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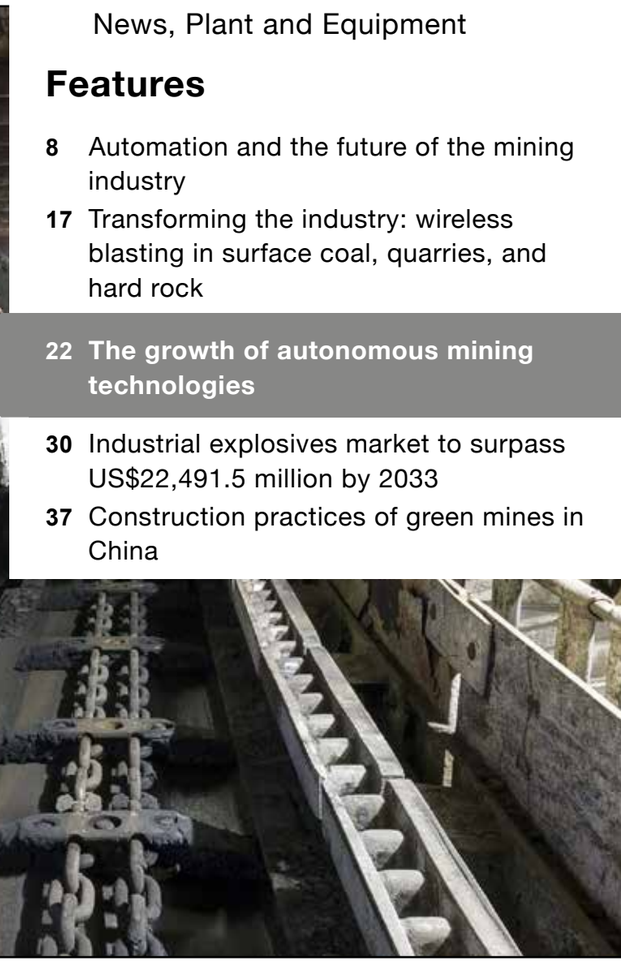

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Coal sector deploys many solutions to attract miners

Subsidiaries of ViệtNam National Coal-Mineral Industries Holding Corporation Limited (Vinacomin) have deployed many solutions such as applying science and technology to production, improving working conditions, increasing income and providing housing for miners, so that miners will stay with the coal industry.

Nguyễn Văn Nam, a 32-year-old miner, has worked at Vinacomin's Thống Nhất Coal Company in Cẩm Phả District, in the northern-eastern province of Quảng Ninh for more than 10 years.

Nam said in the past, the company's longwall mining was dug manually, but now the company installed a modern frame system which is much safer. Excavators, drills and winches were used for longwall mining now to increase productivity.

Thanks to that, the average income of the company's workers was more than VNĐ1 million (US$40) per day. It could reach VNĐ1.3-1.4 million ($52-56) each day if the miner worked on the weekend.

Nam said he earned about VNĐ500-600 million ($20,290-24,350) per year.

In 2010, he moved from the coastal central province of Nghệ An to the north-eastern province of Quảng Ninh to learn mining. After graduation, he was recruited by the company.

Currently, he is the team leader of a group of 32 miners.

Because of stable income, he already bought nearly 100 sqm of land to build a three-storey house where he, his wife and his children can live quite comfortably.

Thus, he encouraged his elder brother to work for the company and both of them were now exemplary faces of the company in terms of labour productivity.

Implementing the corporation's policy (mechanisation, computerisation and automation), the company has decided to invest in a monorail system combined with diesel locomotives to serve mining production.

Nguyễn Mạnh Toán, director of the company told the Nhân Dân (The People) online newspaper that the company had poured a total VNĐ27.4 billion ($1.1 million) into increasing the production capacity in Lộ Trí coal mining area.

The company also put into use a diesel power station, providing backup power for equipment in case the grid power is suddenly cut.

All workshops of the company also run production-order software, reducing administrative procedures and improving efficiency in production management, he said.

The company was added to the top list of the corporation's coal mining companies with annual mining output reaching two million tonnes of raw coal.

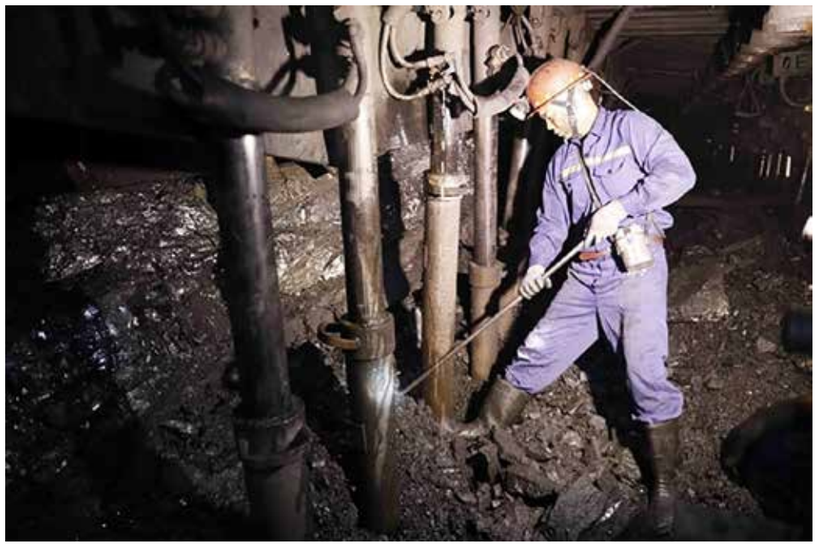
In the meantime, Mạo Khê Coal Company in Đông Triều District, has reached an annual mining output of about 2.3 million tonnes in recent years, although it is an old mine having been in continuous exploitation for nearly 70 years.

Achieving the above results, the company's top strategy is innovation, application of science and technology, deployment of mechanisation and synchronous automation at all stages.

Director of the company Nguyễn Văn Tuân said Mạo Khê coal mine was classified as a mine, which contained much natural methane gas, always posing potential risks of fire and explosion.

Therefore, the company installed a modern centralised monitoring system to manage the gas 24 hours a day to ensure safe production.

Last year, the company had 10 miners earning more than VNĐ600 million ($24,500) each year, nearly 200 miners earning from VNĐ500 million ($20,400) to VNĐ600 million ($24,500) each year, and more than 400 miners earning from VNĐ400 million ($16,350) to VNĐ500 million ($20,400) each year.



Providing accommodation

Currently, the corporation has 50 companies located in Quảng Ninh Province, with a total of nearly 80,000 workers, including more than 51,000 migrant workers, so the need for stable accommodation is an increasingly urgent problem.

Since the 2000s, the companies have built 26 high-rise apartment buildings, providing accommodation for nearly 10,000 people.

In early October 2023, the corporation's Trade Union coordinated with relevant units to advise miners to buy social housing apartments in an area in Hạ Long City.

After the consultation session, nearly 100 workers registered to buy the apartments, costing from VNĐ700 million ($28,600) to 1.2 billion ($49,000) per apartment, with an area of 40-70 sq.m.

The corporation's Trade Union plans to organise many similar programmes to advise miners to buy social housing.

By 2025, the corporation will remove problems to build 10 social housing areas, covering more than 5 ha, providing accommodation for about 2,400 miners.

A social housing building for miners in Hòn Gai Coal Company under Việt Nam National Coal-Mineral Industries Holding Corporation Limited in the northern-eastern province of Quảng Ninh. – VNA/VNS Photo Tuấn Anh

As calculated, Thống Nhất Coal Company has 3,500 workers, half of them in need of housing.

However, the company's two dormitories now only accommodate nearly 700 workers.

Thus, the company is completing administrative procedures to build another accommodation complex in Cẩm Thành area. The complex is initially expected to have seven floors with 68 apartments, providing accommodation for 272 people, with a total investment of VNĐ73 billion ($2.98 million).

Chairman of the corporation's Trade Union Lê Thanh Xuân said the corporation's companies had made efforts to deploy a lot of solutions to improve working conditions, productivity and income for miners over the past time.

Additionally, the trade union also worked with relevant units to implement many welfare programmes every year for workers, such as building "Trade Union's Warm House" for disadvantaged and poor miners, and providing jobs for the wives of miners who suffered accidents or injuries during work.

It is estimated that the corporation needs to recruit and train about 4,000-4,500 candidates to supplement the number of workers who retired or quit their jobs because of hardship each year.

Teck expects to close coal unit sale to Glencore by Q3, CEO says

Canadian miner Teck Resources plans to close the sale of its steel-making coal unit to Glencore no later than the third quarter of 2024, CEO Jonathan Price told Reuters in an interview recently.

Teck, one of the leading producers of steel-making coal, last year announced the sale of the business to Swiss miner Glencore for $9-billion and said it was shifting its strategy towards building its copper business. The deal needs approval from the Canadian government.

"The regulatory process is still going well, we are still confident of closing that transaction no later than the third quarter of 2024. So all on track at this stage," Price said.

When asked whether Teck was having any conversations with Glencore regarding the sale of its copper business, Price said the company's focus now is to ramp up its QB2 mine in Chile to full production and to invest in current copper projects in Mexico, Peru and British Columbia, Canada.

Besides copper and coal, Teck is also the biggest producer outside China of the rare earth metal germanium, from its Trail Operations in British Columbia. Export restrictions imposed by China on gallium and germanium have had a positive impact on the company.

"We have always been able to sell the production that we generate from that facility," Price said, adding that pricing had improved as a result of some of the Chinese restrictions. "So it's been a positive development for us."

Recently Teck Resources beat fourth quarter profit estimates, helped by an increase in steel-making coal sales and record copper production.

Shares of Teck closed at C$52, up by 1.6% at the TSX.

Yancoal celebrates ‘tremendous’ 2023 performance

Yancoal chief executive officer David Moult has applauded the Yancoal team’s 19% increase in run-of-mine coal production and 35% reduction in total recordable injury frequency rate for 2023.

“At the start of the year, we needed to rebuild mining inventory to underpin a sustainable return to previous years’ production levels,” Moult said.

“The plans took time to implement, but in the second half attributable saleable coal production jumped 32% and cash operating costs fell 21%. We expect to carry this operational momentum into 2024.

“Production volumes will vary each quarter, with higher output (and resulting lower unit costs) likely in the second half.”

Yancoal recorded revenue of $7.8 billion for the 2023 year, a decrease from the $10.5 billion recorded in 2022. The fall was due to the 39% decrease in realised coal price to $232 per tonne.

However, operating EBITDA (earnings before interest, taxes, depreciation, and amortisation) of $3.5 billion and EBITDA margin of 45% demonstrated the quality of Yancoal’s assets in the face of retreating coal prices.

“Coal markets appear relatively well balanced, with seasonal or temporary supply and demand factors poised to determine short-term price trends,” Moult said.

“This year, like past years, we aim to maximise operating cashflow by balancing volume, costs, coal quality and capital expenditure.”

Yancoal has also welcomed a new independent non-executive director to its ranks.

Debra Bakker will join the board from March 1, and will also be appointed as chair of the nomination and remuneration committee and as a member of the audit and risk management committee.

Bakker’s experience encompasses precious metal, base metal and critical mineral mining, oil and gas development, shipping logistics, commodity trading and corporate financing.

“We welcome Ms Bakker to her new role, and anticipate her broad ranging experience will prove invaluable as Yancoal pursues further success,” Yancoal chairman Gang Ru said.

Poland needs EU coal plant subsidies until it builds nuclear plant

Poland will need an extension of EU rules that allow coal plant subsidies until 2028 as it will require coal power generation until it builds its first nuclear plant next decade, the top energy security official in the new government told Reuters.

“I have no doubt that coal units will be needed in the system until they are naturally replaced by nuclear power plants,” Maciej Bando, deputy climate minister in charge of strategic energy infrastructure, said in an interview.

Poland’s new government is aiming to speed up the transition to lower carbon energy, but coal units currently supply 60% of electricity output, backing up intermittent renewable supplies. Warsaw plans to build its first large-scale nuclear plant by 2033.

“An ideal model would see nuclear units replacing coal plants but this a perspective of over 10 years,” Bando said.

He said Poland should take advantage of the fact that other large European Union countries are also discussing support for their power generation assets with the bloc. Germany is seeking EU approval for its plan to subsidise gas plants.”This is the moment when, by uniting, all interested parties can obtain some extension of this deadline,” he said.

The European Commission did not immediately respond to a request for comment.

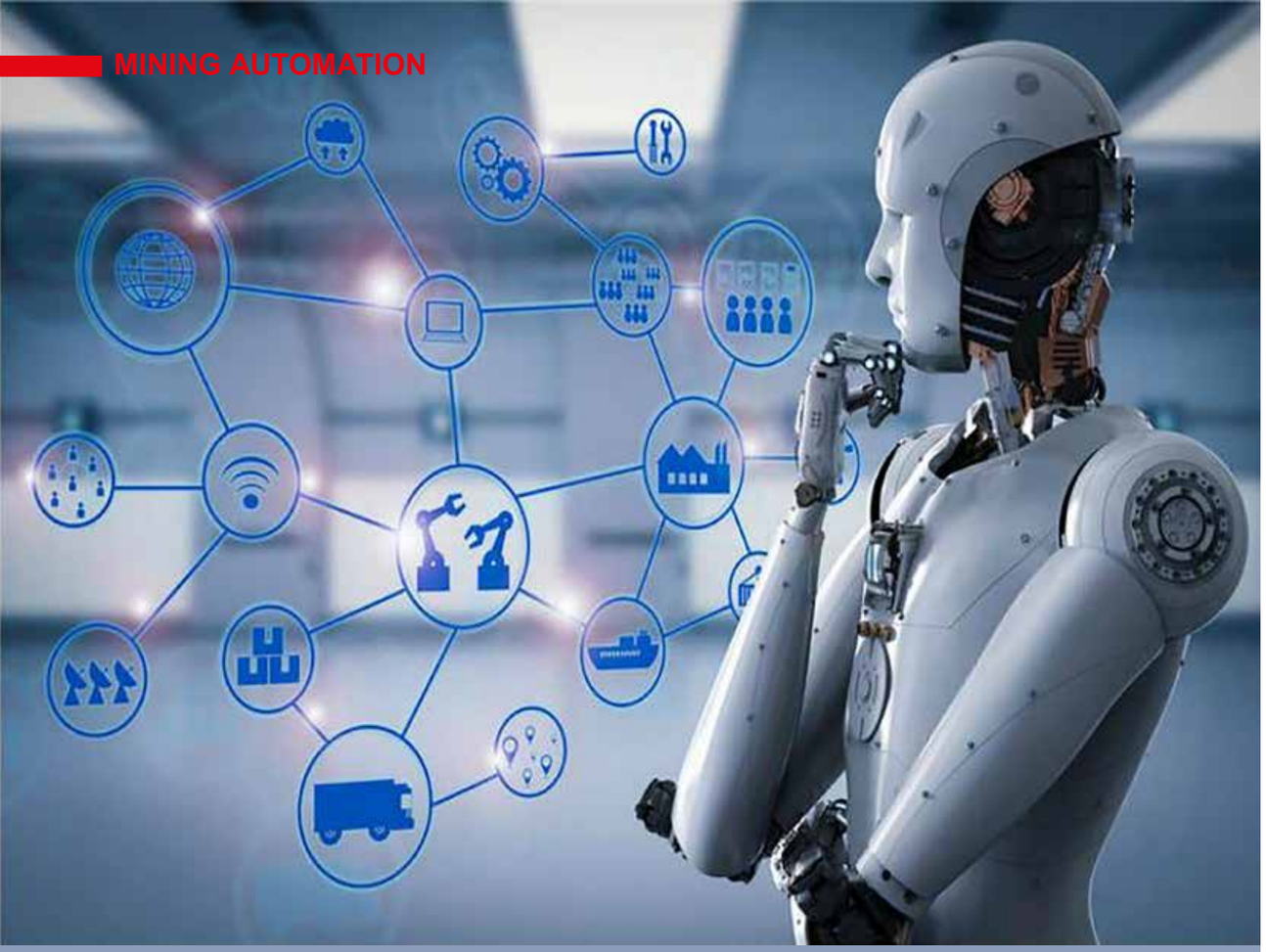
Bando also said Poland did not need to expand a planned floating liquefied natural gas terminal in Gdansk before 2030 amid lower demand for the fuel.

The previous government was looking to add a second floating storage and regasification unit (FSRU) capable of receiving 4.5 billion cubic meters of gas per year to a facility to be built by state-owned pipeline operator Gaz-System by early 2028.

“Based on the analysis prepared by Gaz-System, examining today’s and future gas demand, we do not see the need to build or install a second unit,” Bando said.

“So in the coming years, until the end of 2030, it doesn’t seem there is a need for the second unit.”

In November, Gaz-System said the tender to expand the terminal didn’t attract enough interest from buyers, but in December Warsaw said it was still in talks with Czech, Slovak and Hungarian partners on the expansion.



Automation and the future of the mining industry

While automation technology has been transforming numerous industries for decades, the mining sector has only recently begun to leverage robotics. As mining companies face increasing pressure to improve productivity, reduce costs, and enhance worker safety, the use of mining robots has become increasingly prevalent. This critical industry is being transformed by mining robots, with advancements like autonomous trucks and remote-controlled drilling machines.

The COVID-19 pandemic has shown to multiple industries the benefits of increasing automation systems where human contagion risks are reduced in operations. This benefit is especially noticeable across many mining operations that have seen just a few disruptions during the pandemic, thanks to automation processes. Also, considerable technological improvements and reduced costs have provided new ways to process mining operations remotely, deepen the use of automation, and increasingly employ more robotic systems across different operations.

Implementing the required technology without adapting existing operations and changing the culture won't be enough. Success is being found by mining companies due to increased investment in automation technology from OEMs. ***Coal International takes a detailed look at how technological improvements are being made within the mining industry***.

This success brings case studies mining companies can reference for their own automation projects. Additionally, OEMs often consult companies on integrating automation into their existing operations and transforming their company culture to embrace automation.

Apart from the expanding acceptance and availability of automation solutions, the mining industry is confronted with multiple challenges that are compelling the implementation of automation technology.

One shift that demands a response is the emergence of an important new player in the critical minerals market: government. After seeing rapid demand growth and risky levels of supply chain concentration, governments have formed alliances, instituted new policies, and mobilised funding to secure access to critical minerals. These moves will change the mining business. The inflow of public funds, for example, means that miners must rethink the rates of return they can expect on mining or supply chain assets. Miners will also need to contend with heightened investment risk and greater competition as governments alter the playing field with incentives and interventions.

Then there's the urgent task of decarbonisation. Miners will have to ramp up production to meet rising demand for the critical minerals and other commodities that are required for the energy transition. But they also know they must reduce their carbon emissions. More than one-third of mining CEOs see their company as highly or extremely exposed to climate-related risks. The good news is that decarbonisation can help miners create value at all points along the value chain. More and more, we're seeing miners boost efficiency with low-carbon technologies and methods, partner with processors to produce the "green metals" that customers increasingly want, and access sustainability-linked financing.

The transition to renewable energy and a low-emissions economy will not, however, be straightforward—and neither will change in the mining industry's makeup. The Top 40 mining companies posted strong financial performance in the last few years Their balance sheets are robust, and debt remains low. But EBITDA (earnings before interest, taxes, depreciation, amortisation, and impairments) margins decreased, as predicted, amid swelling costs and economic uncertainty.

What's more, the mix of revenue from mining commodities shifted. Surging demand made coal the biggest contributor to the Top 40's revenue for the first time since 2013, a sign that coal miners still have a role in meeting the world's energy needs. Nonetheless, the long-term trajectory for coal revenue clearly runs downwards.

CHALLENGES

In addition to the increased acceptance and accessibility of automation solutions, the mining industry faces several challenges that are now driving the adoption of automation technology. These primary challenges include Safety, Environmental impacts, and labour shortages.

Safety for workers has always been a challenge for the mining sector. Mining is a hazardous industry, with workers exposed to various risks. Common hazards include:

- **Physical hazards** – cave-ins, rock falls, explosions, hearing damage, vehicle crashes, drowning, vibration, and other physical traumas
- **Biological hazards** – exposure to poisonous fumes, dust, various solvents used for mineral separation, and heavy metals.
- **Ergonomic hazards** – cumulative trauma due to heavy lifting and repetitive movements, overexposure to heat or cold temperatures, and musculoskeletal injuries associated with mining tasks.

The mining industry is also facing pressure from global leaders to reduce its environmental impact. The primary sources of emissions generated by the mining sector include:

- Energy consumption,
- Transportation,
- Processing and refining,
- Land use change.

Mining requires considerable energy to power equipment and machinery, as well as for heating, ventilation, and lighting. This energy is often generated from fossil fuels, which release greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

The mining industry relies heavily on transportation to move equipment, materials, and products. This transportation generates emissions from the burning of fossil fuels in trucks, ships, and other vehicles.

