SI. No.	Categories	Deliverables	Remarks
A	**Mineral Exploration**		
(i)	**Enhance Resource Discoveries**		
1	Deposit Scale Modelling	**1.** Geological & Geophysical maps on the same scale 3D and 4D maps based on integrated studies. **2.** Better resolution Geological Map using Artificial Algorithm.	
2	Mapping Lithospheric Architecture	**1.** Formulation of self-consistent numerical models for the mineralogical evolution of fluid chambers in the lithosphere and upper mantle. **2.** Development of 3D optimization tools for joint inversion of data sets constrained by petrophysics. **3.** Identification of deep-penetrating faults and crustal suture zones, which are important controls on the movement of metal-bearing fluids and, hence, indicators of prospectivity. **4.** Development of laboratory models to study the fluid-rock interaction, resulting in rock deformation and thermal transitions in mineral systems due to heat transfer. **5.** Understanding and characterizing the fluid-bearing mineral system components with respect to their response to geophysical exploration methods.	
3	Mineral Discrimination	**1.** The goal is to improve our fundamental understanding of the linear and non-linear polarization phenomena of natural mineralized porous media at various scales and over the frequency band of 1 MHz to 30 MHz. **2.** The interfacial and textural properties of rocks will be characterized.	
4	Petrophysical Data Base	**1.** Petrophysical data sets of the different metallogenic provinces of India, consisting of density, susceptibility, conductivity, resistivity, chargeability, velocity, location, stratigraphic unit, lithology, weathering, alteration, metamorphism, porosity, and geochemical and mineralogical information.	
5	Remote Survey Hyper-spectral imaging	**1.** System development & deployment **2.** Mineral mapping and feature extraction for Hyperspectral Imaging (HSI). One of the biggest challenges in HSI is determining which types of features should be extracted from pixels.	
6	Rare Earth Elements and Platinum Group of Elements	**1.** Develop geophysical approaches to rare earth element evaluation. **2.** Conduct geochemical and mineralogical analyses of heavy mineral sand samples from both archives and field efforts. **3.** Analyze new and existing data on the samples to evaluate links between geophysical, geochemical properties, rare earth element content, and local geologic processes. **4.** Synthesize geophysical, geochemical, and geological data using AI, and relate results to geological processes acting on a regional scale. **5.** Study the dispersion of REE/PGE in secondary environments such as placer deposits, weathered horizons, and gossans.	
7	Cross Well Tomography	**1.** Cross-well tomography maps. **2.** Integration of these maps with surface maps to reduce uncertainties.	
8	Development of a Novel Low-Cost Ambient Reconnaissance Technique for the Exploration of Mineral Deposits in Geosciences and Exploration	**1.** To develop a new passive low-frequency surface wave field test methodology. **2.** To develop a new wave field transformation technique to generate high-resolution images of the subsurface from a passive surface wave test. **3.** To develop a fast and accurate numerical algorithm to model the subsurface earth. **4.** To develop an analytical Jacobian-based inverse model. **5.** To develop a convolutional neural network-based algorithm to predict mineral deposits.	

9	Development of an Automated Mineral Detection System Using Underwater Hyperspectral Imaging for Deep-Sea Mining in Geosciences and Exploration	**1.** To develop the Underwater Hyperspectral Unfixing algorithm and design a prototype for mineral detection. **2.** To preprocess the images using a suitable dimensionality reduction technique for subsequent analysis to extract the end members' signatures and estimate the abundance fraction using deep convolutional neural networks. **3.** To validate the results obtained using the proposed method with ground truth data. **4.** To implement the developed algorithm in FPGA-based reconfigurable computing.	
10	Developing an Integrative Approach to Geophysical Exploration with Simultaneous Application of Polarization-Sensitive Hyperspectral Imaging and the HVSR Method Assisted by Machine Learning in Geosciences and Exploration	**1.** Development of an automated prototype to assist polarization-sensitive hyperspectral imaging devices in capturing a large field of view. **2.** Exploration of mineral content or deposits in test fields using the developed system. **3.** Ambient noise recordings with analysis via the horizontal-to-vertical spectral ratio technique on sites determined by hyperspectral imaging, and subsequent correlation using machine learning-based analysis.	
