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Development of Energy and Mining Governance Systems Based on New-Generation Information Technology

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Abstract: To address the risks and challenges encountered by China's energy and mining security sectors, the changes and development patterns of China's energy demand in achieving the target of carbon peak and carbon neutrality are analyzed herein. The coupled development of new and fossil energy resources is inevitable for ensuring a stable supply of diversified energy in China. In this study, we investigate the characteristics of fifth-generation communication, big data, blockchain, and artificial intelligence technologies, as well as their application prospects in energy and mining fields. Subsequently, we propose a technological path for reforming China's energy and mining governance systems based on the abovementioned new-generation information technologies. Specifically, we investigate the integration of the new-generation information technologies with energy and mining development technologies, as well as their application to energy production, transportation, consumption, market, and government regulation. Moreover, we propose a strategic approach for developing a new governance model for energy and mining industries based on the new-generation information technologies. In this regard, we must strengthen basic research and equipment development, support new infrastructure construction in energy and mining fields, provide policy and fund guarantees, and establish a national intelligent platform for energy and mining safety production and trade.

Keywords: energy security; next-generation information technology; energy and mining; government regulation; governance systems

1 Introduction

Energy and mineral resources are vital to human society development and indispensable for promoting the sustainable development of society and the economy. The current international energy paradigm is undergoing profound transformation, which poses increasing concerns and threats to China's national energy security [1,2]. In-

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creasing development and utilization efficiency, reducing costs, and enhancing energy and mining governance capabilities are important steps that enable China to pursue high-quality development.

Owing to the unceasing development of the Fourth Industrial Revolution, new-generation information technologies including fifth generation (5G), big data, artificial intelligence (AI), blockchain, and the Internet of Things (IoT) have progressed significantly. The commercial application of 5G technology is being promoted, and satisfactory application results have been achieved in some industries, such as the medical and mining industries [3]. Big data technologies and algorithms have been successfully deployed in the financial, manufacturing, and logistics industries, which affect every aspect of our lives that involves the use of data governance technology [4]. Blockchain modifies some conventional business models in the financial, machinery, food, and medicine industries, and exhibits the characteristics of traceability, immutability, unforgeability, smart contracts, and decentralization [5]. Integrating the development and usage technology of energy and mining resources with the abovementioned new-generation information technologies based on their features will modify the exploitation and utilization mechanism of fossil energy and mineral resources, as well as stimulate the evolution of production, delivery, warehouse, consumption, and utilizing techniques. As such, (1) a solid technical foundation for the revolution of energy technology will be provided, (2) a low-carbon, safe, and efficient energy and mining system will be formed, and (3) the modernization of the energy and mining governance systems in China will be promoted.

2 Challenges encountered by energy and mining industries in achieving carbon peaking and carbon neutrality

2.1 Changes in China's energy pattern in achieving carbon peaking and carbon neutrality

In addition to the vigorous development of the social economy in China since its reform, China has committed to maintaining the sustainable development of the Earth's ecosystem and signed the *United Nations Framework Convention on Climate Change* in 1992 as one of the first contracting states [6]. In 2015, China submitted relevant materials to the Secretariat of the Convention on *Enhanced Actions on Climate Change – China's Intended Nationally Determined Contributions*, and set the goal of reaching peak carbon dioxide emission by 2030. In September 2020, President Xi Jinping promised at the 75th United Nations General Assembly that China would peak its carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. Carbon peaking is not energy peaking and carbon neutrality is not zero. The economic and social development of China will rely on fossil energy for a significant amount of time into the future; nevertheless, China must consider safe and efficient development as well as low-carbon and clean utilization.

In 2019, China's per capita primary energy consumption was 3.47 tons of standard coal (ranking 48th in the world), which is significantly lower than that of developed countries [7]. Owing to the steady progress of China's industrialization, urbanization, informatization, and agricultural modernization, the number of middle-income groups as well as consumption have increased gradually. As the material basis of economic and social development, energy and mineral resources should be further developed to balance between their demands and carbon peaking.

To achieve carbon peaking and carbon neutrality, the energy paradigm of China will change. However, based on China's resource endowment and development requirements, coal will remain the main resource of China's energy for a long period into the future. Thus, the dominant position of coal resources in the energy structure cannot be replaced in the short term. While further strengthening the guarantee of coal and coal power for energy stability, the goal of carbon peaking and carbon neutrality will ensure that China's coal resources is green, clean, low-carbon, and efficient in terms of development and utilization. In this new era, various uncertainties have emerged in the coal market, and higher requirements have been imposed in terms of the elasticity of coal demand. The supply and demand structure of the domestic coal market has changed significantly. The existing coal production and supply model cannot be easily adapted to the new development requirements. Hence, a new flexible coal production and supply guarantee system based on new-generation information technologies is urgently required to ensure national energy security.

