Conventional to Smart Mining: Technology Transformation of Coal India Limited

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Coal mining remains central to India's energy security and industrial growth. CIL has driven a strategic shift towards modernising both underground (UG) and open-cast (OC) operations for greater efficiency, safety and sustainability. It has rapidly moved away from the conventional mining technology and methods to more advanced tools and practices. Advanced digital interventions – IoT, AI and data analytics – are reducing hazard exposure, improving recovery rates and enabling predictive maintenance, smart control rooms, automated dispatch and 'Smart Mines'.

The Present: Technology in Action Today

Exploration

Resources are detected using invasive (core drilling) and non-invasive 2D/3D seismic survey, which reduces boreholes by up to 50% and, with Spectral Enhancement (SPE) assaying, sharply improves determination efficiency. Machine-learning techniques (SVM, Decision Tree, Random Forest, MLP, XGBoost) interpret banded coal seams from Gamma-ray, Density and Resistivity logs. CMPDI applies remote sensing, GIS, LiDAR, drones and bathymetric surveys across pre-, syn- and post-mining stages. CIL has signed an MoU with NRSC to develop an AI-powered satellite-based geo-spatial dashboard for mine monitoring and environmental auditing.

Open-Cast Mines

CIL is progressively deploying higher-capacity HEMM – 42 CuM shovels, 240 te dumpers, draglines and surface miners for blast-free mining – standardised since 2021. Blast-free technology minimises dust, noise and vibration while improving product quality and reducing coal loss. Electric detonators were phased out in 2024-25 in favour of ultra-safe electronic detonators. AI-based safety features – operator fatigue monitoring, proximity warning, 360° cameras and automatic fire detection/suppression – are being incorporated in major HEMM, supported by AI simulators and VR training. Digitalisation through GPS-based truck dispatch/OITDS, payload monitoring (PLMS) and vehicle health monitoring (VHMS) further improves utilisation.

Underground Mines

CIL is committed to raising UG production to around 100 MT using Continuous Miner, Longwall and Highwall technology. Continuous mining is already adopted, with large-scale Longwall now being introduced. Major investments are planned in Paste Fill to unlock high-grade coal otherwise locked in pillars, alongside enhanced ventilation and strata management to strengthen safety.

Major Infrastructure Execution

CIL is strengthening coal evacuation through First Mile Connectivity (FMC) and critical railway infrastructure. Of 92 planned FMC projects integrating CHPs, silos, conveyors and Rapid Loading Systems, 46 are commissioned – creating about 432 MTPA capacity – with the ~₹27,800 crore programme targeting 994 MTY mechanical loading capacity by FY 2029-30. Complementing this, four of seven critical railway projects (~₹23,465 crore) are commissioned, with the rest targeted by FY 2027-28. High-angle/sandwich conveyors are being adopted for in-pit transport in place of HEMM.

Coal Processing & Environment Management

Beneficiation technologies – Heavy Media Cyclone, Hydro Cyclone, Teeter Bed Separator, Reflux Classifier and Jigs – are operational across CIL washeries. On the environment side, CIL's inventory is at par with global levels, with continued focus on real-time monitoring and efficient, cleaner applications.

IT Initiatives & Digital Transformation

CIL's digital landscape rests on two pillars. In Operational Technology (OT), CIL has deployed Integrated Command and Control Centres (ICCCs), Vehicle Tracking, RFID systems, weighbridge automation and GPS fleet monitoring, with the DigiCoal pilot covering seven mines. In Enterprise IT, CIL has implemented SAP S/4HANA, e-Office, cloud infrastructure and data analytics – integrating procurement, inventory, finance and HR, enabling paperless file movement and faster, data-driven decisions.

The Future: Roadmap to Intelligent, Green Mining

Next-Generation Mining

The next phase moves towards intelligent, autonomous and low-carbon mining. Remote-operated Line-of-Sight dozers are being piloted in SECL and NCL (approx. ₹2.0 Cr per equipment), with electric mobility and Trolley Assist technology planned for 190T+ diesel-electric dumpers. CIL is working with IIT Madras on safe electrification of fossil-fuel equipment. In UG mines, 5G networks, digital twins and autonomous monitoring rovers are being developed for communication, automation and simulation.

Smart Infrastructure, Processing & Environment

- Smart conveyor systems with PLC-based HMI and IoT-enabled monitoring of speed, load and temperature for remote command and control.
- Dry beneficiation of coal – Air Table, Dry Jigging, Coal Winnowing and XRT sorting – under active exploration.
- Real-time CAAQMS and CEQMS monitoring, AI-based dust prediction, GIS/satellite/drone monitoring, Zero Liquid Discharge systems and large-scale overburden-to-sand utilisation.

Digital & Enterprise Roadmap

CIL envisages 5G, IoT, AI/ML, edge computing and advanced automation to enable real-time monitoring, predictive maintenance and remote operations, progressively creating connected, automated and data-driven mines. The Bhuvan Geospatial Dashboard is being developed with NRSC to monitor coal fires, mine closure, afforestation and R&R. The 17 DigiCoal solutions tested in 7 mines will be replicated across all mega mines, alongside strengthened Information Security Management (ISMS).

Research & Development

CIL's R&D thrust gained momentum in FY2024-25 with the National Centre for Coal and Energy Research (NaCCER), a hub-and-spoke centre shifting focus from proof-of-concept to prototype development (TRL-4 and above). Three Centres of Excellence – CLEANZ (IIT Hyderabad), CSE (IIT Madras) and IMiN (IIT-ISM Dhanbad) – host 13 high-TRL and 11 low-TRL projects. Key projects include

Underground Coal Gasification (Kasta, ECL), 5G in OC and UG mines, indigenous Perovskite Solar Cells (with IIT Bombay) and 500-tonne Self-Advancing Goaf Edge Supports (SAGES) under trial at Churcha UG Mine, SECL.

R&D Roadmap to FY 2030

- Investment of ₹1,900 Cr by FY30 for R&D projects and Centres of Excellence.
- Pilot-scale plants for gasification, battery recycling and coal-based membranes; new CoEs at IIT Bombay/Roorkee/Kharagpur/Delhi and a dedicated centre in North-East India.
- A Pilot Integrated Coal Refinery Complex, permanent NaCCER centre, and emerging projects in hydrokinetic pumped storage, coated spherical purified graphite and dry coal beneficiation.

The Indian mining sector still faces challenges – large capital needs, skilled manpower and adapting global technologies to diverse geologies. CIL's trajectory is defined by deeper integration of automation, robotics, AI and green mining technologies, backed by capacity building and enabling policy – keeping innovation, research and skill development central to a safe, efficient and sustainable mining ecosystem.

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