(ii)	**Get Real-Time Data**		
1	Development of an autonomous multirotor unmanned aerial vehicle for geophysical survey	**1.** Develop an unmanned aerial vehicle (UAV) capable of carrying up to a 10 kg payload (e.g., geophysical instruments, measurement systems) and flying/ hovering for up to 90 minutes. **2.** Design the craft using materials that do not interfere with the functionality of the instruments being carried as a payload. **3.** Create appropriate interfaces to provide the necessary power for the onboard devices during the survey. **4.** Minimize the turnaround time to facilitate easy preparation for the next round of surveys.	
2	Drilling Technology	**1.** Interpretational techniques for hyperspectral data. **2.** Hand-held and down-hole analytical instruments. **3.** Directional drilling, improved drill bits, and down-hole logging. **4.** Improvements in slim hole drilling and in-situ measurements.	
B.	**Safe, Smart, and Sustainable (3S) Mining**		
(i)	**Smart Mining**		
1	Optimization of mining machinery and resources using CPS	**1.** Improve operational efficiency (OE) by optimizing unit operations in mining through the application of smart sensors, real-time data acquisition, data transfer, and analysis for performance prediction using Cyber-Physical Systems (CPS). **2.** Increase machine reliability and availability through continuous condition monitoring, online real-time data transfer using suitable sensors and IoT, prediction of failures through AI-based data analysis, and implementation of routine and preventive maintenance schedules based on machine health condition monitoring. **3.** Optimize resources by ensuring optimum machine deployment through capturing real-time data on machine downtime, idle time, operational delays, etc., and analyzing this data using AI. **4.** Optimize energy usage in all activities from mine to mill by capturing unit-wise energy consumption data, analyzing it using CPS, and benchmarking energy consumption. **AI-CPS for Optimization of Mining Machinery and Resources**: **5.** AI combined with Cyber-Physical Systems (CPS) can optimize mining machinery and resources by analyzing real-time data from sensors embedded in equipment and mining operations. This allows for predictive maintenance, efficient resource allocation, and dynamic scheduling to maximize productivity and minimize downtime.	

2	Mine Simulation Systems	1. 3D Simulation & Modelling 2. Digital Twins: 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 optimized 3. Autonomous Drilling 4. Autonomous Equipment: Greater use of self-controlling machines in harsh environments 5. Reducing environmental impact with AI: Sensors and IoT to monitor excavation, extraction, and general mining activities, keeping tabs on the spread of waste and harmful materials. 6. GIS analytical information with graphical representation for better understanding and policy making and AI-based decision support system. **AI-Powered Mine Simulation Systems**: 7. AI-driven simulation systems can model various mining scenarios, including equipment deployment, resource extraction, and logistics, enabling miners to simulate and optimize operations before implementation. This helps in reducing risks, optimizing processes, and improving decision-making.	
3	Reduce risks: Development of Smart Communication, Sensing and Monitoring Technologies	1. Development of an effective underground mine communication system for dynamic and challenging sub-surface environments: Improved Through-The-Earth (TTE) Communications for Underground Mines. 2. Designing portable communication devices based on UHF frequencies for miners in underground coal mines. 3. Development of Underground Positioning Systems (UPS): Smart portable systems for tracking miners, including mine safety monitoring, and alerting. 4. Creation of a low-cost AI/ML portable RADAR system for monitoring and predicting rock and dump slope failures in open-cast mines. 5. Designing a novel surveillance and evacuation system for underground mine safety. 6. Implementation of Drone, LIDAR, GIS, and Remote Sensing-based Mine Surveillance System. **Development of Smart Communication, Sensing, and Monitoring Technologies for Risk Reduction**: 7. AI can be utilized in developing smart communication, sensing, and monitoring technologies to enhance safety and reduce risks in mining operations. AI algorithms can analyze sensor data in real-time to detect potential hazards, monitor environmental conditions, and provide early warnings to workers.	