A stable and reliable supply of new energy sources, such as wind and light, is difficult to form in the short term; furthermore, their unstable supply under severe weather increases the vulnerability of the system operating using them. Various incidents, such as large-scale power outages in Texas in the United States under extreme weather, the recent significant increase in coal prices in China, and power outages in some areas of China, reflect the vulnerability of new energy sources. The comprehensive or large-scale incorporation of new energy into existing energy supply systems is challenging because large-scale low-cost energy storage technology has not demonstrated

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breakthroughs. Using fossil energy (particularly coal and coal-fired power) as a stabilizer, as well as a ballast to increase the proportion of new energy and achieve the mutual assistance and coupled development of new energy and fossil energy is the only approach that will allow China to form a stable supply of multiple energy sources in the future.

2.2 New challenges encountered by energy and mining in achieving carbon peaking and carbon neutrality

Conventional industries are difficult to transform or upgrade. Currently, the proportion of China's high-investment, high-consumption, high-pollution, and low-benefit industries is relatively large [8]. Although some innovations have been achieved in some industries, the transformation and upgrading of the industrial structure is affected by problems such as insufficient independent innovation, bottleneck in key technologies, low efficiency of energy and resource utilization, and increasing costs of various production factors. Furthermore, China's energy decarbonization and energy utilization efficiency are relatively low, and the transformation of the economic growth mode is affected by significant challenges.

Several challenges are encountered when applying renewable energy at a large scale. Owing to its technicalities, renewable energy power generation is volatile and intermittent. In the near and medium terms, fossil fuel power remains relevant for safeguarding peak regulation. The widespread application of large-scale and industrialized non-fossil energy not only faces technical problems, such as peak shaving, long-distance transmission, and energy storage, but also institutional and mechanism problems. China's electricity market is still in the development stage, and the absence of an optimal renewable energy market consumption mechanism restricts the development of renewable energy.

Low-carbon technology is still in the research and development (R&D) and experimental stages, and the maturity of large-scale, economical, and reliable application technologies is relatively low. Low-carbon technology involves technologies such as the low-carbon utilization of high-carbon raw materials, CO_2 capture, and industrial utilization. The existing technology is immature and necessitates complex links and high costs. Therefore, systematic technological innovations are urgently required.

To address the technical challenges encountered in energy and mining development for achieving the carbon peaking and carbon neutrality, new generation information technology can be integrated with energy and mineral resource development technology to promote the construction of modern energy and mining governance systems. This allows a new strategy for energy security to be implemented as well as promotes energy revolution, which are key to supporting the modernization of the national governance system and governance capacity. Consequently, the national economy can be developed in a rapid, sustainable, and healthy manner.

3 Development and system characteristics of new-generation information technology

3.1 5G communication

Mobile communication obviates the necessity for wired connections and realizes flexible network access, data acquisition, and information exchange. Mobile communications are updated every 10 years, and each update has significantly promoted the upgrading of related industries and the development of the social economy.

The International Telecommunication Union has identified three primary application scenarios at the beginning of 5G design: enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (urLLC), and massive machine-type communications (mMTC) [9]. These three scenarios exhibit many similarities with the production, consumption, market, and regulatory governance demands of energy and mining. Fig. 1 shows the application services of 5G based on network slicing technology in multiple energy and mining scenarios. eMBB technology can effectively support large-bandwidth business requirements, such as ultra-high-definition video transmission in mines. Meanwhile, urLLC technology can satisfy the communication demands of intelligent mining equipment such as unmanned mining vehicles and unmanned excavators. Finally, mMTC technology can support various coal mine safety monitoring and other data acquisition requirements more effectively [10]. Therefore, the application of 5G communication in energy and mining governance systems will promote the intelligent mining of energy and mining and provide a foundation for the construction of intelligent green mines.

In the physical layer, 5G technology expands the network with abundant spectrum resources and obtains a large communication bandwidth by applying advanced massive MIMO + beamforming [11,12], co-frequency co-time full-duplex [13], non-orthogonal multiple access [14], and other technologies.