Extracting and processing minerals and metals can also generate significant emissions, particularly during the refining stage. For example, smelting metal ores typically involves high temperatures and chemical reactions that release greenhouse gases and other pollutants.

Mining can also contribute to emissions through land use change, such as deforestation, soil degradation, and habitat destruction. These activities can release carbon stored in trees and soil, as well as disrupt local ecosystems.

The challenges mining companies face can seem massive in scope. However, automation can help companies begin to resolve these issues.

One of the most significant benefits of automation in the mining industry is improved safety. Direct exposure to mining processes and equipment operations poses risks to miners. By automating a process, companies directly reduce the risk of injury to their operators.

Mining operations can be dangerous, and automation can help remove human workers from hazardous work areas, reducing the risk of accidents and fatalities.

In addition, automated mining equipment can monitor equipment performance and detect potential problems, helping prevent breakdowns that lead to accidents.

Automation can also contribute to a more sustainable mining industry. By optimizing consumption and reducing environmental impact, automation can help increase the sustainability of mining operations.

For example, automated equipment can optimize energy use. Energy consumption emits considerable amounts of greenhouse gases into the atmosphere which political leaders are keen to limit.

Automation can help reduce water consumption. Excessive water displacement leads to a host of environmental issues such as sinkholes and negative impacts on local wildlife. Both examples here can lead to infrastructural damage and dire effects on people, animals, and fauna.

As mining is placed under more scrutiny, it's important to consider how automation can help the industry meet regulatory requirements for environmental protection and sustainability.

HAULING

The current advancement of robotics, especially in Cyber-Physical Systems (CPS), leads to a prominent combinations between the mining industry and connected-embedded technologies. This progress has arisen in the form of state-of-the-art automated giant vehicles with Autonomous Haulage Systems (AHS) that can transport ore without human intervention. Like CPS, AHS enable autonomous and/or remote control of physical systems (e.g., mining trucks). Thus, similar to CPS, AHS are also susceptible to cyber attacks such as Wi-Fi De-Auth and GPS attacks. With the use of the AHS, several mining activities have been strengthened due to increasing the efficiency of operations. Such activities require ensuring accurate data collection from which precise information about the state of the mine should be generated in a timely and consistent manner. Consequently, the presence of secure and reliable communications is crucial in making AHS mines safer, productive, and sustainable.

Hauling is a key task in mining and is required to move material from the pit to be unloaded for further processing. Typically, this is handled by human operators driving large haul trucks. However, mining companies find autonomous trucks to be valuable for hauling applications.

Autonomous haulers are commonly used in open-pit mining operations, where they can transport ore and waste material without the need for human drivers. Autonomous units look almost identical to manual haul trucks. Automated units feature a suite of sensors for path planning, obstacle avoidance, and GPS tracking. Multiple haulers can work together as a connected fleet with fleet management systems.

Often referred to as Autonomous Haulage Systems (AHS) these trucks use a combination of sensors and GPS technology to navigate the mining site and transport material safely and efficiently. Compared to human drivers, autonomous trucks can operate 24/7, reduce the risk of accidents, and optimize routes to minimize fuel consumption and increase productivity.

Autonomous haulers help mining companies increase safety, reduce fuel consumption and emissions, increase productivity, and face labour shortages.

Mine safety has improved over time due to new technologies and regulations, but fatal accidents unfortunately still occur. Studies have demonstrated that interaction between human workers and vehicles is a considerable threat to safety, with one paper finding that 11% of the total fatalities in US mines over a 12 year period involved trucks. Furthermore, 57% of severe injuries were associated with vehicles.

Increasing adoption of automated haulage systems (AHS) is a key trend in the mining industry currently, with numerous companies increasingly employing fleets of autonomous trucks, loaders, and trains. Autonomous robotic haulage trucks navigate a network of haul roads in mines and automatically load and dump ores, without the need for human intervention. Technologies, including smart sensors and AI, allow these vehicles to operate safely, detecting any personnel, mining vehicles, and equipment in their vicinity.

COMPANIES WORKING WITHIN THIS ROBOTICS SPACE

Several companies have developed robotic systems for autonomous haulage. Sandvik and Volvo were early adopters of the technology, providing proof-of-concept vehicles that laid the groundwork for further development in the space.

Volvo tested an autonomous truck at Sweden's Kristineberg mine some 8 years ago. The truck traveled underground for seven kilometers without a human driver. Sandvik demonstrated that an autonomous 38-tonne loader could successfully maneuver through a glass maze in 2018.

Komatsu Mining, an early trailblazer in autonomous mining with the development of field management software in 1990, has developed an autonomous haulage trucks with no cabin, a design that optimizes load distribution and does not distinguish between forward or reverse.

Trials of Komatsu's autonomous systems began in 2008 in partnership with Rio Tinto. Controls, wireless networking, and obstacle detection are standard in models such as the 930E and further series enhanced trucks used by Rio Tinto, but they still look like conventional trucks, complete with cabins.

The cabin-free design means that weight is better distributed across all four wheels. Moreover, without a human driver, the system can move both forward and backward without the need for manoeuvres such as three-point turns, significantly enhancing productivity and reducing tire wear and tear.

AutoMine for Trucks (part of one of the original autonomous haulage developments) is an autonomous ramp haulage solution from Sandvik for underground mines. Smart handover technology enables real-time switching between underground and surface navigation for autonomous trucks. Volvo initiated working on the self-driving FMX truck in collaboration with Saab. Scania collaborated with Rio Tinto to develop next-generation autonomous trucks. Hitachi's AHS solutions leverage Wenco's fleet management system and its Smart Mining Truck System. Caterpillar are working with BHP and FMG to implement autonomous solutions. In conclusion the initial developments coupled with the most recent advances in industries such as mining demonstrate the key role robotics is playing in the 21st century as companies seek to overcome the challenges they currently face. In combination with solutions such as AI, machine learning, smart sensors, and IoT, the future of robotics in mining is an exciting prospect.

DRILLING AND BLASTING

Drilling robots are used in underground mining operations to drill holes for blasting or exploration. Drilling robots commonly take the form of rovers and full-scale blasting rigs. This structure enables sufficient mobility and drilling power.

Autonomous drilling and blasting platforms are equipped with a suite of sensors. GPS and vision systems aid in navigation and path planning. Sophisticated measurement tools enable these systems to report back on metrics like blast fragmentation. This data is reported back to a control system that enables operators to optimize historical blast data across the entire fleet.

These robots can operate in areas that may be too dangerous or difficult for human operators to reach, such as narrow tunnels or unstable rock formations. Drilling robots can also improve drilling accuracy and speed, reducing waste and increasing productivity.

Drilling robots enable companies to increase worker safety, productivity, and reduce waste, helping mining companies resolve several challenges they face today.

EXPLORATION

Robots are increasingly being used in the mining industry for exploration tasks, such as mapping and prospecting. Rover-type robots, drones, and submarine robots are commonly deployed for these tasks.

These robots are equipped with sensors and cameras that can detect geological features and analyse soil samples. They can operate in remote and hazardous locations that are difficult for human explorers to access, such as underground tunnels, deep seabed's, and polar regions.

Exploration can be costly, dangerous, and introduce negative environmental impacts when done using traditional methods.

Human operators are harder to find and more expensive than mining robots. Additionally, exploration in unstable tunnels that are prone to collapse, or flooding can be dangerous. Robotic exploration can reduce exploration costs and hazards to human operators. In addition, robotic exploration can help reduce the environmental impact of mining operations, as it can help identify mineral deposits without the need for extensive drilling and excavation.

Overall, automation technology has brought significant advancements and benefits to the mining industry. As the mining industry continues to face challenges, including a worsening labour shortage and increasing environmental regulations, automation technology will continue to play a critical role in the industry's success.

By adopting robotics technology, mining companies can address challenges threatening the industry's growth, such as safety concerns, increasing environmental regulations and calls for sustainability, and resolving labour constraints.

THE ADVANTAGES OF USING DRONES IN MINING

Drones have emerged as a game-changing aerial survey technology for the mining industry, offering a range of benefits that have not been previously possible. One of the main advantages of using drones in mining is the cost savings that can be achieved. Drones can replace traditional surveying methods, complete surveys more quickly, and reduce labour and equipment costs.

Drones offer a range of benefits for the mining industry, including cost savings, increased safety, and improved efficiency. They can replace traditional surveying methods, reducing labour and equipment costs, and complete surveys more quickly, resulting in significant cost savings.

Here are some of the main advantages of using drones in mining:

- Drones reduce mining costs by replacing traditional surveying methods and decreasing labour and equipment expenses.
- Drones enhance safety by identifying risks, monitoring processes, and detecting leaks and gases.
- Drones aid in predicting stability and monitoring conditions and can provide emergency assistance in the event of an incident.
- Drones improve environmental monitoring by collecting baseline data, managing water, detecting hazardous gases and loose rock, and monitoring open pits.
- Volumetric surveys using drones are 60-80% faster than traditional methods, providing reliable and accurate data for informed decision-making and operations improvement.
- Time-lapse photography by drones tracks mining progress, reducing waste, and increasing productivity by predicting mineral extraction and transportation timelines.
- Drones create 3D models of open pits in real-time, detecting irregularities and assessing safety hazards.
- Drones revisit abandoned mines, providing detailed and accurate maps to calculate sealing and assist in the reclamation process.

LABOUR SHORTAGES IN MINING: SOLUTIONS

As the mining industry grapples with a significant labour shortage, it is increasingly clear that innovative technological solutions are the key to overcoming this challenge. From automation to artificial intelligence, we're leveraging advanced technologies to optimize operations, enhance productivity, and address the labour shortage in the sector. These technologies are not merely mitigating current workforce challenges, but also shaping a future-ready mining industry that attracts a diverse pool of talent, bolstering the resilience of this sector.

While these advancements are transforming the landscape of the mining industry, their adoption must be strategic, ensuring we optimally harness their potential while promoting the wellbeing and satisfaction of our workforce. This short inclusion within this article will delve into several emerging technologies and their application in the mining industry. Each of them offers unique benefits, and their collective use presents a holistic approach to addressing the labour shortage in mining, enhancing operational efficiency, and paving the way for a sustainable future in the resources sector.

The integration of technology in the mining sector is paramount, especially when labour shortages are threatening the vitality and sustainability of the industry. Labour is the backbone of mining operations, and any shortage can lead to significant disruptions, escalating operational costs, and diminishing productivity. Implementing innovative technological solutions serves as a pivotal strategy to maintain uninterrupted operations, enabling the industry to sustain output and adhere to delivery commitments, which is essential in fostering robust relationships with stakeholders and maintaining a competitive edge in the global market.

Moreover, the infusion of technology in mining operations not only addresses immediate labour challenges but also plays a critical role in reshaping the perception of the mining industry. By fostering an environment of innovation and advanced learning, the industry becomes an attractive career destination for a diverse and tech-savvy workforce. This transformation is crucial in ensuring the longevity of the mining sector, as it paves the way for the infusion of fresh perspectives and novel approaches, enhancing adaptability and resilience in facing future industry challenges and fluctuations.

Additionally, strategic adoption of technology underscores a commitment to the well-being and development of the mining workforce. It creates an ecosystem where routine and hazardous tasks are automated, reducing the risk to human life and allowing workers to focus on more value-driven roles, fostering job satisfaction and employee growth. This holistic approach not only addresses immediate labour concerns but also contributes to building a more sustainable, efficient, and inclusive mining industry, thus securing the future of the resources sector across the globe.

AUTOMATION

In addressing labour shortage solutions for the mining sector, automation presents an attractive strategy. Autonomous machinery and robotic systems, such as automated drilling systems and self-driving trucks, can perform tasks traditionally handled by workers, effectively easing labour shortages. With advancements in technology, we see automation not just replacing manual labour, but also improving the precision and efficiency of tasks, which in turn increases overall productivity.

Furthermore, we're already observing some degree of automation within existing mining companies, demonstrating

the sector's receptiveness to these solutions. The potential for more widespread use, however, remains vast. As these technologies become more sophisticated and affordable, we can expect a broader adoption across the sector. Expanding the use of these autonomous solutions will not only meet the immediate needs of mining workers but also enhance the long-term productivity and sustainability of the sector.

INTEGRATING SOFTWARE SOLUTIONS

In the quest to address labour shortages and optimize operations, comprehensive software solutions play an increasingly vital role.

Integrated Software Solutions are designed to manage, analyze, and act upon your asset's health data. Innovative tools not only offers a streamlined platform to implement a holistic condition management program in your business quickly and cost-effectively, but it also enhances visibility and collaboration across your company's departments, thereby optimizing resource utilization. Mining companies can increase availability, extend asset life, reduce maintenance and replacement costs, and track results effectively. It seamlessly connects to existing systems and infrastructure, and is an effortless addition to your technological arsenal, offering solutions that align with the evolving needs of the mining industry.

Software solutions don't just fill the gaps of labour shortages; they redefine the efficiency and resilience of mining operations, ensuring the sector's continued growth and success.

REMOTE OPERATIONS AND TELEOPERATIONS

Remote operations centres, with their capacity to control a multitude of machines and operations, stand as a viable solution to the labour shortage in mining. By enabling a smaller number of skilled workers to manage extensive operations, mining companies can reduce labour demands, particularly in more remote areas. This not only solves the immediate challenge of worker shortage, but it also improves the overall efficiency and effectiveness of mining operations.

The benefits of remote operations and teleoperations extend beyond addressing labour shortages, however. Offering better work conditions by eliminating the need for workers to be physically present at dangerous or remote sites, these technologies can attract a broader pool of talent to the sector. This approach underscores the sector's commitment to prioritizing the health and safety of its workforce, and also serves to enhance the image of mining as a forward-thinking and worker-friendly industry.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

AI and Machine Learning serve as transformative tools within the mining sector, offering valuable solutions to labor shortages. For instance, predictive maintenance, powered by AI, can streamline operations, leading to a more efficient mining process that requires less human intervention. These smart systems can analyze massive amounts of data to identify patterns and make predictions, thereby reducing the need for manual monitoring and analysis.

With the support of international governments, surveyed mining companies are increasingly leveraging these technologies, reducing downtime by predicting equipment failure and scheduling preventative maintenance. This not only solves the immediate labor shortage problem but also increases the lifespan of equipment and the profitability of mining operations. As the mining sector continues to face workforce challenges, the role of AI and Machine Learning in filling gaps and enhancing productivity is likely to increase, paving the way for a smarter and more resilient industry.

ETHICAL CONSIDERATIONS IN AI AND ROBOTICS: CHALLENGES AND SOLUTIONS

As we enter this transformative era, businesses and societies are experiencing unprecedented changes that have the potential to revolutionize the way we live and work The manufacturing sector is at the forefront of embracing robotics and automation. The introduction of robots on the assembly line has enhanced precision, speed, and productivity. Robots equipped with advanced sensors and machine learning algorithms can perform repetitive tasks with greater accuracy, reducing errors and enhancing overall quality.

Automation has also led to cost savings as machines can operate continuously without the need for breaks, resulting in increased output and decreased labour costs. Autonomous vehicles are transforming the transportation industry, offering safer, more efficient, and environmentally friendly alternatives. Self-driving cars and trucks have the potential to reduce accidents caused by human error and optimize traffic flow, leading to reduced congestion and shorter commute times. Additionally, the adoption of autonomous vehicles in logistics and freight transportation promises streamlined supply chains, improved delivery times, and reduced costs. The integration of robotics and automation in transportation is not limited to road vehicles, as drones and unmanned aerial vehicles are being deployed for tasks such as package delivery and surveillance. Innovations in robotics and automation are revolutionizing agriculture, addressing labour shortages, and increasing productivity. Robots equipped with computer vision and machine learning algorithms can identify and selectively harvest crops, minimizing waste and increasing efficiency. Autonomous drones equipped with sensors and imaging technology provide valuable insights into crop health, enabling farmers to optimize irrigation, pest control, and fertilizer usage.

Furthermore, robots are being utilized for tasks such as soil sampling, planting, and weed control, reducing manual labour, and increasing yields. While the transformative power of robotics and automation is undeniable, it also presents challenges. The displacement of certain jobs is a concern, as automation replaces tasks traditionally performed by humans. However, this also creates opportunities for reskilling and up skilling the workforce, fostering the development of new roles and industries.

Highly responsive conveyor belt tracker improves production and safety worldwide

The pioneer in belt conveyor accessories has launched the next generation of tracking technology for a global marketplace. Martin Engineering designed the highly responsive Martin® Tracker™ HD (heavy-duty) belt conveyor alignment system with widely available plate steel to increase availability and affordability across all 6 continents it serves. A mistracking belt produces excessive spillage which increases labor costs for cleanup and may cause contact with the mainframe. This seriously damages both the belt and the structure and increases the potential for a friction fire. The Martin Tracker HD upper and lower units provide immediate, continuous, and precise adjustment of the mistracking belt. The result is greater productivity with less unscheduled downtime from both equipment replacement and spillage cleanup for a lower cost of operation.

"Since most OEM mistracking devices are only designed to prevent contact with the stringer and don't actually realign the belt, operators can spend a lot of time monitoring the system and adjusting idlers to achieve consistent alignment," explained Dave Mueller, Product Manager for Martin Engineering. "With enough manual adjusting, operators find that idlers must be recentered if there's a change in cargo characteristics or to install a new belt. The Tracker HD automates the alignment process, eliminating the need for constant monitoring and manual adjustments, reducing the labor and downtime for maintenance."

How It Works

The Martin Tracker HD's unrivaled precision comes from sensing rollers that ride either side of the belt edge and are attached to the end of an arm assembly. As the rollers detect slight variations in the belt path, the force of the wandering belt causes the arms to automatically position a pivoting idler in the opposite direction of the misalignment. The lever action requires less force to initiate the correction and only slight adjustments mean the consistent contact between the belt and idlers reduces the energy needed to bring the belt back into alignment.

"Certain countries can't buy the square tubing, so we're now manufacturing the equipment from readily available plate steel without any changes to the performance or life of the unit," Mueller pointed out. "This allows the Tracker HD to be produced and supplied across all global business units."

Compatible With Most Belt Conveyor Systems

Easy to install and designed to withstand the stress associated with wider, thicker belts moving at higher speeds and carrying heavier loads, the Martin Tracker HD is suitable for a belt thickness up to 1.125 in. (28.5 mm) and speeds up to 800 fpm (4 m/s). Both the upper and lower units accommodate belt widths of 36-72 in. (915-1828 mm) with an effective tracking distance of 150 ft. (45.72 m).

Available in 20-, 35-, and 45-degree trough angles, there are options for the addition of a Martin® Trac-Mount™ Idler, which allows the entire troughed idler unit to be slid away from the mainframe and safely serviced from outside of the system by a single worker. This important safety element can considerably reduce the amount of labor and maintenance time for the replacement of broken or frozen idlers. Also available are rubber-lagged rollers on the lower tracker and a grease kit for both the upper and lower assemblies. The unit is not suitable for reversing conveyors, belts with substantial rollback, or paddle or chevron belts.

Proper Placement is the Key

It is recommended operators install Martin Tracker HDs after the load zone on belts wider than 24 in. (610 mm) with additional units placed down the system to keep the belt centered and tracking. By placing an upper unit before the discharge, operators ensure the belt is centered on the head pulley allowing for optimal belt cleaning with maximum cargo discharge.

The lower tracker has been redesigned to include an extra safety feature not found in competitor units. Regardless of the conveyor, return rollers have been known to detach and drop, creating a serious safety issue, so the Martin Tracker HD has been equipped with safety guarding on the steering roll to prevent the roller from coming off or putting workers in harm's way. On the return, it is recommended to place a tracker after the discharge zone or take-up pulley, as well as periodically down the system depending on length. To ensure centered loading, the belt must enter the loading zone aligned, so installing a lower unit approximately five times the belt's width in distance from the tail pulley will support an efficient loading process.

Field Tested and Approved

Since the basic design of the Martin Tracker HD is similar to that of its predecessors with square tube construction, the testing focused on performance, durability and installation time. Tested in bulk handling operations including mining and cement where mistracking leading to spillage had historically been a concern, the unit performed up to Martin Engineering's high standards.

"Martin Engineering believes safety should be a core function in any conveyor accessory we design, and the Tracker HD is no different," Mueller said. "By automating consistent belt tracking, this solution reduces equipment wear, maintenance time, and downtime. These factors lower the cost of operation offering the best return on investment of any tracker on the market."

Transforming the industry: wireless blasting in surface coal, quarries, and hard rock

Mining companies need to address decarbonization and meet their ESG commitments. Most need tools to improve their data on emissions throughout their supply chain and should work to benefit the communities in which they operate.