(ii)	**Safe Mining**		
a	**Major hazard mitigation using CPS**		
1	Spontaneous combustion of coal	1. Development of an integrated system for continuous monitoring of indicators of spontaneous heating using sensor-based technology, analysis of spontaneous heating indices using artificial intelligence (AI) based analytical software and activation of control measures including Mass Inertization (N2 or CO2), withdrawal of persons etc. 2. Development of wearable portable sensors for the detection of gases like CH4, H2, CO 3. Detection of portable sensors for detection of hotspot	
2	Explosions in coal mines	1. Development of an Integrated system of continuous monitoring of accumulation of inflammable gases in mine atmosphere using sensor-based detectors, analysis of explosibility indicators using Artificial Intelligence (AI) based analytical software and activation of control measures including ventilation on demand, withdrawal of persons etc., 2. Design and activation of sensor-based explosion barrier to prevent the propagation of explosion,	

		3. Design of sensor-based instrumentation for the detection of methane layering by sensor-based instrumentation, 4. Development of portable sensors for the detection of inflammable gases like CH4, H2, and CO. 5. Development of portable sensors for determination of inert content in roadway dust.	
3	The inrush of huge quantities of water or unconsolidated mass	1. Development of geophysical method or instrument for identifying the presence of water bodies /water logged workings/accumulation of unconsolidated material ahead of mine workings, which are inaccessible, and analysis of geophysical parameters of the presence of water bodies using AI for predicting the location of such water bodies. 2. Development of a handheld portable water body detector for proving the presence of water bodies immediately ahead of mine workings 3. Continuously monitoring the inflow of water into mine workings and analysing the data using AI to identify the probable hazard of the inrush of water.	
4	Ground failure in Underground mine workings	1. Development of an integrated strata management system for continuous monitoring of strata behaviour and analysing the data using artificial intelligence-based software for prediction of failure of strata ahead of time 2. Development of a handy tool for detecting the presence and location of bed separation in roof rock, based on onsite monitoring of geophysical parameters of roof rock and digitally expressing the failure by using analytical software. 3. Development of an integrated strata management system for monitoring the strata behaviour by using sensors on the existing support system like hydraulic props, powered supports etc. and real-time analysis of monitoring data for prediction of strata behaviour as well as activating the controls on the support system as required. 4. Continuous monitoring health condition of the support system and prediction of failure of the support system. Activating alarm for taking action and also activating alarm for withdrawal of persons in case of imminent failure 5. Monitoring behaviour of goaf in caving method of mining, using cavity scanner or similar other instruments, analysing data using AI to predict the behaviour of caving, like interval and magnitude of periodic weighting, main weighting, movement of strata vertically as well as horizontally, impact of superimposition of caving panels etc.	
b	**Minor hazard mitigation using CPS**		
1	Blasting	1. Development of suitable sensor based portable detector for identifying the presence and location of misfired shots by scanning the profile of blasted material and using AI for analysis of scanning data 2. Development of App based tracking system using sensors or tags for ensuring human and equipment exclusion zone during blasting in opencast mines. Same system may be useful. 3. Prediction of fly rocks from data of blasting detail using AI 4. Development of expert system for measurement while drilling (MWD) technology coupled with AI and machine learning to ensure optimum blast design **AI Optimization for Blasting**: 5. AI can analyze geological data, historical blasting records, and real-time sensor data to optimize blast patterns, timing, and explosives usage, reducing environmental impact and increasing safety.	
2	Collision of mobile equipment or hit by machines in UG mines	1. Development of Sensor-based proximity detection devices capable of detecting the proximity of other equipment and activating an alarm for both operators. 2. Development of Sensor-based tags or personal wearable devices to send an alert signal to the machine operator approaching within the operating zones and similar audio-visual alert to the persons approaching the machine.	

		AI-Based Collision Prevention for Mobile Equipment: **3.** AI systems can utilize sensors and machine learning algorithms to detect and prevent collisions of mobile equipment in underground mines by providing real-time alerts and autonomous control.	
3	Potholing and collapse of important surface structures due to unstable subsurface areas from mine workings or subsurface mine fire	**1.** Development of suitable technology using geophysical method for detecting subsurface unstable areas and application of AI for locating such unstable areas. **AI-Driven Surface Structure Stability Monitoring**: **2.** AI can analyze subsurface data, including geospatial information and mine workings, to predict areas prone to potholing and collapse, enabling preventive measures to protect important surface structures.	