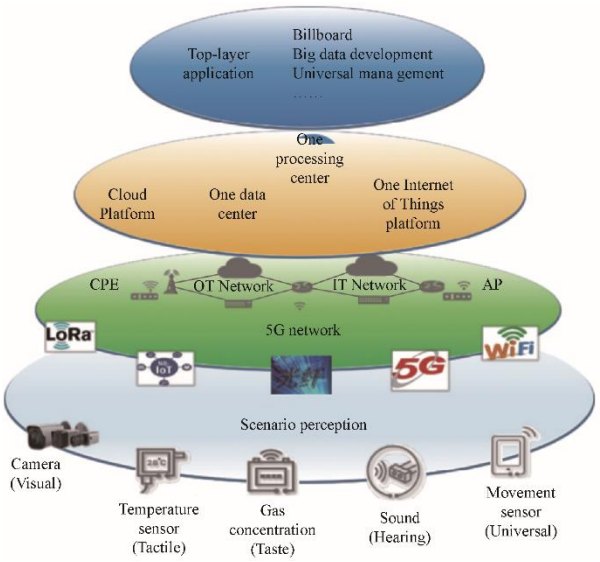

Fig. 1. Application of 5G technology in energy and mining scenarios.

Note: CPE refers to Customer Premise Equipment; OT refers to operation technology; IT refers to Internet technology; AP refers to access point.

In the network layer, network slicing technology based on a software-defined network and network function virtualization [15,16] decouples the underlying communication hardware devices from network resources and realizes the independent and flexible allocation of network resources. In fact, it provides a technical foundation for the construction of multiscenario dedicated 5G slicing for modern energy and mining, thereby facilitating the construction of an extensive interconnected network of man–machine environments, as well as realizing the management of energy and mining systems, such as intelligent mining, digital operation and maintenance, inspection, and security, as shown in Fig. 2.

The construction of 5G private networks in the energy and mining fields must adhere to the development trends of public 5G networks. In addition, planning and application deployments should be further improved to accommodate practical application scenarios of energy and mining, particularly underground coal mine scenarios. For example, it is necessary to consider the attenuation characteristics of wireless transmission in an underground environment, networking problems in narrow spaces, and coexisting problems arising from the integration of multiple access technologies such as WiFi6 (802.11ax)/NB-IoT.

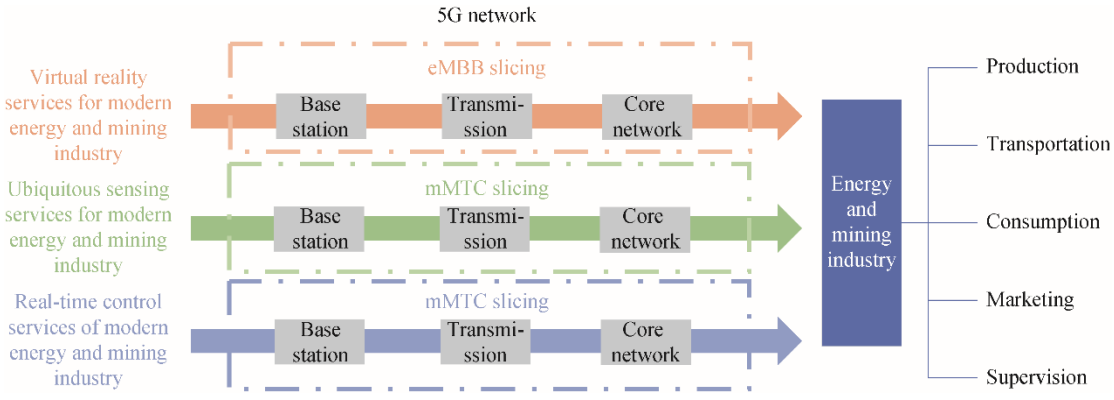

Fig. 2. Application of 5G slicing technology in various services of energy and mining industries.

3.2 Big data

Big data is key to intelligent analyses and decisions. To promote the development of big data, the Chinese government, through the State Council, has issued the *Outline of Action for Promoting the Development of Big Data*, where data are highlighted as an important strategic resource for the country that has promoted the implementation of the national big data strategy.

Big data technology features a large data volume, multiple characteristics, and low data value density. The goal

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of big data processing and analysis technology is to provide assistance in decision making for various applications via data comprehension. From a technical level, big data processing technology can be classified into front-end preprocessing technology in the data acquisition process, data compression technology in the transmission process, and data fusion and data mining technology in the control decision-making process. Data preprocessing in the front-end sensor data acquisition process includes data cleaning, data completion, data reduction, and conversion [17–19]. Through data preprocessing, noise reduction in the original sampling data, abnormal data identification, and repair are realized, and the quality of the big data is improved. Data compression can effectively reduce the amount of data and alleviate the information load of the system while ensuring identification accuracy. Typical data compression methods include compression based on digital coding, matrix conversion, and tensor decomposition [20,21]. The aim of big data fusion and mining technology is to integrate multisource data using mathematical methods, extract feature information, and match feature data with a knowledge base via reasoning and decision-making to perform decision judgments and determine the inherent value of big data.