This year marks Orica's 150 years of investment in technology and innovation to deliver blasting products and digital solutions that optimise safety, productivity, recovery, and sustainability outcomes to meet industry challenges. Since 2017, more than 250,000 WebGen™ wireless primers have been fired in over 6000 blasts worldwide. Most of these blasts were in underground mines, where the first generation WebGen™ 100 wireless blasting system quickly proved its value by reducing the exposure of workers to unstable ground and recovering ore that would have otherwise been left behind.

The latest generation of the product, WebGen™ 200 offers four variants, including one specifically designed for surface mining applications. In this article we explore the use cases for wireless blasting in surface mines to understand how open cut mine operators and owners can exploit this technology for safety and productivity benefits.

BLASTING WITHOUT WIRES

Before the advent of wireless blasting in 2017, blastholes were initiated with physical connections using electrical wires or signal tubes. These methods are labour-intensive and can be prone to missed connections and breakage, leading to potential misfires. In certain jurisdictions, the practice of sleeping tied blasts is prohibited, posing challenges for adjusting blasting schedules on short notice. Furthermore, sleeping blasts occupy considerable bench space, impeding the operational efficiency of load and haul fleets, particularly in deep mines and on narrow cutbacks. Orica's WebGen™ stands as the world's first fully commercialised wireless initiation system, eliminating all wires from the blast. WebGen™ uses a low frequency magnetic induction signal that penetrates hundreds of metres through rock, air, and water to initiate blastholes wirelessly. WebGen™ primers are assembled and encoded on the blast pattern and lowered into the blasthole. Once there, they can sleep for up to 90 days[1] and be ready to fire within minutes.

WIRELESS BRINGS PRODUCTIVITY AND SAFETY BENEFITS TO SURFACE MINES

Although the first five years of the WebGen™ story was all about underground customers, surface customers are now exploring ways to exploit wireless blasting. The primary advantages for open cut mines are enhancing worker safety and optimising fleet productivity. These benefits align with Orica's premise that when blastholes are stemmed and the primers are positioned a minimum of three meters from the collar, the risk of unintended initiation due to factors like lightning strikes or a vehicle inadvertently running over a

blasthole are significantly mitigated. Orica proposes that with appropriate quality control and demarcation, sleeping WebGen™ blasts can be converted into temporary haul roads. Orica refers to this concept as Mine Schedule Flexibility as it frees short term planners from many of the constraints imposed by conventionally primed sleeping blasts. It is proving most valuable in deep open pits and on narrow cutbacks but will have application in surface coal mines too.

Orica's Geoff Stevenson was responsible for much of the work that went into proving the Mine Schedule Flexibility concept. Geoff said "*running heavy mining equipment over loaded blastholes is anathema to anyone who works in mining. However, we did a very detailed analysis of the risks. Provided a site can maintain reliable demarcation and control over drills and excavators, there is no plausible risk to running a grader over the loaded blastholes and using that part of the bench as a haul road.*"

Armineh Hassanvand is an Orica Senior Research Engineer who ran a program of testing at a coal mine in NSW to validate the concept.

Armineh said "*We loaded test boreholes with ungassed emulsion, inert WebGen™ primers, and several pressure measurement devices. Some of these test holes had as little as 0.5 meters of stemming or no stemming at all, to simulate worst-case scenarios. We then drove over the test holes with loaded dump trucks, excavators, an Orica Mobile Manufacturing Unit, and various other mining equipment. The experiment was later repeated at a coal mine in Queensland with a dragline transversing over test holes. The tests demonstrated that even the largest and heaviest mining machines can safely traverse blastholes primed with WebGen™. Recorded increases in pressure were well below levels that could damage the primer or compromise the quality of the bulk explosives. Through desktop modelling, we have also found the risk of ignition from a heavy vehicle fire over a loaded hole to be negligible.*"

The use of wireless primers also reduces the number of blast crew visits to each hole and minimises the time spent at the collar of the hole. In contrast, traditional wired and non-electric downlines usually require a crew member to hold the downline while loading and stemming the hole. Geoff said "*Placing dry crushed aggregate stemming presents a serious respirable dust hazard to the worker holding the leads, and there are secondary risks of interaction with the stemming loader, as well as the risk of cutting the downline. Wireless primers eliminate or greatly reduce all these risks.*" WebGen™ also minimizes the duration blast crew workers need to spend within the rockfall zone under highwalls while priming, charging, and stemming holes.

Lightning risk reduction is another key value proposition of wireless blasting advocated by Orica. Mines situated in areas with frequent lightning strikes often face significant productivity losses due to the need for exclusion zones around sleeping blasts to mitigate the risk of unplanned detonation. Orica asserts that blastholes primed exclusively with WebGen™ primers are impervious to unplanned initiation by lightning strikes.

Armineh was also responsible for eliminating key risk factors associated with lightning. Armineh said *"for a sleeping bench, lightning poses unplanned initiation risk to conventional detonators that use electric wire, signal tube, or detonating cord. WebGen™ mitigates risk by eliminating this path. When a WebGen™ primer is deeper than 3 meters below the surface, even a direct lightning strike at the collar of the hole fails to generate the heat or pressure needed to initiate the primer or the bulk explosive."*

WIRELESS RELIABILITY AND SECURITY

In the absence of wires connecting blastholes, it is important for the Shotfirer to have confidence that sleeping WebGen™ primers will effectively respond to signals to arm and fire at the designated time. Given its wireless nature, it is essential for the Shotfirer to have

confidence that the primers will only respond to the intended signal. To meet these critical safety standards, WebGen™ incorporates technology to assess the signal's reliability within the blasthole where the wireless primer is to be placed.

WebGen™ blasts are initiated using a WebGen™ transmitter and inductive antenna with a self-contained power supply. The larger antenna is a 40m metre diameter loop, usually set up in a semi-permanent installation. There is also a semi-portable quad-loop antenna. The range of the signal primarily depends on the antenna and mineralisation, particularly the presence of ferromagnetic and sulphide minerals.

Before implementing WebGen™ at a mine site, Orica's WebGen™ Technicians conduct a thorough signal survey to assess the signal range from the intended antenna location. This survey is repeated before each blast to verify that conditions haven't changed between charging and firing. Additionally, the transmitter and antenna undergo four routine tests to guarantee the reception of transmissions by the sleeping primers.

WebGen™ is designed to the international Safety Integrity Level 3 (SIL-3) to ensure WebGen™ primers will only respond to valid WebGen™ transmissions. Orica's Vice President of Commercialisation, Nigel Pereira has been involved with WebGen™ since the start. He said, *"Orica sought the demanding SIL-3 rating for WebGen™ to demonstrate our confidence in the WebGen™ system, and we believe it sets a benchmark for wireless blasting in the industry."*

INTRODUCING THE WEBGEN™ SURFACE PRO PRIMER

One of the biggest challenges in bringing wireless blasting to the surface market was designing a primer capable of enduring the rigorous demands of large diameter, deep blastholes. Rhys Patterson is the Senior Global Product Manager of WebGen™ for Orica. Rhys said *"sleeping WebGen™ primers must withstand the hydrostatic pressure imposed by the explosive column and the dynamic pressure and acceleration created by adjacent blasts. While designers of electronic detonators have already recognised and addressed these problems, solving the issues for a user-assembled primer with more complex electronic components has not been easy. We believe our WebGen™ Surface Pro primer can meet the demands of large diameter surface customers, and sleep for up to 90 days, depending on blasthole temperature."*

Another challenge for early adopters of wireless technology is regulation. Orica has deployed WebGen™ on more than 75 sites across 6 continents and in 13 countries globally since 2017. Rhys said "in many places blasting regulations and site procedures are written specifically for conventional blasting methods using wires and signal tube. Orica is now experienced in bringing wireless blasting to such places for the first time. We believe we have a solid understanding of the unique risks and controls required to do wireless blasting safely, and that we can demonstrate how it reduces net risk."

THE WIRELESS FUTURE

The evolution of wireless technology in some ways mirrors the early stages of wired electronic systems introduced circa 2000. Initially embraced by underground mines, this innovation later found traction in surface mines as manufacturers tailored the product to align with industry needs. Rhys notes *"as with electronic detonators, we don't expect wireless blasting will completely replace conventional systems any time soon. However, there are many scenarios where going wireless clearly creates value on the surface and underground. We expect our customers*

will discover more clever ways to use WebGen™ as adoption grows."

Although the current version of WebGen™ is a one-way communication system, Orica plans to incorporate two-way communication in future generations. Nigel said *"all the latest wired electronic blasting systems on the market have offered two-way communication, so this is something customers have grown used to and expect from a wireless system. Orica is focussed on two-way communication as a future feature, and we are well on the way to solving that problem."*

Orica's next generation of digital technologies and solutions look to deliver solutions beyond blasting. Using data, analytics and modelling to connect end to end workflows across the mining chain allowing customers to optimise their entire operations. The integration of innovative products like WebGen™ and the 4D™ bulk emulsion delivery system with Orica's SHOTPlus™ software equips engineers with the necessary resources to design for improved blast performance and deliver downstream benefits.

Eventually, Orica expects wireless primers will enable fully mechanised blasthole charging and autonomous or remote operation of surface blasthole charging equipment. Nigel said *"WebGen™ is a key enabling technology for Orica's Avatel™ mechanised development charging system for underground. Similarly, we expect that wireless systems will help us bring autonomous charging for surface mining to reality."*

LATEST NEWS

Orica plans to demonstrate the WebGen™ 200 system at an open cut coal mine in the Hunter Valley, New South Wales in mid-2024. This will be the first use of WebGen™ at a coal mine in the region. The demonstration will use WebGen™ Surface Pro wireless primers in overburden blasts. The objectives of the demonstration include measuring the productivity benefits of wireless blasting for the blast crew, and showing mine operators and regulators how wireless blasting can reduce risk and improve productivity. Keiran Balkin, South Surface Coal Area Business Manager said, "We're interested to see how this maturing technology can be adapted to the unique conditions and requirements of large-scale overburden blasting and bring benefits to our customers and the mining industry."

NEWS, PLANT AND EQUIPMENT

Bulgaria sees surge in solar power and coal plant decline in 2023 electricity report

A remarkable shift in Bulgaria's energy landscape has been unveiled in the latest report from the Commission for Energy and Water Regulation, submitted to the Bulgarian parliament. The data reveals a staggering increase of over 140% in electricity production from photovoltaic plants, accompanied by a significant decline in output from coal-fired power plants in the year 2023.

According to the report, Bulgaria's total electricity production in 2023 amounted to 35,861,159 MWh. Notably, the nuclear power plant in Kozloduy claimed the lion's share at 43%, followed by thermal power plants contributing 29%. However, the most notable shift was witnessed in the realm of renewable energy sources, which accounted for 18% of the total electricity generated, with hydropower plants contributing half of this output.

The surge in solar energy was particularly pronounced, with photovoltaic plants witnessing an astounding growth of 140.92% compared to the previous year. The electricity generated from photovoltaics amounted to 1,558,739 MWh in 2023, signaling a doubling of installed capacity and marking a significant milestone in Bulgaria's renewable energy transition.

In contrast, wind power plants experienced a more modest growth of 5.23%, producing 809,580 MWh of electricity throughout the year.

However, amidst this renewable energy boom, traditional coal-fired power plants faced a sharp decline in output. Lignite coal plants saw a staggering drop of 45.56%, while brown coal plants fared even worse with a decline of 50.99%. This significant downturn underscores the shifting dynamics within Bulgaria's energy sector as the country seeks to reduce its reliance on fossil fuels and embrace cleaner alternatives.

The data from the Commission's report highlights a paradigm shift in Bulgaria's energy landscape, with renewables emerging as a key player in the nation's quest for sustainability and energy independence. As the country continues to chart its course towards a greener future, the challenges and opportunities presented by this transition are set to shape the trajectory of Bulgaria's energy sector in the years to come.

The growth of autonomous mining technologies

Remote and autonomous mining technologies have grown from a high-tech niche to a dominant market position. This growth has been spurred by the COVID-19 pandemic and lockdowns put in place to stem it, increased pressure on mine operators to work as efficiently as possible due to economic circumstances, and the applicability of ruggedized technology to the harsh conditions of mining in the real world.

Longwall mining is a primary method for extracting coal from underground mines. As shown in **Figure 1**, three kinds of mining equipment used in the longwall face are a shearer, an armoured face conveyor (AFC), and a roof support system. The shearer moves back and forth along a rail connected to the AFC, while the roof support system maintains the stability of the coal seam roof. Traditionally, the shearer and roof support system are controlled manually, which inevitably causes the rock to contaminate the coal and reduces the mining productivity. In addition, worker safety is greatly threatened because they are directly exposed to the mining worksite. Improving mining productivity, protecting worker safety, and achieving environmental sustainability are the goals that the coal mining industry has been pursuing. Longwall mining automation is a mining process that is carried out using mining equipment without the need for manual intervention. It involves the intelligent perception of the mining environment, intelligent control of the mining equipment, and autonomous operation of the mining process. Longwall mining automation technology has shown significant potential to achieve those goals through providing shearer positioning, face alignment, horizontal control, seam tracking, visualization and monitoring, and remote control. Among them, shearer positioning is a foundational aspect of the autonomous mining operation, and it is a key technology that enables face alignment and horizontal control. Therefore, the accurate positioning of the shearer is of great significance to longwall mining automation.

The shearer positioning method is of great significance to the automation of longwall mining. The research teams in the Longwall Automation Steering Committee (LASC) of Australia and China University of Mining and Technology (CUMT) have focused on shearer positioning and identified the shearer inertial navigation system, the measurement of longwall retreat and creep displacement, and the backward calibration of the shearer trajectory as three key technologies to obtain accurate shearer positioning information.

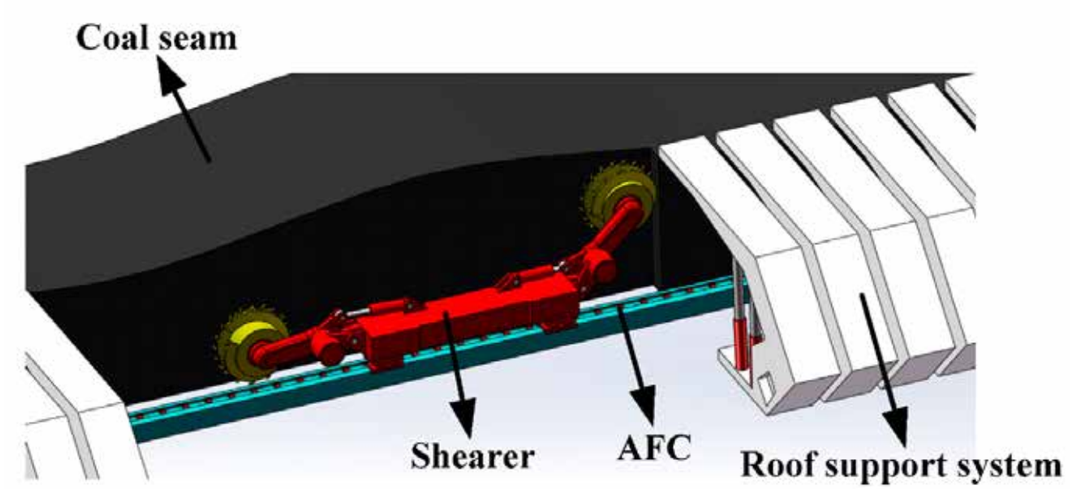
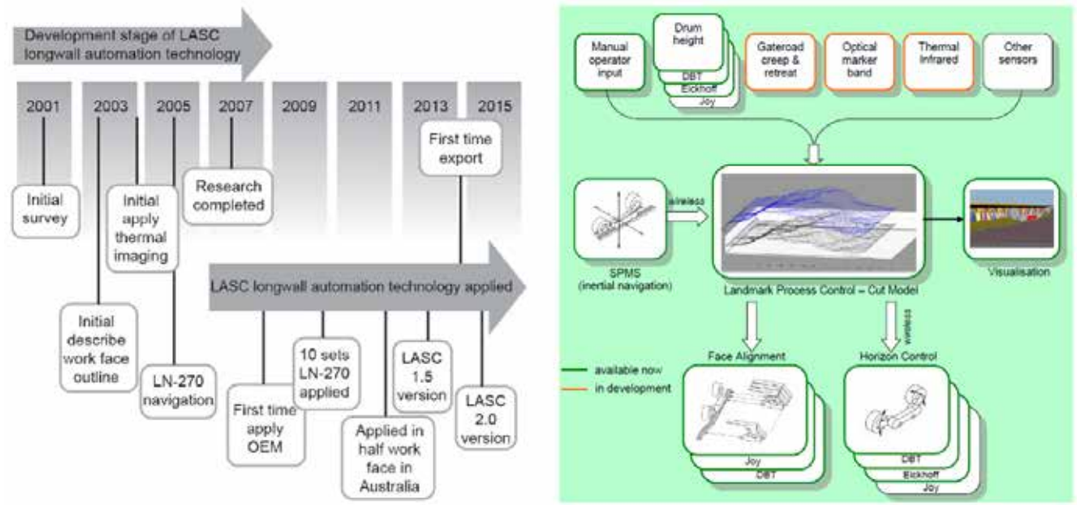


Figure 1: The diagram of the shearer, AFC, and roof support system.

As early as 2001, the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia began developing the longwall automation technology known as the Longwall Automation Steering Committee (LASC). LASC is the abbreviation for the research team responsible for this technology. The LASC can fix the 3D position of the shearer, maintain the straightness of the conveyor, and supports, raise the shearer drum automatically, and provide 3D remote monitoring video feeds. The technical framework is shown in **Figure 2**.

The latest version, LASC 2.0, has been adopted in 70% of Australia's coal mines. DBT, JOY, and Eickhoff are all licensed manufacturers of LASC. The social benefits of LASC application have contributed to reducing the number of accidents and deaths, and the costs that are avoided as a result are likely to save mining industries millions of dollars each year. In addition, improving the accuracy of longwall mining operations and reducing the amount of waste rock leads to less environmental disruption. LASC technology has great influence on the development of longwall mining automation around the world.



(a) (b)

Figure 2: The diagram of (a) the development stage of LASC and (b) the technical framework of LASC.

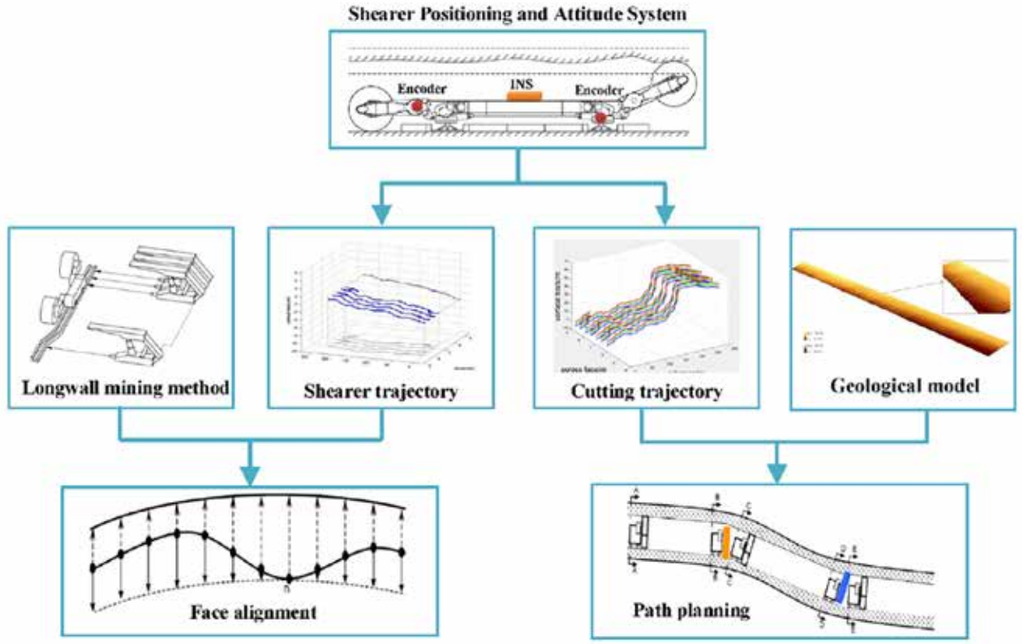


Figure 3: The technical framework of CUMT.

In China, research on the automation of longwall mining commenced at a relatively later stage. Under the support of the National High-tech Research and Development Program (863 Program) and the National Natural Science Foundation of China, the research group at China University of Mining and Technology (CUMT) has devoted significant efforts to the longwall mining automation.

Figure 3 shows the technical framework developed by CUMT for this purpose. The digital model of a coal seam is constructed using drill geological data and the seismic CT detection technique. Combining the digital model of the coal seam, shearer positioning technology is employed to obtain the shearer 3D positioning within the coal seam. Based on this, it is possible to achieve AFC trajectory straightening and shearer cutting path planning. The industrial test was carried out and demonstrated satisfactory performance.