4	Exposure to Diesel Particulate Matter (DPM) beyond safe limit	**1.** Development of an integrated system for sensor-based continuous monitoring of exhaust discharge from the machines like SOx, NOx, CO and DPM, **2.** Analysis of data using AI and prediction of concentration of DPM or other harmful diesel exhaust and **3.** Automatic activation of mitigating measures like ventilation flow control, controlling the movement of diesel vehicles	
5	Exposure to toxic gases beyond safe limit	**1.** Development of an integrated system for sensor based continuous monitoring of exhaust discharge from the machines like SOx, NOx, CO and DPM, analysis of data using AI and prediction of concentration of DPM or other harmful diesel exhaust and activation of mitigating measures like ventilation flow control, controlling the movement of diesel vehicles **AI Monitoring for Air Quality and Toxic Gases**: **2.** AI-powered monitoring systems can continuously analyze air quality data and gas concentrations in underground mines, providing early warnings when Diesel Particulate Matter (DPM) or toxic gases exceed safe limits.	
6	Workmen's Fatigue and physiological stresses or disorders	**1.** Measuring and monitoring of physiological effects of the human body due to fatigue, physiological stresses due to working and task conditions, and physiological disorders due to lack of proper ergonomic design of machines **2.** Prediction of fatigue level, level of physiological stresses and physiological disorders by analysing the data using AI **3.** Activation of machine interlock with digital fatigue detectors. **AI for Fatigue Management and Physiological Stress**: **4.** AI algorithms can monitor worker activities, physiological parameters, and environmental conditions to detect signs of fatigue and physiological stresses, optimizing work schedules and environments to reduce the risk of accidents and health issues.	
7	Loss of structural stability and integrity of heavy machines or structures in mines	**1.** Sensor-based continuous monitoring of structural integrity of complex and large-size machines or structures in mines and prediction of failure by analysing the data using AI before actual failure. **2.** Sensor-based monitoring of structural stability of heavy machines in mines and prediction of loss of stability by analysing data of the physical effects of structural stability on different parts of machines. **AI for Structural Integrity Monitoring**: **3.** AI can monitor equipment and structural health using sensor data to detect anomalies, predict potential failures, and schedule maintenance, preventing loss of structural stability and integrity in heavy machines or structures.	

8	Dump body stabilizers for tippers	1. Sensor-based continuous monitoring of structural integrity of complex and large-size machines or structures in mines and prediction of failure by analysing the data using AI before actual failure. 2. Sensor-based monitoring of structural stability of heavy machines in mines and prediction of loss of stability by analysing data on the physical effects of structural stability on different parts of machines. **AI-Enabled Dump Body Stabilizers**: 3. AI systems can optimize dump body stabilizers for tippers by analyzing terrain data, load conditions, and vehicle dynamics in real-time, ensuring safe dumping operations and preventing accidents.	
(iii)	**Sustainable Mining**		
1	Reducing Green House Gas (GHG) emissions, and monetization of methane gas through CBM/CMM activities	1. Development of knowledge/method/process to determine the peak gas rate or well potential of CBM/CMM well in the exploratory stage and do away with the requirement of pilot wells. 2. Development of knowledge/method/process to deliver robust Mechanical Earth Models (MEM) with the integration of geological, geophysical, petrophysical, coal reservoir, and production data with coal reservoir geomechanics. 3. Development of structured well-drainage-area based AI models as general methane production forecasting tool for coal seam degasification using ML-based algorithms. 4. Development of policy framework and guidelines for the CBM/CMM drainage. 5. Development of a technical screening guide system using an artificial neural network (ANN) to assist in the selection of production methods such as drilling, completion, and stimulation in the CBM/CMM reservoir. 6. Development of Indigenous Pneumatic Controllers for cost-effective separation of gas and water in the separator and accurate metering of water. 7. Development of technology and process that offers economical ways of carbon capturing and utilization in enhanced coalbed methane (ECBM) operation. 8. Development of an AI-enabled reservoir surveillance approach for timely identification of the reason for any production decline, the reversal of production decline by removing wellbore damage, and minimizing shut-down of CBM/CMM wells for an extended period. 9. Development of indigenous permanently mounted sensors in CBM/CMM wells to enable smart good technology 10. Development of cost-effective technologies for treatment and management of water and wastewater.	

