared to traditional methods. The data is captured once, completely, and accurately eliminating the need to revisit the site to double-check measurements.

14.15. Autonomous Trucks:

Rio Tinto had already been using autonomous haul trucks that can carry 350 tonnes and operate totally independently since 2008. These trucks have impacted the company's bottom line by reducing fuel use by 13 percent and are safer to operator.

Some companies have begun to use smart sorting machines that can sort the mined material based on whatever criteria a company wants. This work can lead to savings in fuel and energy during processing and reduce grade dilutions.

14.16. Data Twinning

Rio Tinto's other initiative called data twinning. By creating a virtual model that is fed real-time data from the field, scenarios can be quickly tested, and operations and production can be optimised. This ability to test out decisions before they are implemented in a replica system leads to better outcomes and savings.

14.17. Rope Conveying

An innovative conveying system for difficult terrain.

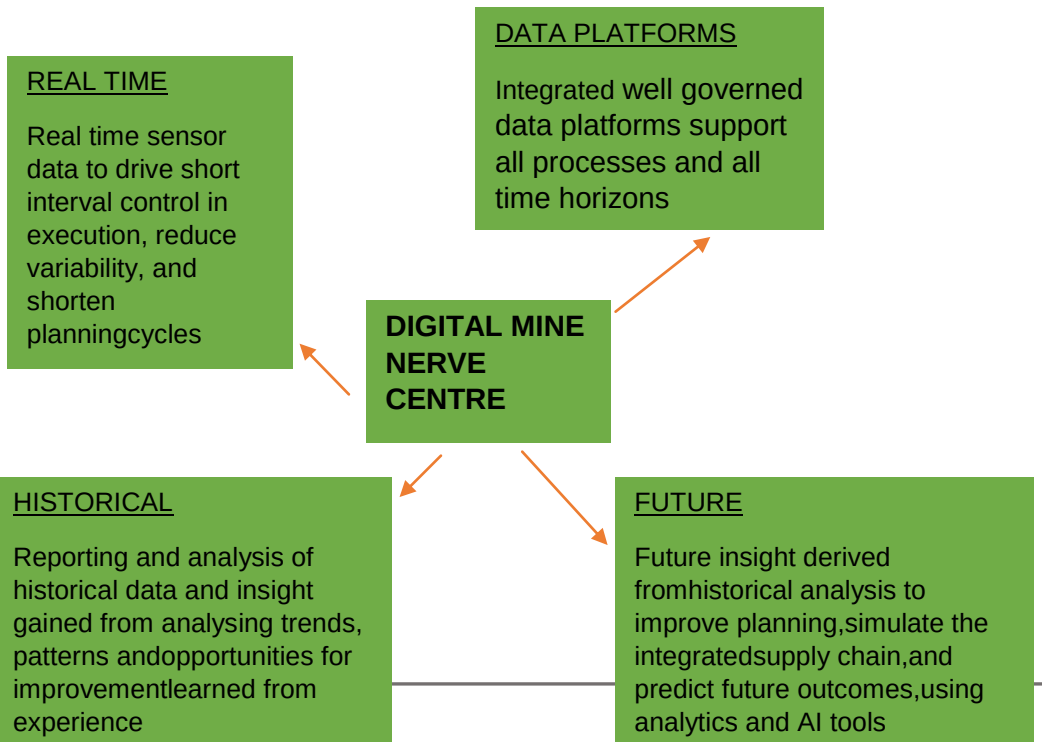
- ✓ Rope conveying technology and was specially developed for handling materials of all kinds. This system has shown itself to be unbeatable – even in impassable terrain.
- ✓ It can cross obstacles such as rivers, buildings, deep valleys or roads without any problem.

- ✓ Rope provides handling capacities of up to 25,000 t/h while occupying a minimum structural footprint. Simple maintenance of the conveying line and low space requirements are the key features of this product.
- ✓ Rope transports material on a flat belt with corrugated side walls. The belt performs the haulage function and is driven and deflected by a drum in the head or tail station.
- ✓ The belt is fixed to axles arranged at regular intervals to support the belt. Running wheels are fitted to either end of the axles. These run-on track ropes with fixed anchoring and guide the belt. The track ropes are elevated off the ground on tower structures.