LONGWALL MINING METHOD

Longwall mining is widely recognized as a highly efficient method for extracting coal from underground mines. In a coal seam, many elongated and narrow roadways are excavated to form the boundaries of several longwall panels, as shown in Figure 4a. The roadways serve as a passageway of transportation for coal, equipment, and workers. The sectional area of roadway is approximately 5 × 4 m in general. The coal is extracted from the longwall panel, which is generally 300 min wide and 5000 min long, with a thickness ranging from 1.2 to 8.0 m. At the end of the longwall panel, the shearer, AFC, and roof support system are installed across the longwall face.

As shown in **Figure 4b** and **Figure 5**, the shearer moves along a rail associated with the AFC, cutting a 0.8 m-wide slice of coal from the coal seam. The extracted coal is deposited onto the AFC and subsequently transported far away the longwall face. When the shearer is in motion, the hydraulic push arms, which are connected to the roof support system, gradually push a section of the AFC behind the shearer along the advancing direction for the next cutting cycle.

In **Figure 6**, the shearer is in operation during n-th cycle, while the AFC behind the shearer has been moved into the n + 1 cycle. When the coal is cut, the roof support systems support the roof of the coal seam. There are approximately two hundred roof support systems in a typical longwall face. After the AFC is pushed towards the coal seam, the roof support systems are relocated along the advancing direction. Behind the roof support systems, the collapse of the roof results in the formation of a goaf.

3. SHEARER POSITIONING TECHNOLOGY

The Shearer Inertial Navigation System

Due to the unavailability of Global Position System (GPS) and BeiDou Navigation Satellite System (BDS) signals in underground environments, the positioning method based on the inertial navigation system (INS) is considered to be a feasible shearer positioning method. The INS exhibits a high level of autonomy, making it widely applied in aircraft, ships, submarines, and so on. The accelerometer and gyroscope serve as the core measurement units to obtain the state of an object. The tri-axis accelerometer measures the linear accelerations of an object with respect to its body reference frame in three orthogonal axes. The

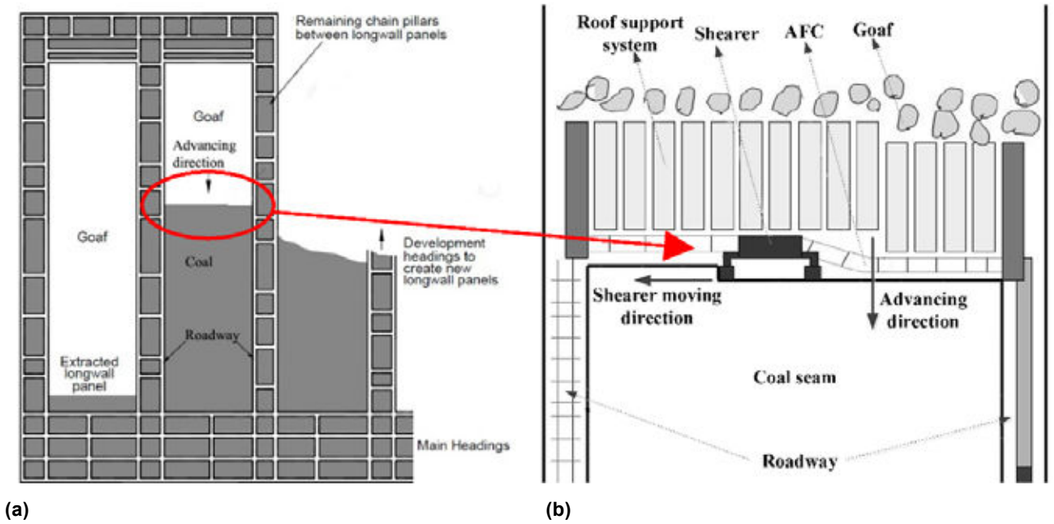


Figure 4: Typical plan view of (a) a coal mine and (b) a longwall face.

gyroscopes are utilized to quantify the angular velocities of rotation of the object with respect to the inertial reference frame. In summary, the navigation algorithm of the INS is founded upon the principles of Newton's laws of motion. The attitude angles are derived through the integration of rotational angular velocities. Subsequently, the rotation matrix, also known as the direction cosine matrix (DCM), is obtained. Through integrating the measured accelerations from the accelerometers and applying the rotation matrix transformation, the velocity and position in the navigation coordinate frame can be determined.

To acquire the shearer position in three dimensions (3D), the LASC has developed a measurement system known as the Shearer Position Measurement System (SPMS). This system utilizes a Northrop Grumman LN270 INS, as shown in **Figure 7a**. The LN270 was installed within an explosion-proof enclosure in the shearer body. In addition to the INS, an odometer, connected to the shearer haulage unit, was required to accurately measure the distance travelled across the longwall face. Afterwards, the second-generation SPMS (SPMS-II) using IXSEA PHINS INS was finished, as shown in **Figure 7b**. Due to the noise and vibration in underground environments, the INS calculation error increases exponentially over time. That is to say, the INS exhibits a very low relative error over short time periods, but over long time periods, the error increases dramatically. Based on this, Reid *et al*. employed zero-velocity updating technology (ZUPT) to periodically correct the velocity error during stationary motion for an INS. Furthermore, the development of integrated navigation with an INS and odometer aims to continually enhance performance. After replacing the odometer with a Doppler radar, Dunn *et al*. introduced a practical and accurate aiding source. Through analysing the longwall mining method, Reid *et al*. determined that the horizontal closing distance between two adjacent cutting cycles remained constant. This constant value was found to be instrumental in enhancing

Figure 5: The shearer, AFC, and roof support system across the longwall face in an underground mine.

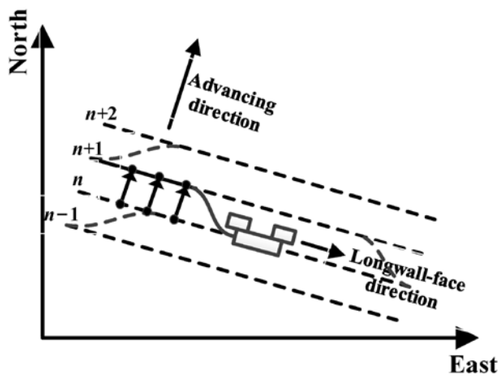
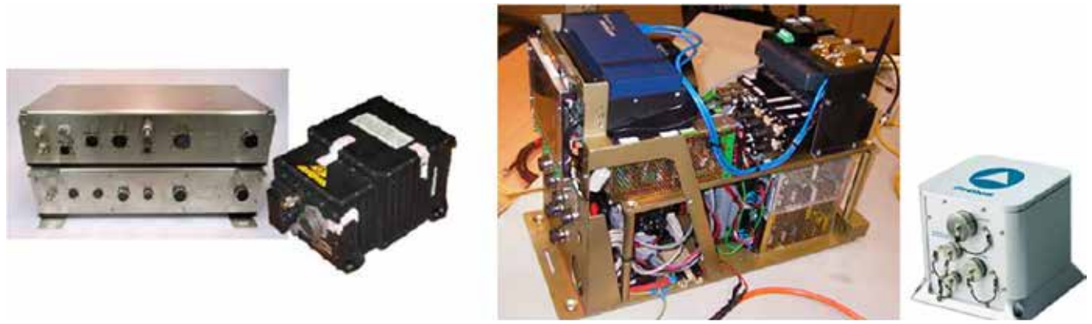


Figure 6: The diagram of the AFC profile as the shearer moves.



(a) (b)

Figure 7: The shearer position measurement system (SPMS): (a) SPMS-I and (b) SPMS-II.

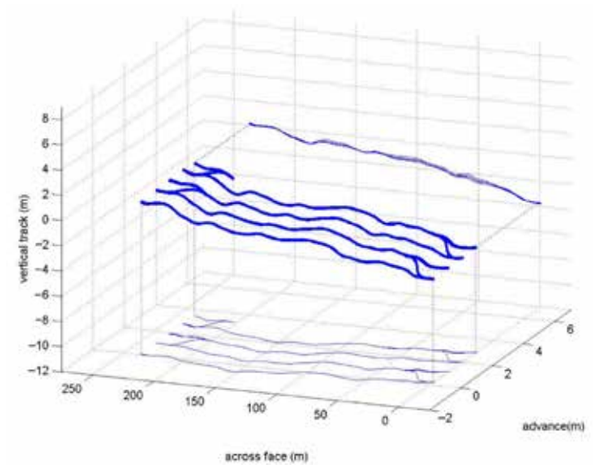


Figure 8: The shearer's 3D path in an underground mine measured using the SPMS.

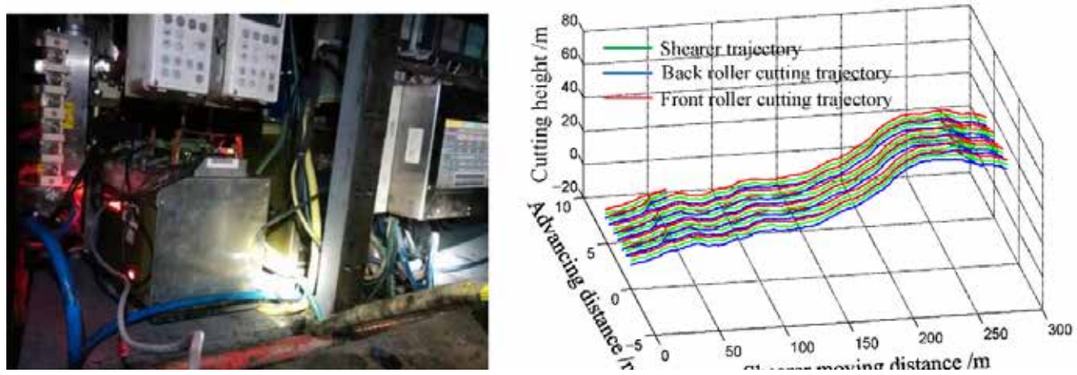
the longtime stability of the INS. The 3D path of a shearer in an underground mine, measured using the SPMS, is shown in **Figure 8**.

In CUMT, the authors built the Shearer Positioning and Attitude Systems (SPAS), including SPAS-I and SPAS-II, as shown in **Figure 9**.

The Spatial FOG INS from ADVANCED NAVIGATION provided the attitude angles of heading, pitch, and roll. The axial encoder connected to the travelling unit provided the velocity value of the shearer. The shearer position was then obtained using the dead-reckoning algorithm. The effect of the installation and initial alignment noncoincidence of the INS on the shearer positioning error was analysed, and a calibration method for the two deviation angles with the two-point method was proposed. The current axial encoder is a 12-bit system with a resolution of 1/4096. This implies that the accuracy of INS attitude greatly affects the position error, especially the

(a) (b)

Figure 9: The shearer positioning and attitude system (SPAS): (a) SPAS-I and (b) SPAS-II.



(a) (b)

Figure 10: The diagram of (a) the underground field test in Shanxi and (b) the shearer trajectory acquired using the SPAS.

heading angle accuracy. Based on previous research, the heading angle error was found to increase at a faster rate than the pitch error and roll error over time. Furthermore, it was observed that the heading angle error directly affected the plane positioning accuracy. According to the longwall mining method, two constraints on the shearer velocity and position were obtained. Therefore, the dynamic zero velocity update (DZUPT) model and the closing path optimal estimation model were built using a Kalman filter.

In order to improve shearer positioning accuracy, an information filter was proposed to integrate these two models. An underground field test was performed at 18,201 longwall faces in Shanxi Province, China, and **Figure 10** shows the shearer trajectory acquired via the SPAS.

The Measurement Method of Longwall Retreat and Creep Displacements

The utilization of auxiliary sensors, ZUPT, DZUPT, and kinematics model reduced INS drift error and improved the positioning accuracy. However, due to the lack of periodic GPS calibration, the INS longtime error is still relatively large. After several cutting cycles, the shearer positioning accuracy cannot meet the requirement of the longwall mining automation. According to the longwall mining method, the shearer reciprocates between two roadways along the longwall face. When the shearer reaches the end of the longwall face, the longwall retreat and creep displacements become significant parameters to measure, which can be utilized to back-correct the shearer trajectory after the completion of each cutting cycle. As shown in **Figure 11**, according to the longwall mining method, the retreat displacement is the advancing distance of the mining equipment along the advancing direction every time.

In the LASC, Reid *et al*. installed the scanning laser on the roadway conveyor structure linked to the AFC to scan the roadway profile. Accordingly, the first generation of a scanning device with SICK LMS200 as the core sensor and the second generation of an explosion-proof 3D laser scanning device called Ex Scan have been developed.

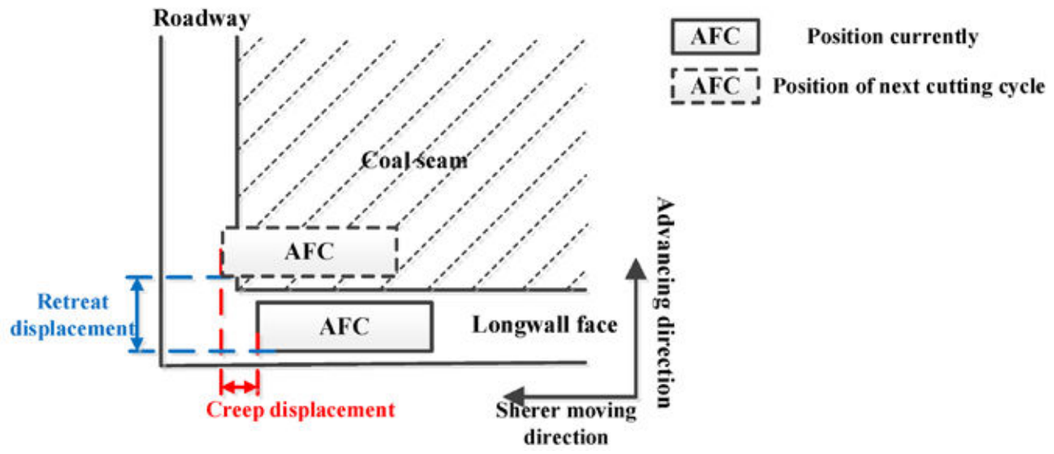


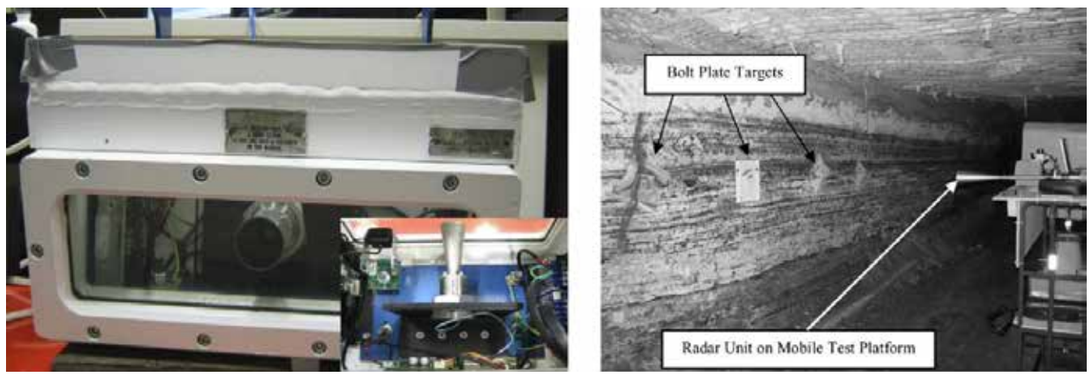
Figure 11: The diagram of the longwall retreat and creep displacements.

(a) (b)

Figure 12: The diagram of (a) the SICK LMS200 scanning laser and (b) Ex Scan.

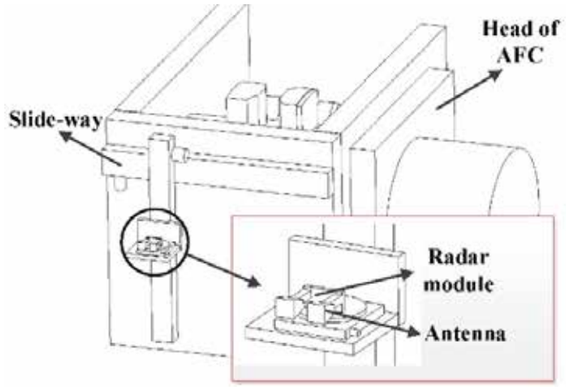
The current scan was matched to the global map with the scan-matching algorithm to acquire the retreat and creep displacements, as shown in **Figure 12**. However, the dust and moisture in an underground mine would greatly increase the attenuation and distortion of the laser beam, which affect the laser measurement accuracy. Then, Hargrave *et al*. used the FMR 250 radar from Endress-Hauser company in Germany to measure the retreat and creep displacements, and a field test in Australia's Beltana mine was carried out to verify the effectiveness of the proposed method, as shown in **Figure 13**. The radar is sensitive to distance information, and the creep displacement was obtained through measuring the distance between the radar and roadway wall. The number of bolt-plates on the roadway surface represented the position information, thus enabling the measurement of retreat displacement through the recognition of these bolt-plates. However, in most mines, the bolt-plates lack position information, thereby limiting the applicability of this method.

In CUMT, the authors provided a novel measurement solution with the ultra-wideband (UWB) radar imaging method. UWB radar is characterized by a radar with a fractional bandwidth exceeding 25%. Through transmitting electromagnetic wave signals with a strong ability to penetrate a coal-dust environment, UWB radar can obtain target or scene images all day and, in all weather, which has the technical advantage of application in the complex environment at the end of a longwall face. As shown in **Figure 14a**, the radar was mounted on a slide-way, and the slide-way was placed on the roadway conveyor structure connected to the head of the AFC. The radar was moved along the slide-way to image the bolt-plates. Two imaging results were obtained before and after the movement of the longwall face. Then, the



(a) (b)

Figure 13: The diagram of (a) the Endress-Hauser FMR 250 radar and the (b) field test in an underground mine.



(a)

(b)

(c)

Figure 14: The diagram of **(a)** the measurement principle, **(b)** the measurement device, and **(c)** a field test in an underground coal mine

feature-based image registration algorithm was employed to identify the correct-match pairs, and subsequently, the similarity transformation model was calculated to determine the retreat and creep displacements. The measurement device was developed (**Figure 14b**), and the algorithm program including radar imaging and image registration were embedded. The field text was performed in Xuzhuang Coal, China National Coal Group Corporation, and the mean values of retreat and creep measurement displacements were 8.0 mm and 8.6 mm, respectively.

South32 to sell Illawarra for $2.5b

South32 Limited has entered into a binding agreement to sell Illawarra Metallurgical Coal for $US1.65 billion ($2.5 billion).

An entity owned by Golden Energy and Resources (GEAR) and M Resources is set to snap up the assets, with the deal expected to be completed by the end of the year.

"GEAR and M Resources are established participants in the Australian metallurgical coal industry, with a strong commitment to environmental and safety standards, who are well positioned to continue Illawarra Metallurgical Coal's contribution to the local steel industry and the Illawarra and Macarthur regions," South32 chief executive officer Graham Kerr said.

"Our focus remains the safe and reliable operation of Illawarra Metallurgical Coal. Over the coming months we will work with the buyer, our workforce, the local community, government, customers and suppliers to support a successful transition of ownership."

The transaction comprises a deferred cash consideration of $US250 million ($385 million), payable in 2030, and is contingent on a price-linked cash consideration of up to $US350 million ($539 million).

South32 said the sale will significantly reduce the company's capital intensity, with Illawarra Metallurgical Coal currently comprising 35% of the company's capital expenditure.

"This transaction will realise significant value for our shareholders and is consistent with our strategy to reshape our portfolio toward commodities critical in the transition to a low-carbon future," Kerr said.

"It will streamline our portfolio, strengthen our balance sheet and unlock capital to invest in our high-quality development projects in copper and zinc. The transaction will also simplify our business and reduce our capital intensity.

"Illawarra Metallurgical Coal produces high-quality metallurgical coal, a key ingredient in the production of steel, which will be required until low-carbon steel becomes economically viable on a commercial scale."

Industrial explosives market to surpass US$22,491.5 million by 2033

The mining industry is poised on the threshold of some exciting opportunities. It has been realized that the unit operations such as drilling, blasting, excavation, loading, hauling and crushing are interrelated variables in the total cost equation. The development, advancement and utilization of the innovative technologies are very important for the mining industry to be cost effective In order to improve performance, the drilling and blasting industry is rapidly adopting technology in all forms. In the modern mines it is very common to encounter the latest forms of laser measurement technologies, global positioning systems (GPS), communication technology and computer systems. The developments in the areas of planning and design of blasts, drill monitoring, drillhole deviation, drill machine navigation systems and laser profiling systems are currently being used within the mining sector.