C.	**Enhancing mining activities and novel use of minerals/coal**	
1	Extraction Cost Reduction	1. Estimation of the effect of different physical and chemical properties of particles on their breakage. 2. Quantification of different particle processing stages' effect on comminution. 3. Strategies for the introduction of efficiency-boosting techniques like controlled blasting and particle pre-processing within and around comminution circuits. 4. Development of novel comminution circuits integrated with blasting for improving energy efficiency 5. Development of robust simulators aided by sensor-based online PSA (Particle Size Analysers) to reduce the processing cost and even capital cost
2	Life extension of mining equipment	1. Development of AI-based prediction model of wear and tear of screen panels, grinding media, liners etc.

		2. Ultra-fast onsite repair of worn out and corroded components of [illegible] machinery with the ability to prevent heat-related distortion, and requirement of inert gas or vacuum sealed environment 3. Cost effective way to extend the useful life of mining machineries significantly	
3	Deep cleaning of coal	1. Sensor-based/Processor controller aided cost-effective, environment-friendly technology for deep cleaning of high-ash Indian coal 2. Report on techno-economic comparison of different deep-cleaning techniques	
4	Carbon based nanoparticles	1. Development of AI-based CNTs, graphene and graphene oxide for their usage as supercapacitors in high-energy storage materials to increase catalytic performance and effective drug delivery in biomedical applications respectively. 2. Mechanistic understanding of nanoparticle synthesis from heterogeneous coal	
5	Urban municipal waste processing for energy and precious metal recovery	1. Sewage sludge as a source of energy 2. Sensor and AI-based enhanced water recovery from sewage sludge 3. Pyrolysis char as a source of valuable metals/minerals e.g., phosphate, lead, mercury, etc.	
6	Mixing sewage sludge with fine coal waste/ carbon anodes/ forest bio-mass to increase calorific value for subsequent use in cement plants	1. Sewage sludge as a source of energy. 2. Proper utilization of coal waste /carbon anodes/ forest biomass to increase calorific value. 3. AI/Sensor based cleaner cement production	
7	Recovery of valuable metals from process plant water	1. Mine and mineral processing plant water as a source of precious metals 2. Sensor and Process controller aided treatment of wastewater to make it available for use in agriculture, horticulture, fisheries and if possible, as potable water	
8	Holistic utilization of end products to address social and environmental concerns	1. Application of AI in developing modified scheme for improved dewatering performance of Indian red mud slurry 2. Production of dewatered red mud for re-use 3. Improved recovery of water from red mud slurry for recycling back to the plant to reduce freshwater consumption. 4. Increased availability of land, reduced pollution of nearby water bodies and land area, conservation of nearby forests, etc.	
9	Machine Learning Approaches for Water Quality Testing	1. Prediction of water quality degradation and potential aquifer vulnerability in down-gradient regions from a hypothetical uranium in situ recovery (ISR) operation site. 2. Identification of data gaps in mitigating these vulnerabilities, hydrogeological characterization, and development of monitoring programs.	
10	Utilization of Coal Cleaning Plant Rejects	1. Sensor/processor controller aided blending of sal leaves and plant reject 2. Potential for rural employment generation through the social forestry programme 3. Reduction of carbon footprint by utilizing renewable energy sources 4. Utilization of low-grade coal	
11	Extraction of Rare Earth Elements (REE) from coal and its by-products	1. Database on the occurrence of REE in Indian coals 2. Information on the distribution of REE in different by-products of coal utilisation 3. Sensor/processor controller aided technique(s) for the extraction of REE from coal at a different stage of preparation and utilisation and comparisons thereof.	
12	Carbon and Sulphur Capture	1. Green and Clean method for CO2 and SO2 capture 2. Sensor-aided monitoring of Carbon capture and formation of conversion product 3. Biofuels from CO2 and SO2 capture 4. Obtaining carbon credit	

13	Early detection and prevention of spontaneous combustion of coal using UAV	**1.** Early detection and prevention of spontaneous combustion of coal using UAV in coal stockyards, non-active coal mines etc.	