Rope Conveying at a glance

- ✓ Continuous conveyor system for bulk materials and unit loads of all kinds
- ✓ Proven conveyor technology combined with decades of ropeway experience
- ✓ Conveying capacities of up to 25,000 t/h
- ✓ Rope span length of approx. 1 km possible.

Annexure-1


DATA PLATFORMS
Integrated well governed data platforms support all processes and all time horizons
REAL TIME
Real time sensor data to drive short interval control in execution, reduce variability, and shorten planningcycles
DIGITAL MINE NERVE CENTRE
HISTORICAL
Reporting and analysis of historical data and insight gained from analysing trends, patterns andopportunities for improvementlearned from experience
FUTURE
Future insight derived fromhistorical analysis to improve planning,simulate the integratedsupply chain,and predict future outcomes,using analytics and AI tools

Digital Mine

Annexure-2

Coal India as compare to leading global coal miners in terms of digital initiatives:

Area	Digital enablers	Coal India	AngloAmerican	[illegible]	exxaro	bhpbilliton	RioTinto	ArchCoal
Business	Coal production	602 MTPA	49 MTPA	30 MTPA	47 MTPA	70 MTPA	Exited from coal business	100 MTPA
	Typical SR (cum/t)	~2 .0- 2.2	3.5*	2.3 – 3.2*	0.5 – 3.5*	2.4 – 9.7*	NA	
	Digital Maturity	**Low**	**High**	**High**	**High**	**Advance**	**Advance**	**Low**
Data Management	Physical Server	✓	✓	✓	✓	✓	✓	✓
	Cloud storage	X	✓ Single cloud platform	X Developing	✓ Migrating SAP to Microsoft Azure	X Planning	✓ Azure Stack to be deployed	✓ WorkForce – employee cloud solution
	2D/3D/4D data modelling	✓ SURPAC use in NCL	✓ GOCAD Mining Suite PaleoGIS	✓ 3D Modelling & RCubed	✓ Xpac, acQuire, EQuIS	✓ 3D Interpretation software	✓ 3D Interpretation software	✓ 3D Interpretation software (Minex)
Mine operations	Robotics and equipment automation	X Developing tele robotics	✓ DR412i blasthole rig	✓ BIKE Paltform from GE	X Introducing gamification & robotics (Digital Twin)	✓ Autonomous truck - BHP's Jimblebar mine	✓ Autonomous mining trucks	X
	Advance analytics	X	✓ Machine learning analytics	✓ Big Data Analytics	✓ LightApp - enery analytics	✓ Machine learning applications	✓ Digital Twin	X
	IoT devices	X	✓ Digital Twin	✓ Optical Laser Scanner	✓ Underground wifi	✓ L&T Infotech developed IIoT	✓ IoT application on automation	X
	Drone technology	✓ CMPDIL to develop	✓	✓ LiDAR and Drone technology use	✓ Rocketmine drones	✓ UAV in Goonvellya	✓ Drones & Remotely Operated Vehicles (ROVs)	✓ DroneMapper Technology
Mine health & safety	Remote Operations Centre	✓ Wireless communication	✓ Electronic tablet in UG	✓ Safe-halo app	✓ Belfast Coal – remote monitoring & tracking	✓ Integrated Remote Operations Centre	✓ Operation Centre – entire operation in action – in real-time	✓ Wireless communication (IWT Wireless System)
Supply-chain	Automation and robotics	X	X	X	X	✓ Blockchain	✓ AutoHaul™	X
	Artificial Intelligence/ Real-time advance analytics	X	X	X	X	✓ FactoryTalk Historian Site Edition (SE) software	✓ AutoHaul™	X
Business Process	Integrated Enterprise, Platforms	✓ ERP by Tech Mahindra	✓	✓ ERP by Tech Mahindra	✓ SAP Enabled	✓	✓ SAP estate into the Microsoft Azure	✓

* - Selected opencast mines

✓ - implemented or likely to be implemented | X - Not implemented