EXPLOSIVES MANUFACTURING PROCESS

The explosives manufacturing process involves several steps to ensure safety and effectiveness. It typically begins with the selection and preparation of raw materials, followed by mixing and blending them to create a homogeneous mixture. This mixture is then shaped into the desired form, such as pellets or sticks. Next, the explosives are subjected to a curing process to enhance stability and performance. Finally, quality control measures are implemented to ensure compliance with safety regulations and standards. The entire process requires strict adherence to safety protocols and expertise in handling hazardous materials. An explosive (or explosive material) is a reactive substance that contains a great amount of potential energy that can produce an explosion if released suddenly.

The 3 fundamental types of explosives are mechanical, chemical and nuclear. A mechanical explosive is one that depends on a physical reaction such as overloading a container with compressed air, a mechanical device is often used in mining where a chemical reaction is undesirable.

A chemical explosive is a mixture that when subjected to heat, impact, friction, or detonation, it undergoes a rapid chemical change, involving large volumes of heated gases that exert pressure on a surrounding medium. A nuclear explosive is a device that from a nuclear reaction, releases a vast amount of energy that causes an explosion.

The 3 types of explosives that we will be focusing on are:

- Blasting and bulk explosives – an emulsified Ammonium Nitrate solution incorporating a fuel phase. Typically used for commercial blasting applications.

- Perforating explosives – intended for use in the oil and gas well industry, perforating guns carry explosive-shaped charges downhole, where they are detonated to create tunnels that act as conduits through which reservoir fluids flow from the formation.

- Special-application explosives – high explosives used for other applications, including primary explosives.

USES AND WHY WE NEED THEM

In recent years, the largest commercial application of explosives is mining, which has increased their usage in surface and underground mines. Whether the mine is on the surface or buried underground, blasting explosives are the most cost-effective way of displacing a large volume of material. Emulsion explosives have a lot of great advantages including safety and security, excellent resistance to water, increased velocity of detonation, transport, handling and storage, savings in drilling operations and low gas emissions.

The mining industry tends to use nitrate-based explosives such as emulsions of fuel oil and ammonium nitrate solutions, mixtures of ammonium nitrate prills (fertilizer pellets) and fuel oil (ANFO) and gelatinous suspensions or slurries of ammonium nitrate and combustible fuels.

Many factors contribute to increased sales of emulsion explosives. Developing countries are constantly on the quest towards rich materials through mining and quarrying. On the other hand, infrastructure projects like underground railways, road tunnels and construction projects all favour market growth.

PRODUCTION OF EXPLOSIVES

Emulsion Explosives have been commercially available for over 50 years now and during this period, their popularity and production have been increasing year after year. In the process of manufacturing emulsion explosives, two basic pre-mixes are formed. The first comprises an aqueous solution of inorganic oxidizing salts, and the second, hydrocarbon fuel components, which provide the oil phase of the water-in-oil emulsion.

The unique feature of EE makeup is that they are insensitive to initiation and cannot sustain detonation without being sensitised. Due to this classification, the requirements for transporting EE matrices are much less stringent than the requirements for transporting traditional energetic materials. The simplistic transportation of emulsion explosives was the key factor underlying the development of bulk emulsion explosives.

WORLD GROWTH IN EMULSION EXPLOSIVES

India

The emulsion explosives market in India is expected to rise by 5.7% by 2028. A vast number of open mines in India use bulk emulsion explosives, with an annual use of around 550,00 tons per year. Some of the major projects in India include Transalpine railway tunnels and roads, and dams for hydroelectric power plants and power stations, with the number of major projects increasing year on year. The country's emulsion explosives value is expected to reach over $159m by 2028.

United States

Compared with India, the US is expected to rise at a steady rate by 2028, with around a 4.7% year-on-year growth by volume. This is mainly due to the country already being a leader in the market, so it is hard to achieve such growth. North American explosives producers are now looking at opportunities in the Latin American market, as there is a strong presence of precious metals such as lithium, silver and copper. This attracts significant investment from international mining companies, which is expected to increase demand for Bulk emulsion explosives.

China

The demand for emulsion explosives in China is expected to increase by a massive 6.2% by 2028, with the Chinese mining industry playing a substantial role in the Chinese economy. This is due to China being the world's leading producer of steel, coal, aluminium, lead, rare earths, tin, zinc, tungsten and magnesium and other metallic minerals. The country's emulsion explosives value is expected to reach over $262m by 2028.

CHALLENGES

Transportation

NG dynamites possess poor safety properties during their manufacture transportation and use. For example, the use of dynamites is diminishing with time. Safer explosives such as emulsion explosives are gradually replacing them.

Volatility

Volatility is the readiness with which a substance vaporizes. Excessive volatility often results in the development of pressure within rounds of ammunition and the separation of mixtures into their constituents. Volatility affects the chemical composition of the explosive such that a marked reduction in stability may occur, which results in an increase in the danger of handling.

Toxicity

Many explosives are toxic to some extent. Manufacturing inputs can also be organic compounds or hazardous materials that require special handling due to risks. The products, residual products or gases that make up explosives can be toxic, whereas others are harmless.

Structural Collapse

Using explosives when mining can cause a risk of entrapment following the collapse of a structure. Measures must be put in place to try and mitigate this risk and plans should be in place should this eventuality arise.

THE FUTURE OF EXPLOSIVES

The mining explosives industry's development rate has been significantly boosted by the surging demand for minerals and metals worldwide. Mining explosives are widely used in metal mining, quarrying, non-metal mining, and coal mining applications. Coal mining is one of the most important applications of mining explosives.

The accelerated use of coal as well as rare earth metals such as silver and gold along with earth minerals like bauxite and iron ore in diverse industries like chemical, automotive, and thermal will foster the need for extremely potent explosive products.

New and modern explosives technologies are compatible with both augured and pumped loading techniques across wet, dewatered, and dry hole conditions. Companies active in the mining explosives industry are focusing on enhancing their research capacities to develop more innovative technologies that can let mining customers carry out operations more precisely and efficiently. The combination of modern digital technology, explosives delivery technology, and formulation chemistry is providing great leverage to mining customers.

Industrial explosives, crucial for mining and construction, transform rapidly into gases under trigger conditions. In the US, the construction sector is the largest consumer of these powerful blasting materials

In the most recent survey conducted by Persistence Market Research, the global industrial explosives market is currently enjoying a market valuation of US$ 12,324.6 Mn as of 2023, with a projected expansion at a Compound Annual Growth Rate (CAGR) of 6.2% from 2023 to 2033.

The market is expected to reach a substantial valuation of US$ 22,491.5 Mn by the conclusion of the forecast period.

The industrial explosives market sector has witnessed substantial growth in recent years, and this upward trend is expected to persist due to a heightened demand for blasting materials from the mining and construction sectors.

The Latin America and Africa regions are poised for significant growth, primarily attributed to increased investments in the mining industry.

Urbanization and population growth will provide numerous opportunities for current and emerging industrial and commercial entities, fostering growth throughout the projected period.

Market Scope:

Report Coverage	Details
Market Revenue 2023	US$ 12,324.6 million
Estimated Revenue 2033	US$ 22,491.5 million
Growth Rate - CAGR	6.2%
Forecast Period	2023-2033
No. of Pages	297 Pages
Market Segmentation	• Type • End Use • Region
Regions Covered	• North America • Europe • Latin America • East Asia • The Middle East & Africa • South Asia & Pacific
Key Companies Profiled	• Orica Limited • NOF Corporation • Enaex S.A. • African Explosives Limited • Dyno Nobel • Exsa S.A. • Maxam corp Holdings • Austin Powder Company • Irish Industrial Explosives Ltd • Ideal Industrial Explosives Limited • Sichuan Yahua Industrial Group Co., Ltd • BME Mining • Solar Industries • LSB INDUSTRIES • Eurenco S.A.

Market Growth Drivers:

Increased Investment in the Mining Industry: The surge in investment in the mining sector, particularly in regions like Latin America and Africa, is a significant driver for the industrial explosives market. These explosives play a crucial role in mining operations, contributing to increased demand.

Rising Demand from the Construction Industry: The construction industry's continuous growth and development contribute to the increased demand for industrial explosives. These materials are essential for activities such as quarrying and excavation in construction projects.

Urbanization and Infrastructure Development: The ongoing process of urbanization and infrastructure development worldwide creates a demand for industrial explosives in various construction and development projects. As cities expand and new infrastructure projects emerge, the need for these explosives grows.

Population Growth: Population growth, especially in developing regions, leads to increased demand for housing, infrastructure, and related construction activities. Industrial explosives are essential in the excavation and foundation preparation processes for such projects.

Technological Advancements: Continuous advancements in explosive technologies contribute to the efficiency and safety of industrial explosive products. Innovations in blasting techniques and explosive formulations enhance their effectiveness in various applications.

Market Restraints:

Stringent Regulatory Frameworks: Strict regulations and safety standards imposed by governments and regulatory bodies may pose challenges for the industrial explosives market. Compliance with safety measures can increase operational costs for manufacturers and end-users.

Environmental Concerns: Growing environmental awareness and concerns regarding the impact of explosive materials on ecosystems and air quality may lead to increased scrutiny and restrictions. This can result in the development and adoption of more environmentally friendly alternatives, impacting traditional explosive sales.

High Costs and Operational Risks: The costs associated with the manufacturing, storage, and transportation of industrial explosives can be substantial. Additionally, the operational risks involved in handling explosive materials can lead to increased insurance costs and adherence to stringent safety protocols.

Volatility in Raw Material Prices: The industrial explosives industry is sensitive to fluctuations in raw material prices, such as chemicals and minerals used in explosive formulations. Unpredictable changes in these prices can impact production costs and profit margins for manufacturers.

Global Economic Uncertainties: Economic uncertainties and downturns can affect industries dependent on construction, mining, and infrastructure development, leading to reduced demand for industrial explosives. The cyclical nature of these industries makes the market vulnerable to economic fluctuations.

Alternative Technologies: Advancements in alternative technologies, such as non-explosive demolition methods, may pose a challenge to the traditional industrial explosives market. Some industries may seek more sustainable and less hazardous alternatives for specific applications.

Opportunities:

Technological Advancements: Opportunities for innovation in explosive formulations and blasting technologies can enhance the efficiency, safety, and environmental sustainability of industrial explosives, opening new markets and applications.

Green Explosives and Sustainable Practices: Growing environmental concerns provide an opportunity for the development and adoption of "green" explosives that are more environmentally friendly. Manufacturers can focus on sustainable practices to meet evolving regulatory standards and market preferences.

Emerging Markets and Regions: Exploring and expanding into emerging markets and regions with increasing industrial activities, such as parts of Asia and Africa, can provide new avenues for growth. Rising investments in mining, construction, and infrastructure development in these areas offer significant opportunities.

Infrastructure Development Projects: The increasing focus on large-scale infrastructure projects, including transportation, energy, and urban development, presents opportunities for the industrial explosives market. These projects often require blasting materials for excavation and construction purposes.

Mining Exploration and Extraction: With the demand for minerals and metals continuing to rise, there are opportunities in providing explosives for mining exploration and extraction activities. New mining projects and expansions in existing mines create a demand for blasting materials.

COUNTRY-WISE INSIGHTS

How big is the opportunity for industrial explosives in China?

Despite initial concerns due to the global pandemic, the Chinese industrial explosives market is expected to grow by 7.5% annually in 2022. With China being the world's largest producer of coal and metal, the rapid expansion of its construction industry and increasing mining activities contribute to a significant surge in demand for industrial explosives. China is set to dominate both East Asian and global markets, accounting for about three-fourths of the market share in East Asia. Key Chinese companies are focusing on strategic changes, high-quality products, and after-sales services to boost overall demand.

How the mining sector is driving the Indian industrial explosives market?

India is a key player in the South Asian industrial explosives market, holding the largest share. High demand in coal mining and quarry sectors, coupled with rapid industrialization and being the second-largest global coal producer, is driving a 7.4% CAGR growth in the Indian industrial explosives market. Favorable policies and a thriving mining sector contribute to a conducive environment, offering significant opportunities in the global explosives market.

How are end-use industries of industrial explosives performing in the US?

In the United States, the construction sector is the primary consumer of industrial explosives, representing the largest segment. The government's announcement of new construction projects during the forecast period is expected to drive increased demand for industrial explosives. The country is also witnessing widespread mining activities, contributing to rapid growth in the industrial explosives market. In 2021, US miners produced approximately $90.4 billion worth of minerals, a significant increase from the $86 billion produced in 2020, according to the Geological Survey. These minerals are vital for manufacturing and trade, with many being used in common household products, leading to substantial demand.

How mining industries are solely dominating the consumption of industrial explosives?

The mining industry holds an 88% share in the global industrial explosives market, according to Persistence Market Research. Industrial explosives are crucial for mining activities, breaking through hard rocks beneath the earth's surface. The increasing demand for earth metals and minerals, coupled with government-supported exploration activities, is driving growth in the global mining sector. This growth is expected to significantly boost the demand for industrial explosives in the forecast period.

Why are bulk explosives experiencing a rise in demand?

Bulk explosives, comprising over 90% of the market share, experience high demand primarily due to their use in mining and detonation. These paste-form explosives are directly delivered to on-site working areas, with manufacturers handling the explosives themselves. The affordability of bulk explosives compared to packaged alternatives is another key factor driving their market demand.

KEY RECENT DEVELOPMENTS

Technological Advancements: Ongoing developments in explosive technologies, including advancements in formulations and blasting techniques, are enhancing the efficiency and safety of industrial explosives.

Sustainability Initiatives: Increasing focus on sustainable and environmentally friendly explosive formulations as part of industry-wide initiatives to address environmental concerns and regulatory requirements.

Market Expansion in Asia: Significant market growth in China and India, driven by expanding construction, mining activities, and infrastructure development, positioning these countries as key players in the global industrial explosives market.

Government Policies and Regulations: Implementation of new policies and regulations favouring the industrial explosives sector, creating a conducive environment for growth while ensuring safety and compliance.

Digitalization in Blasting Operations: Adoption of digital technologies and data analytics to optimize blasting operations, improving precision, efficiency, and overall performance in various applications.

Strategic Collaborations: Increased collaboration and partnerships among industry players, leading to strategic alliances, joint ventures, and technology-sharing agreements to enhance market presence and capabilities.

Focus on Safety and Training: Growing emphasis on safety measures, including training programs and consulting services, to address concerns related to the handling and usage of industrial explosives.

Rising Demand in the US: In the United States, a surge in construction projects and widespread mining activities is contributing to increased demand for industrial explosives.

Some of the market players:

- Orica Limited: Orica is a global leader in the explosives and mining services industry, providing a wide range of products and solutions for mining, quarrying, and construction.
- NOF Corporation: NOF Corporation is a Japanese company engaged in the manufacturing and distribution of industrial explosives, specialty chemicals, and various related products.
- Enaex S.A.: Enaex is a Chilean company specializing in explosives and blasting services for the mining industry, offering a comprehensive range of products and solutions.
- African Explosives Limited: African Explosives Limited (AEL) operates in the explosives and chemical sectors, with a focus on providing blasting solutions for the mining and construction industries in Africa.
- Dyno Nobel: Dyno Nobel is a global explosives company offering innovative blasting solutions for the mining, quarrying, and construction industries, with a commitment to safety and sustainability.
- Exsa S.A.: Exsa S.A. is a leading explosives manufacturer based in Peru, providing a diverse range of products and services for the mining and construction sectors.
- Maxam Corp Holdings: Maxam is a global technology company specializing in energetic materials and blasting solutions, serving various industries, including mining, defense, and civil engineering.
- Austin Powder Company: Austin Powder Company is a US-based explosives manufacturer and distributor, offering a comprehensive range of products for the mining, quarrying, and construction industries.
- Irish Industrial Explosives Ltd: Irish Industrial Explosives Ltd is an explosives manufacturer based in Ireland, providing a range of blasting solutions for mining, quarrying, and infrastructure projects.

- Ideal Industrial Explosives Limited: Ideal Industrial Explosives Limited is an Indian company specializing in manufacturing and supplying industrial explosives for the mining and construction sectors.

- Sichuan Yahua Industrial Group Co., Ltd: Sichuan Yahua Industrial Group Co., Ltd is a Chinese company with diversified business interests, including the production of industrial explosives for mining and construction applications.

In recent times, the entire world of mining industry, including the biggest industrial explosive suppliers in India has seen a tremendous rise in the usage of emulsion explosives. The vital reason being the rise in demand for these explosives is its ease of adaptation, security, safety, resistance towards water, hassle-free storage, and many other more advantages that it offers as compared to all other explosives that are available in the market.

The industrial explosives company in India has always ensured that the emulsion explosives that they aim to sell hold all of their pumping properties and packaging stably throughout different temperatures. And since the explosives can hold it extremely well, they are stable, and the detonation properties can also be kept at a constant number even if the storage has been for a long time. And that is why the emulsion explosive suppliers India are so sure about its usage for surface mines along with underground mining.

According to a report from Future Market Insights, the global emulsion explosive market was evaluated at around US$ 2.4 billion in the year 2020. The important reason for soaring valuation is the high performance and enhanced safety guidelines provided for the emulsion explosives by the world players and the industrial explosive suppliers in India. Thus, here are a few critical reasons that why emulsion explosives have gained popularity among the mining players and how it hugely benefits surface mining projects.

EASY TO STORE AND TRANSPORT

Transport and storage play a key role in every kind of explosives. And the emulsion explosive suppliers India leave no stone unturned to offer the best quality storage and transportation services to their customers. Since the emulsion is categorized as an oxidizer, there is no danger when it comes to transportation and storage as it will never explode. The only time when an emulsion can turn into an explosive is when it is pumped into the borehole. The industrial explosive suppliers in India always recommend storing the emulsions between temperatures of -20 degrees to -50 degrees Celsius.

DIFFERENT DETONATION VELOCITY

Emulsion explosives have always been the most cost-effective and better choice when it comes to surface mining. The explosives are not only preferred by many experts but their low sensitivity to the mechanical stimulus makes them extremely popular. Apart from that, it can vary density through many ranges that result in varied detonation velocities. These emulsion explosives not only get the job done with their low impact but are also a safer option when it comes to protecting the environment as these explosives can be executed for medium to hard surface mining grounds.

WATER-RESISTANT

Without any doubt, the emulsion explosives are produced in such a way that even if there is water inside and outside, the boreholes can be filled up with the emulsion and nothing will happen to the entire operation as the emulsion are completely resistant to the water.

If the standard striking tests are being conducted, then be sure as the emulsion will not explode during the testing and remain stable. But there are chances of explosion if the emulsion comes in contact with the materials such as aluminum powder, detonators, or dynamites. In the end, these are explosives, and the blasting equipment suppliers pan India always advise to follow all the safety guidelines without fail.

Therefore, if you have the requirement for any type of emulsion explosives, then your attention must turn towards one of the finest and experienced emulsion explosive suppliers pan India SBL Energy Limited. This industrial explosives company in India has various ranges of emulsion packages explosives tailored as per your requirements which can be used for both surface and underground mining. Right from Cap sensitive Emulsion Large Diameter Cartridge Explosives (Booster/ Primer Charge) to Booster sensitive Emulsion Large Diameter Cartridge Explosives, this industrial explosive supplier in India has everything that you need for your next project.

EXPLOSIVE NEW DEVELOPMENT IN SMALL-SCALE MINING

Researchers have developed software and technology to help small-scale mining operations conduct targeted rock blasting with minimal effort and impact on the environment.

There is currently no reliable solution to reduce the environmental impact of small-scale mines, especially considering that current mining technology relies on rock blasting and mobile mining equipment for loading and transportation. Some of this equipment uses the expensive and difficult to install Measurement While Drilling (MWD) system, which is inefficient for small scale mining operations.

The EU-funded SLIM project set out to develop cost-effective and more sustainable ways to blast and fragment rock using explosives in small-scale mining operations. Using advanced automatic blast design software, the SLIM project consortium focused on mitigating typical mining issues such as airborne particulate matter, vibrations and nitrate leaching. “The SLIM approach consists of injecting state of the art techniques into the mining operation by developing tools to control the excavation face, fine-tune the processing plant and reduce environmental effects, in order to improve feasibility, and profitability of mines, and gain public acceptance and trust,” says project coordinator José Sanchidrián.

A NEW GENERATION OF EXPLOSIVES

The SLIM team started by developing technologies capable of characterising explosives, identifying blasted rock fragments using artificial intelligence, and using systems that can predict the effect of certain explosives on specific rock types. SLIM developed a new generation of explosives and smart blast design software that can characterise rocks better than current systems and reduce the impact of rock blasting on the environment. This development is not only important for the European mining industry but for mining operations all over the world, to help them reduce economical costs and environmental impact such as groundwater contamination. The team experimented with, and developed, models to simulate how explosives would perform in mining operations, such as understanding rock fragmentation, the velocities, and the damage caused. Such information has already given mining operations the data they need to better understand and improve their overall performance by being as efficient as possible with minimal environmental impacts.