14	Application of AI in enhancing the efficiency of material handling systems in coal and mineral processing and process metallurgy.	**1.** Optimized use of material handling system through AI application **2.** Operating cost reduction **3.** Maximizing the operating hours	
15	Ore geology, geochemistry, hydrogeology, geometallurgy, mining engineering, and geostatistics using machine learning techniques	AI Techniques for a Multidisciplinary Approach Combining Ore Geology, Geochemistry, Hydrogeology, Geometallurgy, Mining Engineering, Geostatistics, and Machine Learning for the Development of Reactive Transport Simulation Models for: **1.** In Situ Recovery (ISR) of Uranium, REEs, Copper, and Gold from sandstone-hosted and unconformity-associated mineral deposits. **2.** Predicting the Environmental Footprint of Uranium In Situ Recovery.	
Ministry of Coal			
A.	**Improvement of safety, health, and environment**		
1	Ground/strata control /Hard roof management in underground mining	Development of a real-time monitoring system for assessing the health condition of support structures and predicting their potential failures, including the activation of alarms for immediate evacuation. Evaluation and mitigation of coal bumps or rock bursts during the extraction of deep-seated coal seams, and monitoring the behaviour of goaf using cavity scanners or similar instruments, with data analysis performed through AI. Implementation of hydro-fracturing techniques and the use of slow-acting expansion chemicals in drill holes within roof strata to induce fractures for managing hard roofs.	
2	Prevention and control of spontaneous combustion & fire in highly gassy coal seams	Development of an integrated system and wearable portable sensors for continuous monitoring of indicators for spontaneous heating by detecting hotspots and analyzing indices using artificial intelligence (AI)-based analytical software. Activation of control measures including Mass Inertization (N2 or CO2), withdrawal of persons, equipment, etc. Technology development for pre-drainage of coal seam methane by inseam/surface-to-inseam gas drainage system and its standardization.	
3	Surface potholing or collapse due to subsurface cavities	Identification of sub-surface unstable areas due to fire or mining-induced cavities using geophysical methods for stabilizing such areas by remote sealing.	
4	Fatigue management	Measuring and monitoring the physiological effects of the human body due to fatigue, physiological stresses from working and task conditions, and physiological disorders due to the lack of proper ergonomic design of machines. Prediction of fatigue level, assessed by analyzing the data using AI. Activation of machine interlock with digital fatigue detectors is also a key area.	

5	Environmental impact and sustainable development	Monitoring of Mine Reclamation & Rehabilitation using remote sensing, subsidence monitoring through advanced Geomatic tools (Radar Interferometry), application of UAV, tree transplantation, integrated hydrological study for impact assessment of mining activities on perennial rivers, biodiversity assessment, and ecological study of coal mine reclamation/plantation sites following International Union for Conservation of Nature (IUCN) and UNFCCC methodologies. Minimization of Diesel Particulate Matter (DPM), etc., are major areas of research. It is also necessary to develop technologies utilizing excavation without the use of explosives.	
6	Energy efficiency and optimization	Although energy audit is being conducted regularly, energy efficiency and optimization remain green areas for research. It is necessary to optimize the energy input and output of mining operations to improve efficiency and become an energy-efficient industry.	
7	AI for Ground/Strata Control in Underground Mining	AI can analyze geological data, monitoring data from sensors, and historical records to predict ground conditions, manage hard roof formations, and optimize support systems to ensure safety and stability in underground mining operations.	
8	AI-Driven Prevention of Spontaneous Combustion and Fire	AI algorithms can analyze various parameters such as gas concentration, temperature, ventilation data, etc., to detect early signs of spontaneous combustion and fire in highly gassy coal seams, allowing for proactive measures to prevent and control incidents.	
9	AI-Based Surface Cavity Detection and Prevention	AI can analyze geospatial data, including satellite imagery, geological surveys, and ground monitoring data, to detect subsurface cavities and predict areas prone to surface potholing or collapse, enabling preventive measures to be taken. **AI-Based Surface Cavity Detection and Prevention**: • AI algorithms can analyze geospatial data, including satellite imagery, geological surveys, and ground monitoring data, to detect subsurface cavities and predict areas prone to surface potholing or collapse. AI can also suggest preventive measures to mitigate risks and prevent accidents.	
10	AI for Fatigue Management	AI can monitor operator activities, equipment status, and environmental conditions to detect signs of fatigue and optimize work schedules to ensure worker safety and productivity. **AI for Fatigue Management**: • AI algorithms can monitor worker activities, equipment usage, and environmental conditions to detect signs of fatigue and physiological stress. By analyzing data patterns, AI can optimize work schedules, tasks allocation, and rest periods to reduce fatigue-related risks.	
11	AI for Environmental Impact and Sustainable Development	AI can analyze environmental data to assess the impact of mining activities, optimize resource utilization, and suggest sustainable practices to minimize environmental footprint and comply with regulations. AI algorithms can optimize energy usage in mining operations by analyzing equipment performance data, scheduling tasks efficiently, and recommending energy-saving practices, contributing to cost reduction and environmental sustainability.	

B	**Alternative use of coal and clean coal technologies**		
1	Coal to activated carbon (AC)/carbon nanoparticles /carbon nanotube (CNT) / Graphene	A carbon nanotube is a seamless cylinder of rolled graphene sheet with high length-to-diameter ratio, exhibiting impressive mechanical and electronic properties. Its applications span electronics, composites, sensors, catalysts, fuel cells, textiles, coatings, optics, and more. Graphene, an atom-thick two-dimensional sheet of carbon atoms, is harder than diamond yet more elastic than rubber, tougher than steel yet lighter than aluminium, with superior electrical and thermal conductivity. Its applications include mechanical, thermal, energy storage, coatings, sensors, electronics, catalysis, and biomedicine. Research focuses on converting coal to activated carbon, carbon nanoparticles, CNTs, and Graphene, along with pilot-scale studies and field implementation. **AI Optimization for Coal Conversion Processes**: • AI can optimize the processes involved in converting coal to activated carbon (AC), carbon nanoparticles, carbon nanotubes (CNT), and graphene by analyzing various parameters such as temperature, pressure, feedstock composition, and reaction kinetics, leading to improved efficiency and product quality.	
2	Technology for commercial production of CBM/ CMM/ AMM	Different technology has been established for CBM resource estimation and few technologies are available for the production of CBM/CMM & AMM. It is required to have technologies for commercial production of CBM/CMM/AMM. **AI-Driven Commercial Production Technology for CBM/CMM/AMM**: • AI algorithms can analyze geological data, reservoir characteristics, and production parameters to optimize the commercial production of Coal Bed Methane (CBM), Coal Mine Methane (CMM), and Abandoned Mine Methane (AMM), maximizing gas recovery and profitability.	
3	Surface & Underground Coal Gasification	Mapping of Indian Coal for Gasification & Indigenous development of Surface & underground coal gasification technology and field implementation.	
4	Coal to chemicals, Fertilizer, and liquid	Characterization of coal, experimental and simulation studies, Pilot-scale study & field implementation.	
5	Establishment of geothermal energy power generation	Characterization of the site & development of technology to Capture the Geothermal heat by Simulation, pilot, and field-scale study. **AI Optimization for Geothermal Energy Generation**: ▪ AI can optimize the establishment of geothermal energy power generation by analyzing geological data, reservoir characteristics, and production parameters. AI algorithms can predict reservoir behaviour, optimize drilling strategies, and enhance energy extraction efficiency.	
6	CO2 Capture, Utilisation & Storage	Coal may be a substitution for furnace oil. R&D is needed in this field for the utilisation of coal as a replacement for furnace oil. Development of technology/method for replacement of furnace oil by coal through plasma. **AI for CO2 Capture, Utilization & Storage (CCUS)**: • AI can optimize CO2 capture processes from industrial emissions by analyzing data from sensors and process parameters.	

7	Replacement of furnace oil with coal through plasma	Coal may be a substitution for furnace oil. R&D is needed in this field for utilization of coal as a replacement for furnace oil. Development of technology/method for replacement of furnace oil by coal through plasma.	
8	Coal quality estimation	Coal quality estimation is an important parameter for predicting the future coal reserve. An indigenous method is to be developed for Geotechnical Characterization & Coal quality estimation from Borehole Logging Data. Also, a method is required to delineate the coal potential zone where it is difficult to access the area for exploration.	
9	Assessment of Rare Earth Elements (REE) in Coal & Non-Coal strata	Rare earth is one of the essential materials for different electronic use. India is a poor contributor to it the world market, as of date. Assessment of rare earth is one of the prime areas of research in coal & non-coal strata with special emphasis on North Eastern Coalfields.	