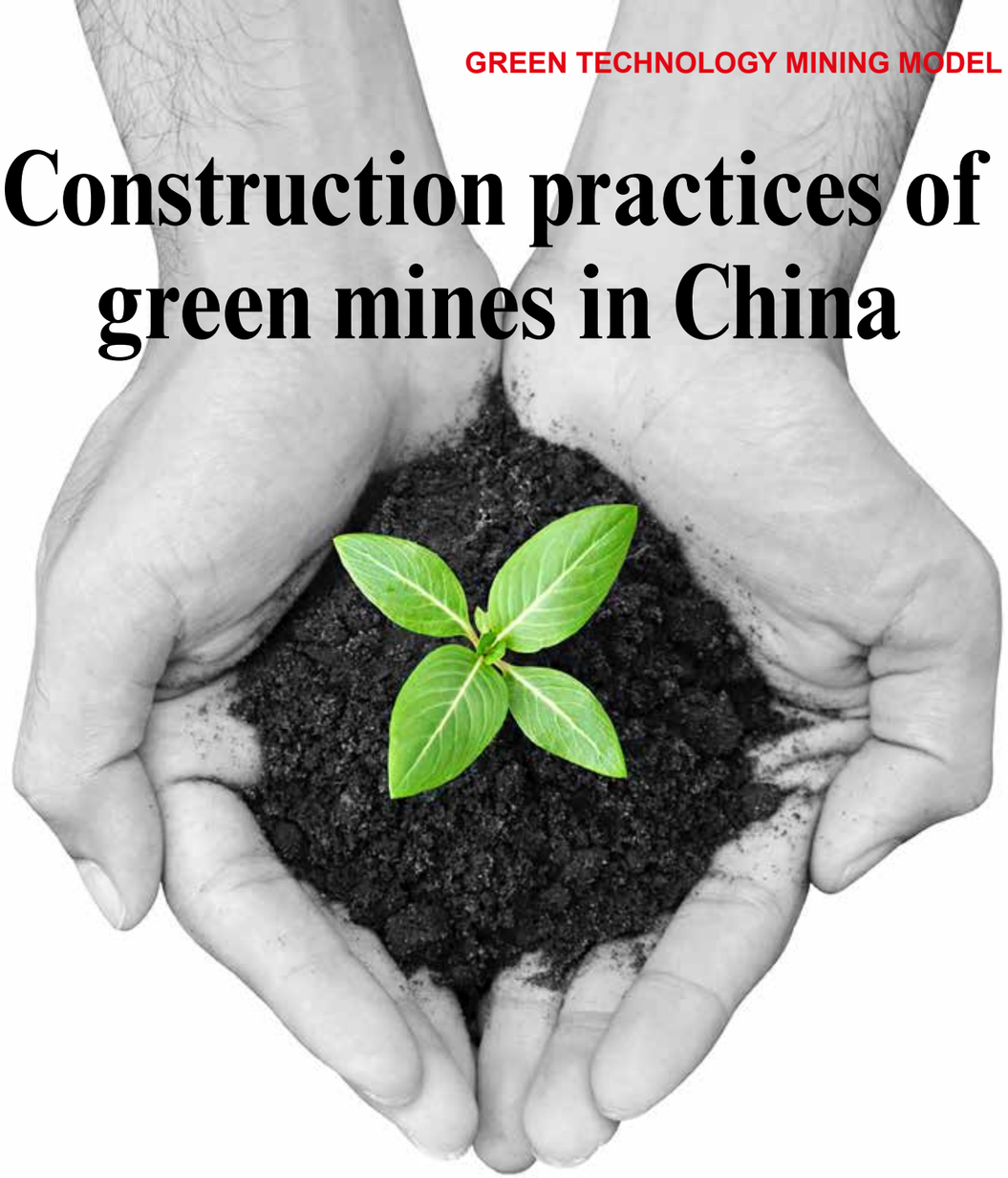
MWD USING LIDAR

SLIM developed and retrofitted a more cost-efficient Measuring While Drilling (MWD) system that uses the detailed analysis of photographs to predict the impact of explosives on target rock. In an effort to make mine planning smoother, the SLIM team created a system that uses light detection and ranging (LiDAR) to analyse rock damage and environmental impact after a blast, as opposed to the non-direct methods used currently. The SLIM team also developed a software that mitigates negative impacts such as fly rock or vibrations, and characterises the result of a blast, or the ‘muck hole’. “This software is important to improve the surface blasting work, as only reliable and correct assessments of blasting results improve mining operations,” Sanchidrián says.

REAL WORLD DATA FOR FURTHER DEVELOPMENT

Minera de Órgiva, a SLIM partner from Spain, used improved rock excavation technologies, and processing plant monitoring and control to nearly double its production at Sierra de Lújar mine. This enabled the profitable mining and processing of lower yielding ore – from a cutoff grade of nearly 40% fluorite to an expected cutoff of 20% by the end of the project. The result is more than a threefold increase in reserves and extending the working life of the mine by at least 50 years. “The SLIM project partners have accumulated an exceptional amount of data from laboratory and field trials and this dataset has a fundamental value in facilitating future research and development in the fields of explosives technology, rock blasting, performance assessment, and mining automation,” Sanchidrián concludes.

Construction practices of green mines in China



To maintain high-level economic development, protect the ecological environment, and achieve carbon peaking and carbon neutrality goals, the construction of green mines has become a critical issue in China. In this article, the importance of mineral resources to human society is discussed, and the construction experiences and sustainable development directions of green mines are summarised, which can provide valuable references for the global mining industry. The entry and management process in China was introduced to help understand green mines’ construction objectives and tasks. Moreover, based on the successful construction cases of green mines, four typical green mine models are concluded: the green technology mining model, operation modernisation mining model, stability mining model, and ecological restoration mining model. In addition, the key construction elements of green mines are concluded, for example, the mining environment, mining methods, comprehensive utilisation of resources, energy conservation, emission reduction, scientific and technological innovation and intelligence, and enterprise-land stability, which provided the directions and guidance for green mine construction.

More than 95% of energy, 80% of industrial raw materials, and 70% of agricultural means of production globally come from mineral resources[1]. Thus, mineral resources are important material foundations for the survival and development of human society. The utilisation of mineral resources destroys the ecological environment and increases carbon emissions to varying degrees in different countries, leading to a series of environmental problems, e.g., solid waste, exhaust gas, liquid waste, ground collapse, and a decrease in biodiversity. According to the Annual Report of the China Geological Survey in 2016, the coal mines in the Greater Khingan Mountains and Hulunbuir Grassland had destroyed and occupied a total of 2772.77 hectares of grassland due to mining operations. Six waste rock yards with a total area of 19.355 hectares and a total volume of 1.07875 m^3 and five tailing sand dumps with a total area of 25.90 hectares and a stacked volume of 943,000 m^3 of Shizhuyuan multi-metal mine have greatly impacted the environments around the Xiangjiang River[2]. The subsidence area of Yangquan coal mines near the Fenhe River in North China is about 406.73 km2, accounting for 27.56% of the mining area[3]. **Figure 1** illustrates the main geo-environmental problems of the mines. As can be seen from **Figure 1**, pit drainage is more severe in the central region. The highest cumulative amount of solid waste is mainly located in the provinces of Xinjiang, Inner Mongolia, and Yunnan. Higher wastewater discharges are mainly found in coastal areas. More serious land destruction is mainly in the eastern and western regions. Areas with more serious landslides and mudslides are Yunnan, Sichuan and Chongqing, and Inner Mongolia. Ground subsidence is a more serious problem in Guizhou, Anhui, and other regions. In addition, the transition from shallow mining to deep mining poses a more severe safety production situation, and the threat of dynamic geological disasters such as water inrush, rock bursts, and high temperatures will continue to increase. From 2001 to 2021, there were 629 mine floods, resulting in 3730 deaths and the highest economic losses among all types of mining accidents[4]. In addition, the environmental problems and carbon emissions caused by mines are particularly prominent. According to the China Carbon Accounting Database (CEADs), China's cumulative carbon emissions in 2022 reached eleven billion tons, accounting for approximately 28.87% of global carbon emissions[5]. Among them, industrial emissions amounted to 4.2 billion tons, accounting for 38.18% of the national emissions, second only to the electricity industry's emissions of 5.1 billion tons, accounting for 46.37%[6]. The main types of energy sources for carbon emissions from

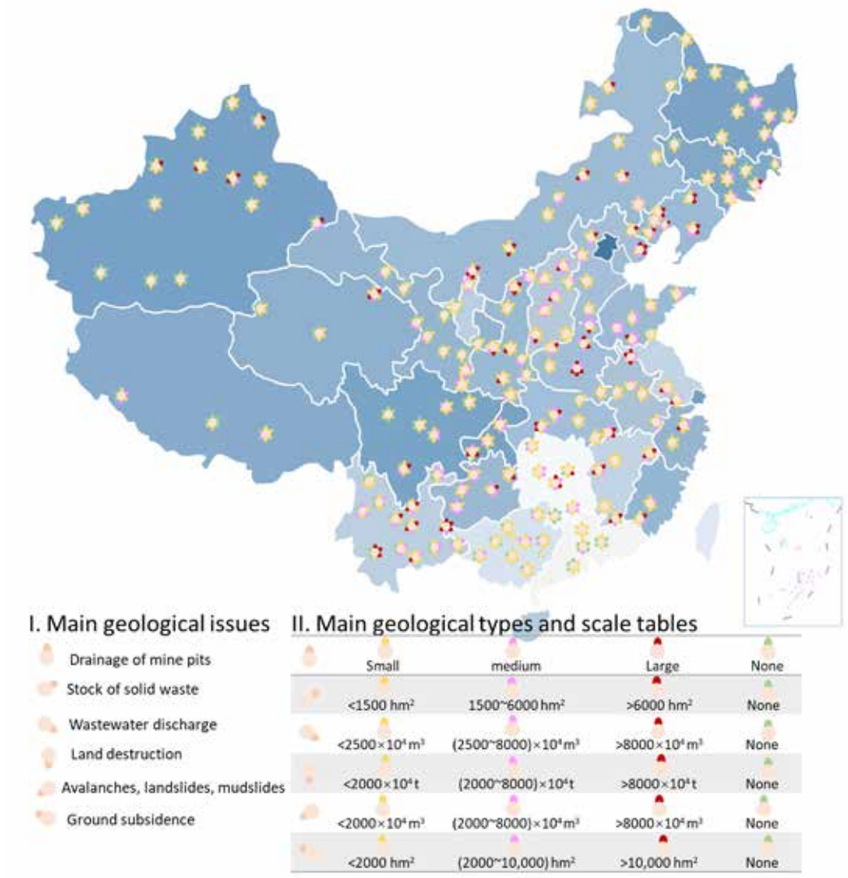


Figure 1: Distribution map of major environmental problems in mines (adapted from[8]).

Figure 2: Global distribution map of mineral resources (adapted from[15]).

China's mining industry are electricity and coal. China's coal-fired power generation accounts for about 50% of the global total[7]. In September 2020, at the 75th United Nations General Assembly, China proposed the "dual carbon" goal of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060, which greatly promoted the green and low-carbon development of mining.

In response to the challenges of mining, the Chinese government has implemented a national strategy of green mining. The specific connotation of green mining is to implement scientific and regulated mining throughout the life cycle of mines, to control mining disturbances and the surrounding ecological environment within a controllable range, to keep environmental ecology, scientific mining, efficient resource utilisation, standardised, enterprise management, standardisation of production safety, and stable mining communities harmonious[9,10].

The construction of green mines has become an important issue for the sustainable development of the mining industry in China. The green mine concept was first proposed in 2007 and has since undergone conceptual proposals, road exploration, and pilot demonstrations. Nowadays, it is advancing towards a new stage of standardised construction[11]. China has gained valuable experience and remarkable results in green mine construction over the past decade. To propel the development of the mining industry and support the achievement of dual carbon goals, promote the sustainable development of the mining economy, and promote the green and high-quality development of the mining industry, this paper summarises the experience of green mine construction. It identifies the problems during green mine construction, providing direction and guidance for mine enterprises building green mines.

MINERAL RESOURCES AND GREEN MINES

Global distribution and utilisation

Figure 2 shows that the distribution of mineral resources globally has distinct regional patterns. The Middle East holds 57% of the world's oil reserves, while Eastern Europe, Russia, and the Middle East contain 72% of the global natural gas reserves[12]. Regarding coal reserves, 53% are concentrated in the United States, China, and Australia[13]. Among non-ferrous metals, 56% of copper reserves are in Chile, Peru, Mexico, the United States, and Canada. Regarding lead reserves, 57.5% are concentrated in Australia, China, the United States, and Kazakhstan. Finally, 48% of zinc reserves are distributed in Australia, China, and the United States[14].

Mineral resources are essential materials for all industries, significantly impacting socioeconomic development and national security. **Figure 3** presents the change in total global production of mineral resources from 2009 to 2022.

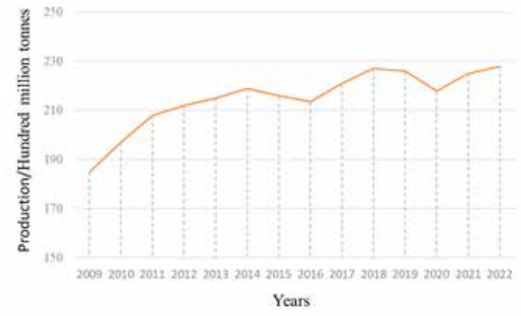


Figure 3: Global production of mineral resources, 2009-2022 (data from[17,18]).

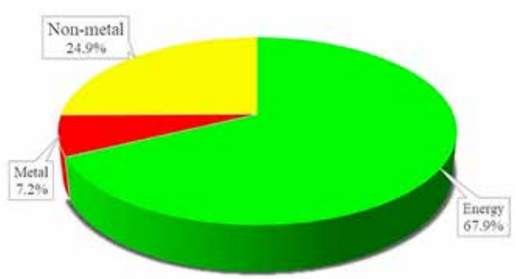


Figure 4: Global proportion of different mineral productions in 2022 (data from[15]).

Figure 4 shows the share of energy, metal, and non-metal production in 2022. In 2022, 1/3 of countries were mining countries, and their ratio of mining output value to GDP was larger than the global average[16]. The mining industry provided 22.7 billion tons of energy, metals, and important non-metallic minerals, with a total output value of USD 5.9 trillion, equivalent to 6.9% of the global GDP[17]. Chinese mining companies account for approximately 12% of the global top fifty mining companies in terms of market value[18]. More than 80% of the natural resources consumed by humans are mineral resources, with an average of three tons of mineral resources consumed per year per capita[19]. China's energy and mineral consumption accounts for approximately 30% globally[18]. Currently, developing countries, such as those in Asia, Africa, and Latin America, are focusing on the construction in the mining industry to support industrialisation, while developed countries, such as those in Europe and North America, are increasing their support for the mining industry to develop the high-end manufacturing industry, further increasing the mining industry's contribution to global economic development[16].

Mineral resource exploitation and utilisation in China

China is one of the largest countries in terms of resource production, consumption, and trade. Field mining is the main method for obtaining mineral resources, and mineral resources are primarily divided into energy mineral, metal mineral, and non-metallic mineral resources in China. The revenue, income, and the proportion of the mining industry in GDP in China are reflected in **Figures 5** and **6**.

Compared to 2020, China's consumption of twenty-eight mineral resources increased in 2021, while the consumption of fifteen mineral resources decreased. The total consumption of thirty-six mineral resources in China, including coal, paste, manganese, chromium, vanadium, titanium, and copper, ranked first in the world. **Figure 7** displays the ratio between China's mineral consumption and that of the world in 2021.

Long-term, high-intensity, and large-scale development of mineral resource exploitation has created enormous pressure on the ecological environment. The National Mining Geo-Environmental Survey Report (2016) shows that from 2002 to 2015, mineral resource mining damaged more than 3.03 million hectares of land, and only about 810,000 hectares have been repaired and treated[23]. The accumulated volume of solid waste generated by mining activities is 48.31 billion tons, e.g., 38.69 billion tons of waste rock (soil), 5.48 billion tons of tailings, and 4.09 billion tons of coal gangue. Solid waste has caused several ecological and environmental problems, such as encroaching on cultivated land[24], causing geological disasters, soil, and water environmental pollution, etc. In addition, the total output of mining wastewater has been 11.48 billion cubic meters, and mining pit drainage has led to a drop in regional groundwater levels, a reduction in spring flow, and even dryness in many areas[25].

Construction mechanisms of green mines

Protecting the ecological environment, addressing climate change, and maintaining energy and resource security simultaneously are common global challenges. Promoting mining transformation and realising green development are the construction goals of green mines. Since 2007, great efforts have been made, and significant progress has been achieved in constructing green mines in China. **Figure 8** lists the key nodes for the development of green mines in China[26-28].

Figure 5: Revenue statistics and revenue growth ratio of China's mining industry from 2014 to 2022 (adapted from[20,21]).

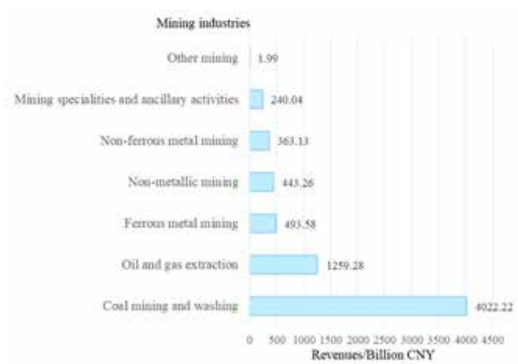


Figure 6: Operating incomes of mining enterprises in different industries above the designated size in 2022 (adapted from[20,21]).

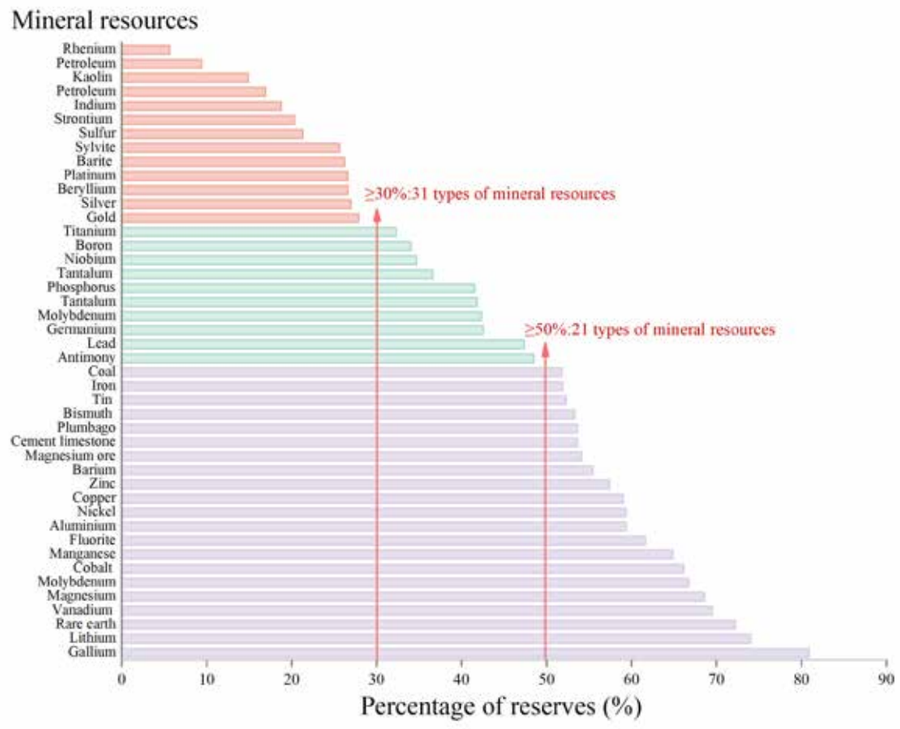


Figure 7: Global proportions of mineral resource consumption for China in 2021 (data from[22]).