10	Development of geophysical exploration techniques	Exploration in areas under forest cover or inaccessible areas, different state-of-the-art geophysical exploration techniques is required to be developed for quick exploration of any unexplored area.	
11	AI-Based Coal Quality Estimation	AI can analyze various parameters like coal composition, mineral content, calorific value, etc., from geological data, drilling samples, and historical records to estimate coal quality accurately.	
12	Machine Learning for Rare Earth Elements (REE) Assessment	AI algorithms can process geological and geochemical data to assess the presence and distribution of Rare Earth Elements in both coal and non-coal strata, enabling better resource estimation and mining planning.	
13	AI-Driven Geophysical Exploration Techniques	AI can optimize geophysical exploration by analyzing seismic, electromagnetic, and other geophysical data to identify geological structures, mineral deposits, and coal seams more efficiently, leading to improved exploration success rates.	
D	**Innovation & Indigenization (Under Make-in-India Concept)**		
1	Indigenous development of an active method of detecting buried humans for opencast and underground mines	Developing an active method for detecting buried individuals in opencast & underground mines. **AI-Powered Sensor Networks**: ▪ AI can analyze data from sensor networks including seismic sensors, acoustic sensors, and imaging devices installed in mines. AI algorithms can detect patterns associated with human presence and movements, enabling early detection of buried humans.	
2	Indigenization of integrated low-power wireless load monitoring, gas monitoring, and tracking system using RFID technology for underground mining	Development of a low-power wireless monitoring and tracking system using RFID technology for load, gas and tracking in underground mining.	

3	Indigenous Development of IoT-Enabled Technology for Monitoring, Analysis, and Interpretation of Longwall Shield Pressures for Improving Safety and Productivity	Developing IoT technology for monitoring, analyzing, and interpreting longwall shield pressures to enhance safety and productivity.	
4	Indigenous development of Self-contained Breathing apparatus (Both closed and open circuit), Escape apparatus, and Reviving apparatus used for below-ground and opencast mining.	Developing self-contained breathing apparatus (closed and open circuit), escape apparatus, and reviving apparatus for below-ground and opencast mining.	
5	Development of an indigenous robotic technology for detecting firefighting in opencast mines and extinguishing the fire	Creating a robotic technology to detect and extinguish fires in opencast mines.	
6	Development of a technique for Artificial Intelligence (AI)/ Machine Learning (ML), data analytics for automated mine management system	Developing a technique using AI/ML and data analytics for an automated mine management system.	
7	Development of Mixed reality (Virtual reality, Augmented reality & Extended reality) for mining (UG & OC) operation & training	Creating a mixed reality solution for underground and opencast mining operations and training.	
8	Development of miners Personal Protective Equipment (PPE) using nanotechnology	Developing personal protective equipment for miners using nanotechnology.	
9	Development of a portable instrument for detecting bed separation, and minor faults/ hidden slips in the roof of coal mines.	Creating a portable instrument to detect bed separation and minor faults/hidden slips in the roof of coal mines.	
10	Machine Learning for Human Detection:	AI algorithms can analyze data from sensors such as seismic, acoustic, or imaging devices to detect buried humans in opencast and underground mines by pattern recognition and anomaly detection.	
11	AI-Enabled Integrated Monitoring Systems:	AI can optimize low-power wireless load monitoring, gas monitoring, and tracking systems using RFID technology in underground mining by analyzing data patterns, predicting potential hazards, and providing real-time alerts.	
12	IoT-Based Technology with AI for Shield Pressure Monitoring:	AI can be utilized with IoT devices to monitor, analyze, and interpret longwall shield pressures in real-time, identifying safety risks and optimizing productivity through predictive analytics.	
13	AI-driven Development of Breathing Apparatus:	AI can aid in the indigenous development of self-contained breathing apparatus (SCBA), escape apparatus, and reviving apparatus for mining by optimizing design, materials, and functionality based on safety standards and historical data.	
14	Robotic Technology with AI for Fire Detection and Extinguishing:	AI-powered robotic systems can be developed to detect and extinguish fires in opencast mines autonomously by analyzing sensor data, identifying fire risk areas, and taking appropriate actions.	