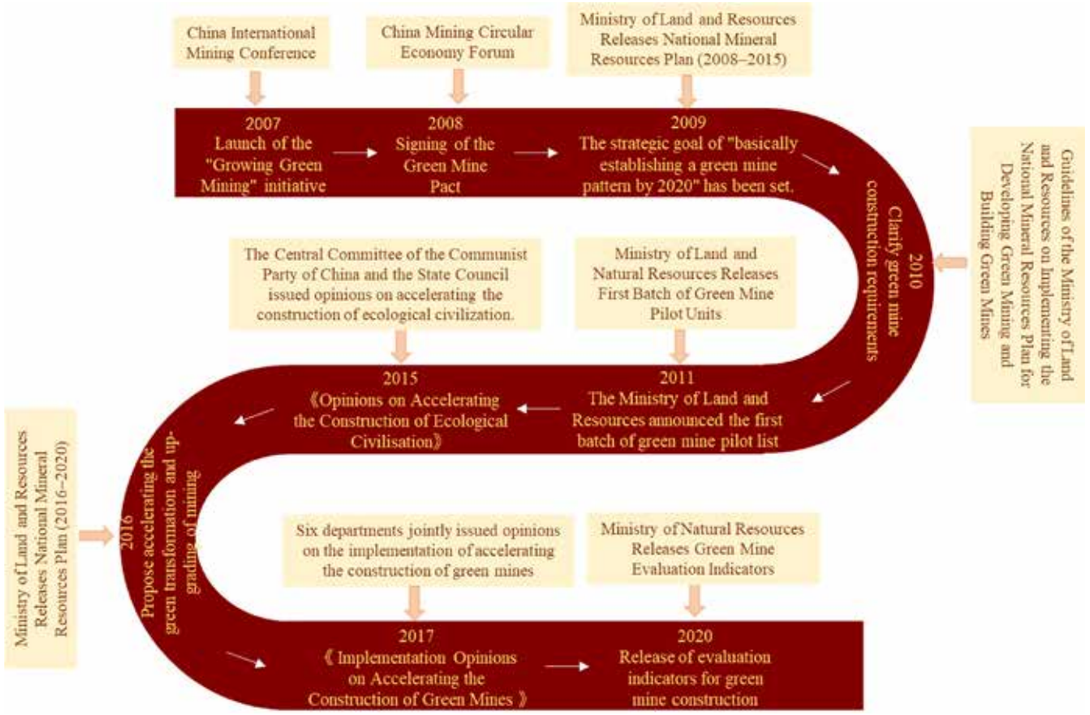


Figure 8: Development history of green mine construction in China.

In 2007, the initiative was proposed to fundamentally transform the development mode and economic growth mode, truly realising the coordinated development of resource utilisation and environmental protection, which has become an inevitable choice for the development of mining enterprises. This is also the first time that China has proposed the concept of "green mining." In 2008, the China Mining Circular Economy Forum was held in Nanning, Guangxi. The China Mining Federation and eleven large mining enterprises advocated for the signing of the "Green Mining Convention," which received recognition and a positive response from many mining enterprises. In 2009, "The National Miner-al Resources Plan (2008-2015)" jointly released by the National Development and Reform Commission and the former Ministry of Land and Resources, put forward clear requirements for the development of "green mining" for the first time, and set the strategic goal of "basically establishing a green mining pattern by 2020".

This also marked the beginning of the comprehensive promotion of green mining construction at the government level. In 2010, the former Ministry of Land and Resources issued the Guiding Opinions on Implementing "The National Mineral Resources Planning, Developing Green Mines, and Building Green Mines". This was the first time that clear requirements for building "green mines" had been put forward in the form of official documents, and the basic conditions for national-level green mines had been listed. In 2011, the former Ministry of Land and Resources announced the first batch of pilot units for "green mines", marking the official launch of China's national green mine pilot work. In 2015, "The Opinions of the Central Committee of the Communist Party of China and the State Council on Accelerating the Construction of Ecological Civilisation" officially included green mines in the document. This marks the shift of this work from corporate self-discipline to departmental advocacy, elevating it to a national strategy. In 2016, the Ministry of Land and Natural Resources issued "The National Mineral Resources Plan (2016-2020)", which proposed improving the quality and efficiency of mining development and accelerating the green transformation and up-grading of mining. In 2017, the former Ministry of Land and Resources, in conjunction with the Ministry of Finance and six other ministries, issued "The Implementation Opinions on Accelerating the Construction of Green Mines (Land and Resources Regulations (2017) No. 4)", marking the transition of China's green mining construction from the "pilot exploration" stage to the "comprehensive promotion" stage. In 2020, the Ministry of Natural Resources issued the "Green Mine Evaluation Indicators", which clarified the prerequisites for selecting green mines and unified the evaluation indicator standards.

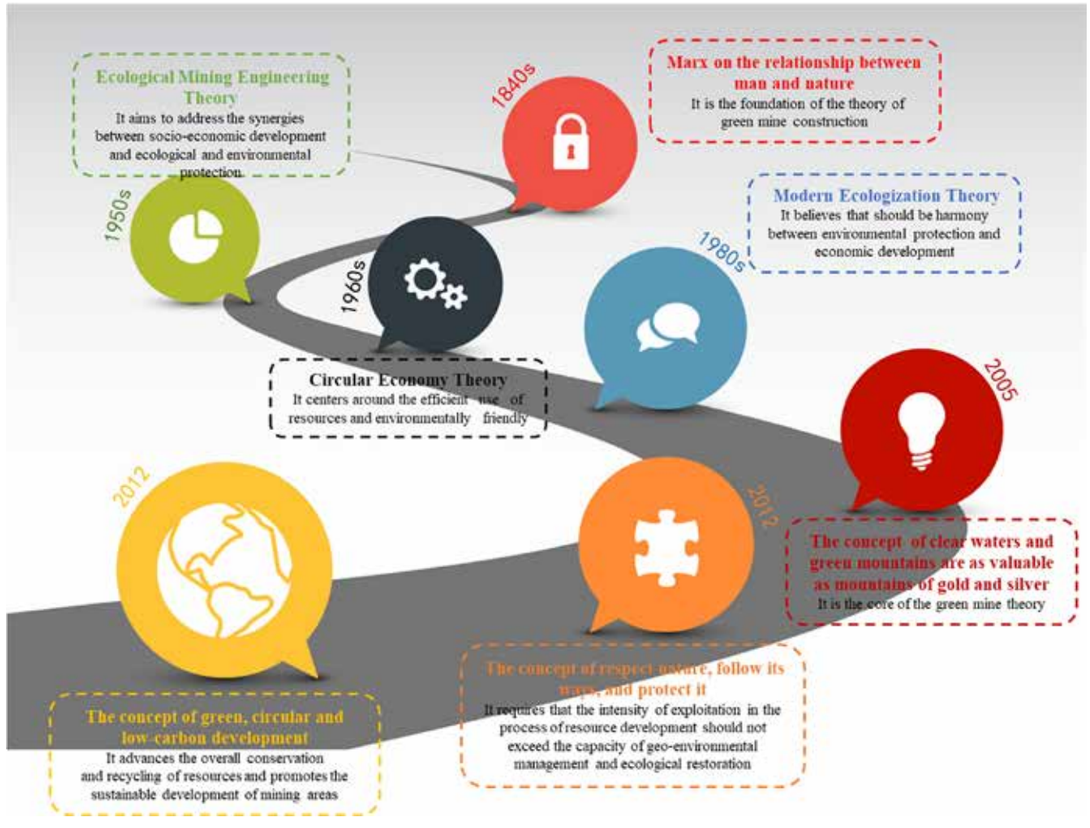


Figure 9: Basic theories for the construction of green mines.

Theoretical basis of Green Mines

The creation of green mines is interdisciplinary and influenced by multiple factors. It is necessary to consider not only the efficient utilisation of resources but also the safety of mining and resource utilisation, as well as environmental damage and ground stability in mining areas. Therefore, the creation of green mines should be informed by the theories shown in **Figure 9**.

Policy support for Green Mines

To accelerate the construction process of green mines, the relevant departments, and provinces (autonomous regions and municipalities) have put forward a series of policies related to green mines. In 2009, the Ministry of Land and Natural Resources issued Regulations of Geological Environment Protection in Mines, which stipulated the responsibilities, rights, and interests of protecting the geological environment in mines. It also provided for the prevention and restoration of damage to the terrain and landscape caused by mineral resource exploration and other activities[29]. In 2010, to speed up the construction of green mines, the Ministry of Land and Resources in China released the Guiding Opinions on Implementing the National Mineral Resource Planning for the Development of Green Mining and Construction of Green Mines[30]. In 2017, six ministries of China, including the Ministry of Land and Resources, issued the Guidance on Accelerating Green Mine Construction, which implemented incentive policies in four aspects: land use, mine use, finance, and funding [31]. In 2021, the National Development and Reform Commission, the Ministry of Finance, and the Ministry of Natural Resources issued the 14th Five-Year Plan for Promoting the High-Quality Development of Resource-Based Regions, which suggested that we should strongly promote green mine construction and all new and expanded mines should meet the requirements[32]. In addition, the provinces answered the call and introduced relevant policies. In 2020, Shandong Province issued the Shandong Province Green Mine Construction Management Approach[33]. In 2022, Shanxi Province released a notice titled the Guiding Opinions on the Comprehensive Promotion of Green Mine Construction[34].

Green Mine selection process and directory management

The mines with construction levels meeting the green mine standards can be included in the National Green Mine List of China. The incentive policies on the list have been implemented for the green mines, which can urge them to fulfil their obligations better[35]. The selection process and list management of green mines are shown in **Figure 10**.

1. Selection process[35,36]

According to the selection notice of green mines in 2020 issued by the General Office of the Ministry of Natural Resources in China, the main creation procedures are as follows.

i. **Application online**. The mining enterprises log into the National Green Mine Directory Management Information System and fill out the relevant application information.
ii. **Self-assessment of mining enterprises**. The mining enterprises conduct self-assessments and create self-assessment reports according to green mines' construction requirements and industry standards. Then, the mining enterprises fill out the self-assessment report through the directory system.
iii. **Third-party assessment**. In the form of government-purchased services, third-party assessment agencies are commissioned to conduct the on-site green

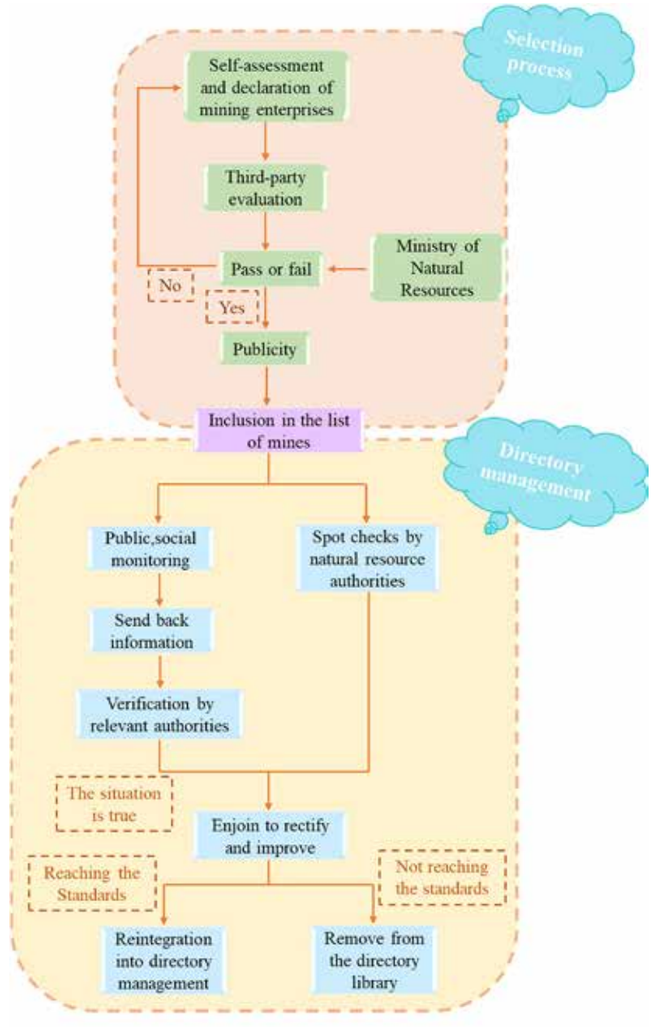


Figure 10: Entry process and list management of green mines in China.

mine construction level assessments. The third-party assessment report is created according to the requirements of unified evaluation indicators. The department in charge of natural resources selects mines and performs field verification.

iv. **Publicity**. The green mine candidates are publicly announced online, in newspapers, and through other channels. After publicity, and should there be no objection or dissent, the candidates are included on the national list of green mines.

2. Directory Management

To reward mines included on the green mine list and urge them to sequentially fulfil their obligations, the management of the green mine list is implemented by the Land and Resource Management Departments. It mainly includes supervision mechanisms, incentive policies, and degradation mechanisms[14].

i. **Supervision mechanisms**. The green mines on the national list are open to the public and subject to supervision. The Natural Resource Regulatory Department conducts on-site inspections of the green mines. If the construction levels of mines do not meet the green mine standards, the mines will be ordered to rectify the matter and excluded from the list. Meanwhile, each province's natural resource management departments conduct spot checks on green mines per the requirements of "double random and one disclosed inspection"[37].

ii. **Incentive policy**. The green mines on the list can enjoy corresponding incentive policy support, and the green mines ordered to rectify cease to enjoy incentive policies.

iii. **Degradation mechanisms**. The relevant departments will re-include the mines that passed the rectification process on the green mine list. The mines with unqualified rectification are removed from the list and no longer enjoy incentive policies.

Evaluation and Certification of Green Mine Levels

In general, the green mines on the national list have experienced self-assessment and third-party evaluations during the declaration process. Self-assessment refers to the preparation of self-assessment reports by mining enterprises or relevant evaluation institutions entrusted by mines to meet the related construction standards for green mines. Units recognised by the commission can also be invited to certify the construction levels of mining enterprises[35]. Once certified, the mine continues to implement green mine construction based on its deficiencies. After submitting the green mine application, the government department will purchase a third-party assessment service to rate whether the mine meets the green mine construction specifications in accordance with the "Implementing Opinions on Accelerating the Construction of Green Mines," "nine industry standards," "The Green Evaluation Indicator System," and other specifications[38]. The assessment process is shown in **Figure 11**.

PARAMETERS OF GREEN MINES

To improve the level of comprehensive utilisation of mine resources, reduce energy consumption and emissions, increase scientific and technological innovation and intelligent mine construction, and explore the stability of the

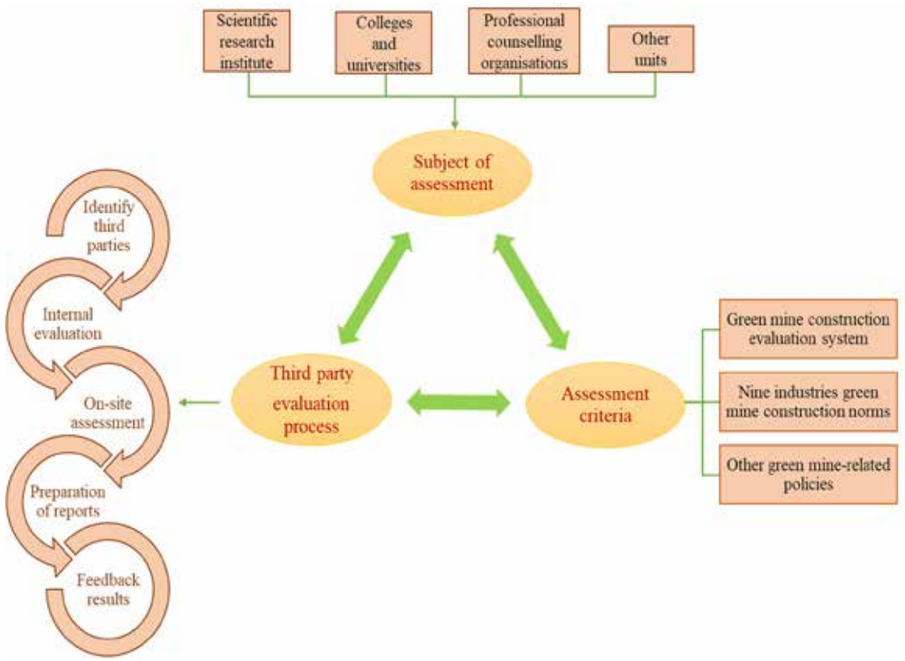


Figure 11: Third-party evaluation flow chart.

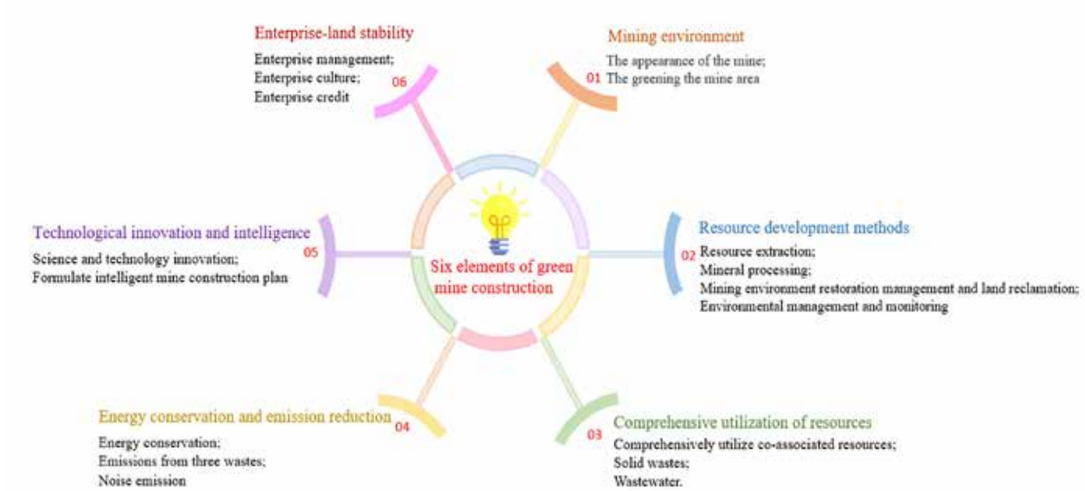


Figure 12: Key points of construction of green mines

mining area, the concept of green development and safety in production exists throughout the whole construction process of green mines to create safe, efficient, economical, and environmentally-friendly mines. The key points for the construction of green mines[39] are shown in **Figure 12**.

Mining Environment

Nearly 53,000 square kilometres of geological environment have been damaged in China, of which the seriously damaged areas account for 50% to 60% of the total area[40]. In addition, the types of mines in China are complex, and the mining methods are diverse, with different degrees of damage to the environment. Therefore, it is necessary to reasonably choose the governance measures according to the actual situation, which will not only improve the quality of mining but also promote the restoration of the mining environment. The main starting point is the appearance of the mine and the greening of the mine area.

For the appearance of the mine, combined with safety, environmental protection, practicality, and other factors, the function of the mine is a standardised layout. For example, the living area and production area are arranged in the safety zone, not less than 300m away from the mine; the production area has set up the corresponding signboards, and the management of materials, equipment, and waste is standardised[41]. The facilities in the mining area, such as water, roads, sanitation, etc., are fully equipped to ensure an orderly life. In addition, the living garbage is properly treated and utilised and there are no private buildings on the mine site. The greening of the mining area should be in harmony with the original ecological environment and not affect the overall harmony of the natural environment of the surrounding area. The greening of the mine area is fully covered, a greening guaranteed mechanism has been established, and the mine area is beautified based on local conditions[42]. More importantly, a systematic assessment and monitoring of geological hazards, terrain and landscape impacts, aquifer damage, soil and water environmental pollution, and land damage caused by mining should be conducted. Based on the evaluation and monitoring, corresponding land reclamation measures should be taken, and the mining area environment should be coordinated with the local natural landscape after treatment.

Resource Development Methods

The detailed demands for the construction of green mines in four aspects. i.e., resource extraction, mineral processing, mining environment restoration and management, land reclamation, and environmental management and monitoring, are described as follows[27].

1. Resource extraction

To meet the quality requirements of the mining face for green mining construction, a reasonable mining scale, mining sequence, mining technology, and equipment are selected based on the geological conditions of the ore body and the characteristics of the ecological environment. During the mining process, solid, liquid, and gas waste is disposed of in a timely and standardised manner[43]. Adopting mining methods can effectively reduce large-scale surface subsidence or uniform subsidence, such as backfill mining, water conservation mining, and other mining processes. To achieve intelligent production and control of various production links and the entire production process indicators, mechanised mining equipment with low energy consumption, low noise, low dust generation, and complete and effective safety protection devices is used. By adopting advanced technology and equipment such as unmanned mining vehicles and intelligent coal mining machines, mines are gradually realising the mechanisation of mining transportation systems, greening mining methods, and improving safety in mining operations.

2. Mineral processing

To minimise pollution to the environment, efficient, low energy consumption and low pollution equipment and processes should be selected. In addition, according to

the characteristics of water quality, mining enterprises should design the wastewater treatment system, and mine water and domestic sewage treatment stations should have complete treatment functions. The appropriate dust removal and dust reduction equipment should be installed.

3. Mining environment restoration management and land reclamation.
The designated areas should be treated and reclaimed to achieve the restoration of ecosystem functions and coordination with the surrounding environment according to the mining geological environment restoration and land reclamation project.

4. Environmental management and monitoring
Mining enterprises should obtain environmental management system certification, ensure that environmental protection facilities are complete, and establish emergency response mechanisms. In addition, it is necessary to establish an environmental monitoring mechanism in accordance with the relevant regulations of environmental monitoring to dynamically monitor the geological environment, reclamation area, noise, and pollutants in the mining area to have a comprehensive understanding of the situation of environmental pollution in mines and take timely measures.

Comprehensive Utilisation of Resources
The comprehensive utilisation of resources varies across different industries. Referring to the Mineral Resources Development and Utilisation Program or other standards, the mines choose appropriate processing technology to comprehensively utilise co-associated resources, solid wastes, and wastewater. Low-grade ores that are complex and difficult to process are utilised to improve technical and economic indexes by adopting combined processing and metallurgical processes. Enterprises should practically dispose of topsoil and recover valuable elements or useful minerals from solid waste. The solid waste that cannot be recycled is fully utilised through backfilling, paving, and other ways, striving to achieve zero resource discharge[44]. In addition, tailings containing mainly calcite and quartz can be used as raw materials for cement[45]; tailings containing mainly quartz or feldspar can be used as raw materials for ceramics[46]; tailings containing Fe, Zn, Cu, Mo, B, and other trace elements can be used as soil conditioner[47]; tailings that cannot be recovered can be used as underground filling material. Wastewater disposal and comprehensive utilisation need to be equipped with corresponding wastewater treatment facilities and recycling systems[48]. Currently, the treatment of acidic wastewater from mines can be categorised into chemical, physicochemical, microbiological, and wetland methods. According to the nature and output characteristics of different mine wastewater, its treatment process and reuse methods are also different.

Energy Conservation and Emission Reduction
It mainly includes energy conservation, emissions from three wastes, and noise emissions.

1. Energy conservation
The enterprise establishes a whole-process energy consumption management system and obtains energy management system certification. The energy consumption of each process should be analysed according to the actual situation of the extraction process. Mining enterprises can optimise the equipment and simplify the process line of those processes whose energy consumption does not meet the standard. In terms of energy consumption in mines, carbon emissions from electricity and transportation consumption account for a large proportion. Therefore, mines should rationally utilise clean energy and adopt unmanned driving to reduce carbon emissions. It is necessary to increase scientific research investment in mining technology and equipment to reduce energy loss through new equipment and technologies[49].

2. Emissions from three wastes
A list of major dust-producing points is created, and drainage pipes and drains are properly installed. The dust generated in the mining process is processed through appropriate dust removal measures, and wastewater from the extraction process is discharged after treatment. For solid wastes that cannot be completely utilised, they are graded and classified or disposed of according to the corresponding regulations.

3. Noise emission.
Noise emissions should be sorted and analysed according to the process to form a noise control list. The noise generated in the extraction process is treated with noise reduction and discharged after meeting the standards.

Technological Innovation and Intelligence
It mainly includes technological innovation and intelligent mining.

1. Science and technology innovation
The enterprise establishes a research and development team of full-time technical personnel and formulates a technology research and development management system. A collaborative innovation system between the industry, academia, research, and utilisation is established, and workers are encouraged to participate in their enterprise's scientific and technological innovation. It is imperative to summarise the scientific and technological achievements, support technological transformation, and select the mining processes, technologies, and equipment that the country encourages, supports, and promotes.

2. Formulate an intelligent mine construction plan.
Build a centralised automation control platform. Implement the processes of three-dimensional reserve management. Develop a production automation system, remote video monitoring system, intelligent working face or unmanned mining vehicle system, and online monitoring system for the mining environment[50].

With the arrival of the 5G era, a number of mining enterprises have introduced the Internet of Things, big data, artificial intelligence, and other advanced technologies to build a dynamic visual three-dimensional geological model, intelligent truck scheduling, all-round video surveillance, real-time monitoring of dust, automation and intelligent distribution of six systems, so that the enterprise production is safer, more efficient use of resources, more environmentally friendly mining methods. For example, loaders, excavators, and other parts of the product line have been mechanised and electrified with a 5G remote control, which improves mining efficiency, reduces carbon emissions, and lowers noise[51].

Enterprise-Land Stability
The establishment of a practical green mine management system is an indispensable guarantee to maintain order at a mine. At the same time, mining enterprises should improve the production safety responsibility system and establish all production safety management procedures and safety operation procedures to guarantee the safety standardisation of the production process. For slope disasters caused by open-pit mining, surface displacement monitoring, internal rock displacement monitoring, and water pressure monitoring are used to control the internal structure of the rock mass and groundwater permeability and increase slope stability. Retaining walls, anchors, anti-slip piles, grouting, and reinforcement methods are adopted to prevent landslides, minimise damage to the surrounding land, and improve the stability of the slopes[52]. The underground mining goaf is mainly treated by setting up isolation walls and observation points, filling them with waste rocks, and collapsing surrounding rocks to reduce disturbance and damage to the land[53]. Among them, waste rock filling can also reduce the occupation of land by waste rock. Enterprises should establish a mining equipment management system, functional area management system, occupational health management system, and environmental protection system. In accordance with the green mine training system and plan, regular training is organised for mine personnel. The dress code for those who enter the site must meet safety requirements. The enterprise must care for its employees, organise regular medical checkups for them, and conduct cultural activities to promote the construction of a green mine culture for the mining enterprise. In addition, the mine pays taxes according to the law, fulfils relevant obligations, cooperates with neighbouring residents, and participates in public welfare activities.

DISCUSSIONS

Construction Achievements
Over the past decade, various regions have promoted policies and regulations, gradually improving upon them, which has led to significant achievements in green mine construction and the overall image of the mining industry. In 2017, six ministries, including the former Ministry of Land and Resources, promulgated the Implementation Opinions on Accelerating Green Mine Construction, officially marking the beginning of China's journey into green mine construction. It symbolises the transformation of green mine construction with Chinese characteristics from point to surface[54]. Concurrently, a preliminary framework of policies and regulations related to green mines has been established, such as the Regulations on the Protection of Geological Environment in Mines[55], the National Green Mine Construction Standards, and the Green Mine Construction Standards for Nine Major Industries[56]. In accordance with the China Mineral Resources Report (2022) issued by the Ministry of Natural Resources, more than 1100 national-level green mines and fifty green mining development demonstration areas will be constructed by the end of 2021. In 2020, 301 mines were included in the National List of

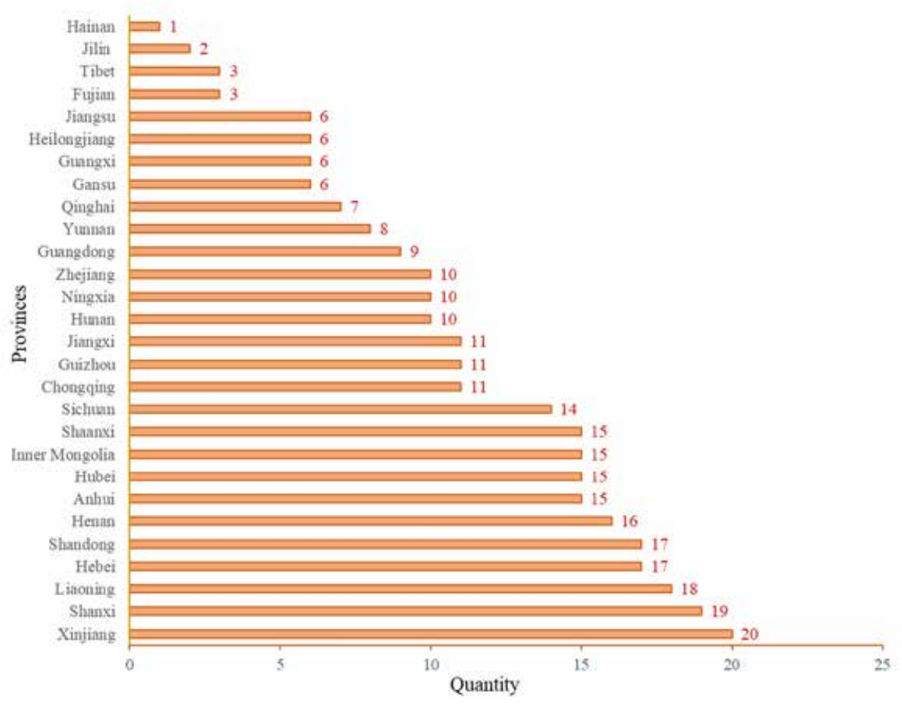


Figure 13: Number of mines included in the National List of Green Mines in 2020 by province (data from[57]).

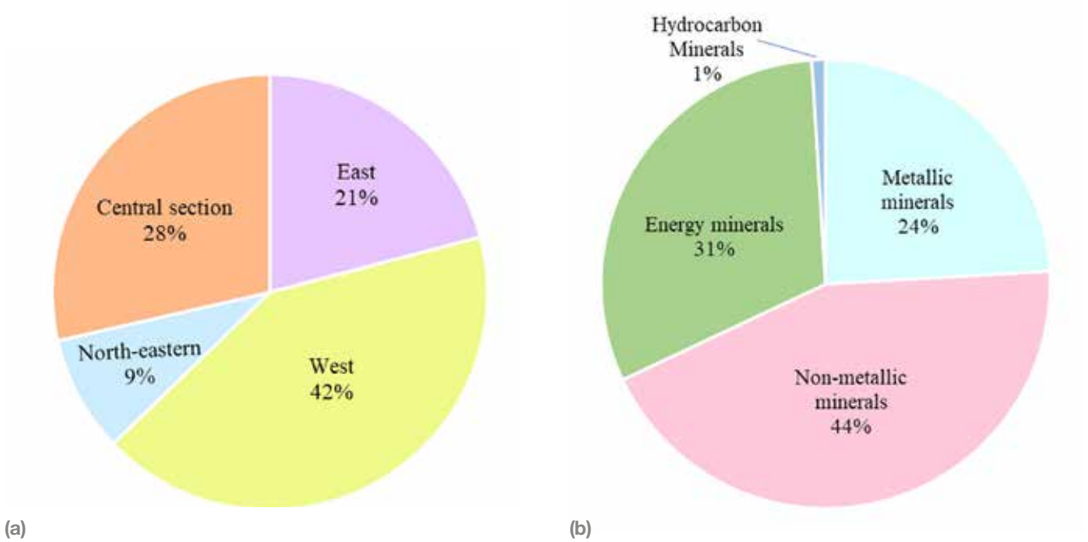


Figure 14: Structural analysis of the 2020 National List of Green Mines (data from[57]). (a) Regional analysis; (b) Mineral analysis.

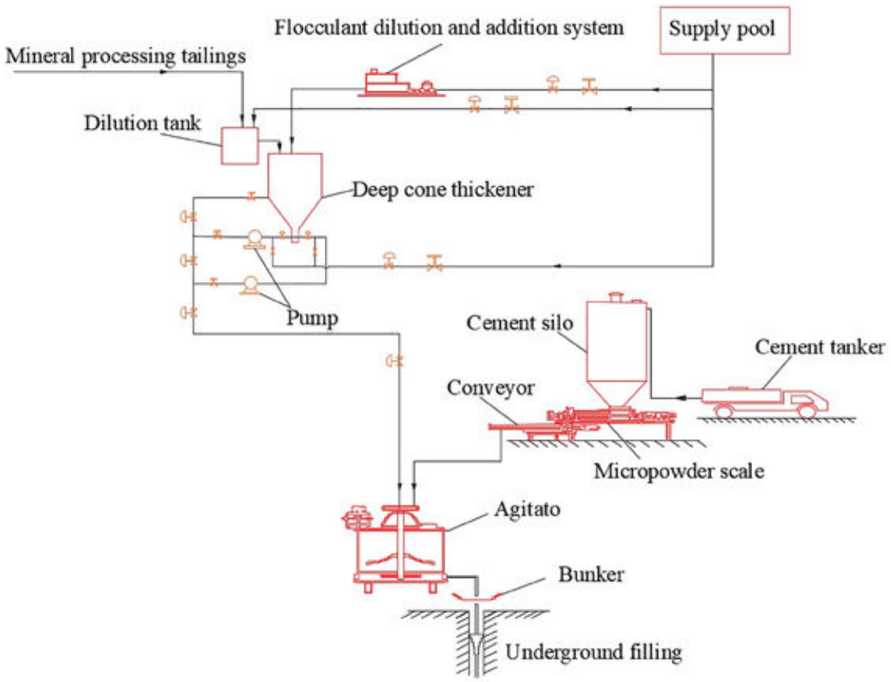


Figure 15: Flow diagram of the filling process (adapted from [61]).

Green Mines[57]. These 301 mines were determined based on their locations and mine types. Xinjiang had the highest number of selected mines, totalling twenty. The western region had the highest number of mines on the list. Non-metallic mineral resources account for the largest proportion. **Figure 13** displays the number of national green mines by province. **Figure 14** analyses the national green mines in 2020 by mine type and location.

Developing Directions of Green Mines

Since the creation of green mines, green mine models have emerged in China, mainly including green technology mining, modern mining operations, stable mining areas, and the ecological restoration of mines[58,59].

1. Green technology mining

The core of the green mining model is to realise efficient and intensive mining of resources and the maximum protection of the ecological environment with green technology so that resource extraction and the environment can achieve a unified green mining development mode. Green mining technologies include fill mining, water retention mining, clean mining, etc.[60]. **Figure 15:** shows the tailings filling system of the green mining.

2. Modernisation of mining operations

Among the 661 pilot units, over 90% of them integrate modern network technology and automatic control technology throughout the entire production and operation process, achieving a beneficial situation for both the economy and the environment. For example, building a smart mine platform allows for equipment to be automated remotely to create smart mines and smart mining areas[62-64].

3. Stability in mining areas

Stability in a mining area means that mining enterprises should fulfil their social responsibilities in the pursuit of development, realising the coexistence between the mining enterprises and surrounding communities, the promotion of mining development and regional economic development, the coordination of mineral extraction and environmental protection[65]. The paradigm is the Yunnan Phosphatization Hanying model. **Figure 16** shows the stable development of economic, environmental, and cultural construction between the Yunnan Phosphorus Chemical Group and Hanying Village through the “321” working mechanism[66].

4. Ecological restoration of mines

Mine ecological restoration refers to the optimal restoration of the original appearance or value of the damaged land and environment around the mining area through a series of restoration technologies. The ecological restoration models of mining areas include the re-greening model, the mine park model, and the tourism landscape model[67,68].

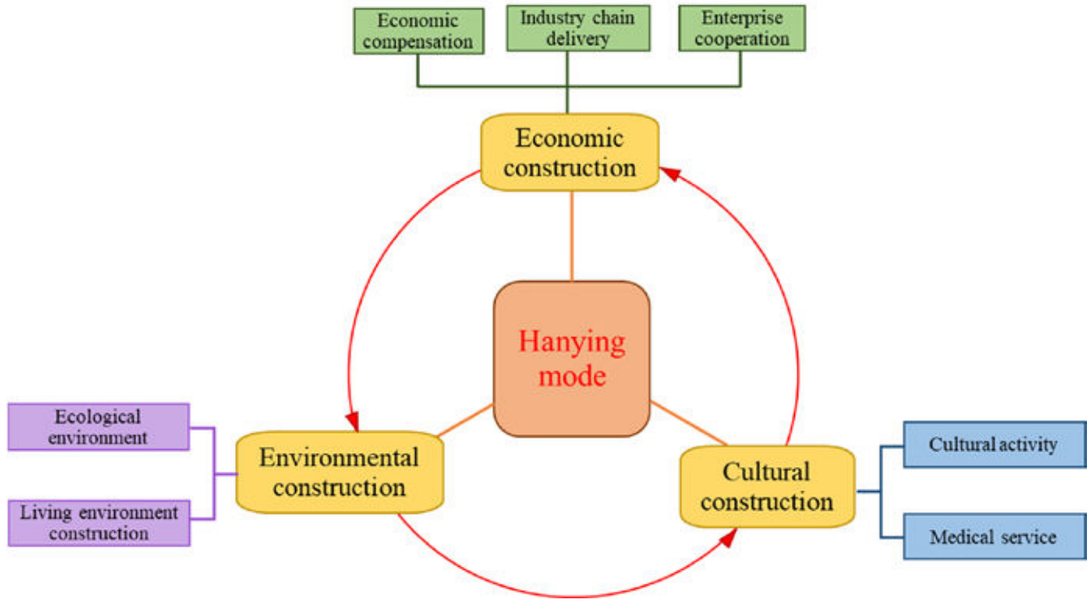


Figure 16: Schematic diagram of Hanying “321” model (adapted from[66]).

Future Goals for Green Mine Construction

1. High-quality development contributes to green mining

Currently, problems exist in green mine construction in China, e.g., insufficient enthusiasm for some mines, inadequate evaluation criteria systems, and a low proportion of small-scale mines[14]. Therefore, the mines that are close to profitability should optimise the industrial structure and take the road of intensification. Small mines are intensive into medium-sized mines, while medium-sized mines should be concentrated into large mines.

It is necessary to vigorously promote technological innovation, transform the development model of mining, and breakthrough key technologies that present bottlenecks[69]. Advanced mining and beneficiation processes should be adopted, novel equipment should be used to improve the utilisation rate of resources, energy consumption during mining operations should be reduced, and a beneficial relationship between the mine and nature should be achieved.

2. Promoting green mine construction overall with a focus on points and areas.

The green mine construction is the “point,” and green mine demonstration areas are the “surface.” Mines with remarkable results in green mine construction are selected as demonstration sites. The government actively guides and promotes institutional innovation, management innovation, institutional innovation, point driven areas and achieves centralised integration through the process, thus promoting the development of green mines across the entire region[70].

Main Measures for Green Mine Development and Construction

1. Mining enterprises

The mining enterprises should fully recognise the necessity of developing green mines, take active measures to establish green mines, and practice the concept of green development. Mines should try their best to increase scientific and technological innovation to promote the transformation and upgrading of the mining industry. In addition, according to existing policy norms, the enterprises design the green mine construction plans and con duct self-assessments according to green mine standards[14]. Then, the mining enterprises make timely corrections to improve their deficiencies.

2. Government

i. Improve the policies and formulate the standards for green mines. The nine industry standards and specifications of green mines released in 2018 do not cover aquatic minerals, radioactive minerals, and other types of minerals[71]. Meanwhile, the issued standards are not applicable to different mines; therefore, it is indispensable for the government to improve the standard construction policies of green mines. Differentiated standards and detailed requirements should be formulated for mines with different scales, stages, and locations[38].
ii. Improve the guaranteed system for the execution of green mine policies. The government should implement incentive policies for green mining enterprises in terms of land usage, mining, finance, and funding[70]. The mines that meet the relevant green mine requirements should be exempted from taxes.
iii. Strengthen publicity and implement regulatory responsibilities. Enterprises actively convene green mine construction exchanges and training sessions to promote mutual learning and progress in various places. Relevant departments implement regulatory responsibilities, conduct random spot checks, guide, and urge mines to rectify problems on time. The mines that do not meet the requirements are promptly removed from the list of green mines.

CONCLUSIONS

With the environmental impacts of mining, including three-waste emissions, ground deformation, geological disasters. Occupation and destruction of land, pollution of ground water resources. It is important to note that, at the same time, as a traditional high-energy consuming industry, mining consumes a large amount of energy. It emits greenhouse gases, so the construction of green mines has become an inevitable trend in the development of the mining industry under the impetus of the dual-carbon target. Over the decade of pushing forward, from pilot exploration to comprehensive promotion, from demonstration sites to demonstration zones, more than 1250 national green mines have been constructed, and four typical green mine models have been developed, achieving significant achievements in the construction of green mines. However, there are still some problems, e.g., unbalanced regional development, insufficient understanding of green mine construction by some enterprises, imperfect policies, and standard systems, etc. Therefore, the construction of green mines in the future requires the joint efforts of enterprises, governments, and society, in accordance with the development model of "government-led, enterprise-oriented, association support, policy guarantee, and market operation," to promote the continuous exploration and innovation of technologies and methods for green mine construction. The government should perfect the policies and standard system, increase the financial support, and strengthen the supervision and management of existing green mines. Enterprises should formulate the construction plan of "one policy for one place and one policy for one mine," provide positivity and initiative, speed up the upgrading and transformation in line with local conditions, and gradually meet the standards of green mine construction. In addition, to achieve breakthroughs in low-carbon technology and efficient resource utilisation, promote green and low-carbon development of mines, and reduce carbon emissions, enterprises should carry out research and development of "energy-saving, low-carbon key technologies" and ecological restoration of mines and implement the "two mountains" theory throughout the entire process of mining development, so that sustainable development of China's mines can be promoted. With the joint efforts of the government, enterprises, and others, we will promote the high-quality development of the mining industry and realise a new situation in the development of the mining industry.

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Author Liang Wang was employed by the company Zhongguancun Green Mining Industry Alliance. The remaining authors declare that the research was conducted without any commercial or financial relationships that could be construed as potential conflicts of interest.

Please note that references and reading can be obtained using the following link: https://www.researchgate.net/publication/377176019_Construction_Practices_of_Green_Mines_in_China

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