From the perspective of application, applying big data in the development and utilization of energy and mineral resources can realize intelligent analysis, decision making, and control during mineral resource exploitation, power supply, ventilation, and drainage [22]. Meanwhile, by applying big data to the health status diagnosis of energy and mining equipment, the remote operation and maintenance of energy and mining equipment can be realized [23]. In addition, big data can be applied to the production and management of new energy; furthermore, by combining big data with AI algorithms, the prediction of distributed clean energy such as wind power and photovoltaic power can be realized [24] to effectively support the refinement and intensification of energy production, thereby facilitating China in achieving carbon peak and neutrality.

3.3 AI

AI can be used to achieve the autonomous perception, analysis, and control of computers by deploying computers to imitate human thinking logic. AI encompasses various technologies such as swarm intelligence and evolutionary algorithms, fuzzy logic, expert systems, and machine learning, and is still evolving [25]. Relevant technologies are gradually being applied in related fields, such as intelligent manufacturing and intelligent mine construction, where favorable application results have been achieved.

The specific embodiment of the integration of the national strategies of AI and energy revolution is the more comprehensive application of AI in the energy and mining governance systems. This enables intelligent sensing and production safety, data-driven technology and optimized decision-making, as well as intelligent analysis and operation control to be realized, thereby effectively improving the country’s ability to supervise and manage complex multi-energy coupling systems and promote the country’s energy revolution.

Wang et al. [26] presented the construction of intelligent coal mines as an example and comprehensively analyzed the core technical shortcomings of AI in the intelligent mining process of coal mines as well as technical problems that must be solved, such as intelligent decision-making and control technology for automatic coal cutting in complex coal seams. Additionally, Wang et al. highlighted that a new generation of AI algorithms is urgently required to realize the accurate identification of various types of coal and rock information, such as vibration and images, to transcend the technical bottleneck of intelligent decision-making and further promote intelligent equipment R&D.

3.4 Blockchain

Blockchain, also known as distributed ledger technology, is a distributed storage mechanism that enables trusted data sharing and state consensus in a fully distributed environment. The basic structural framework of the blockchain is shown in Fig. 3. It comprises the following components: (1) Data layer: when recording data, the Merkle tree is used to solve the problem of block data and transaction message format as well as organize transaction data and state changes; (2) network layer: participants are connected to each other through a specific P2P protocol to form a network, enabling each participant to exchange messages with the surrounding neighbors; (3) consensus layer: as the core of the blockchain, it ensures that all blockchain participants can form a unified ledger; (4) contract layer: it encapsulates various script codes and algorithms of the blockchain system and generates smart contracts, which is the basis for the flexible programming and data manipulation of the blockchain system; (5) application layer: the blockchain develops decentralized applications by calling the interfaces of the protocol layer and smart contract layer, provides users with various services and application scenarios, and realizes the rich ecosystem of the entire blockchain [27].

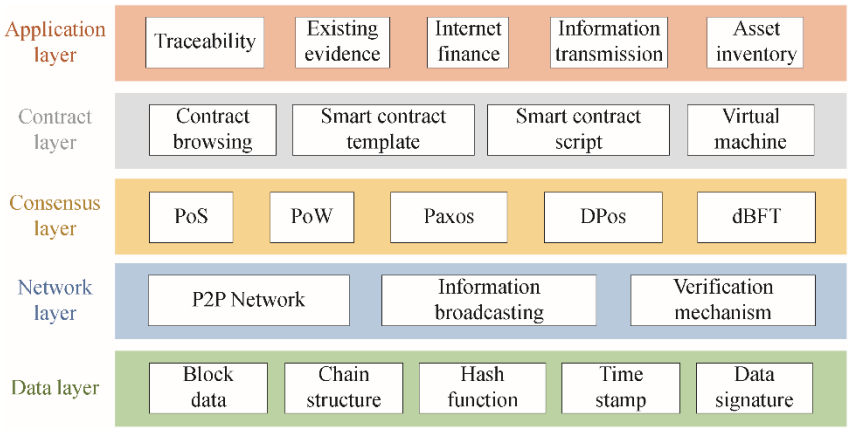

Fig. 3. Basic structural framework of blockchain.

Although blockchain originated from Bitcoin, it has gradually expanded from a purely financial industry to other industries, including energy and mining. In the *Action Plan for Building a High-Standard Market System* issued by the General Office of the State Council in January 2021, blockchain is identified as one of the most important technologies for the construction of new national infrastructure during China's 14th Five-Year Plan period. The decentralization, immutability, traceability, and collective maintenance of blockchain allows many problems in the energy and mining industries, such as oligopoly, information barriers, and flexible transactions, to be solved, as well as enable an open, unbiased, and equitable system to be constructed. A new system for energy and mining governance [28] is shown in Fig. 4.

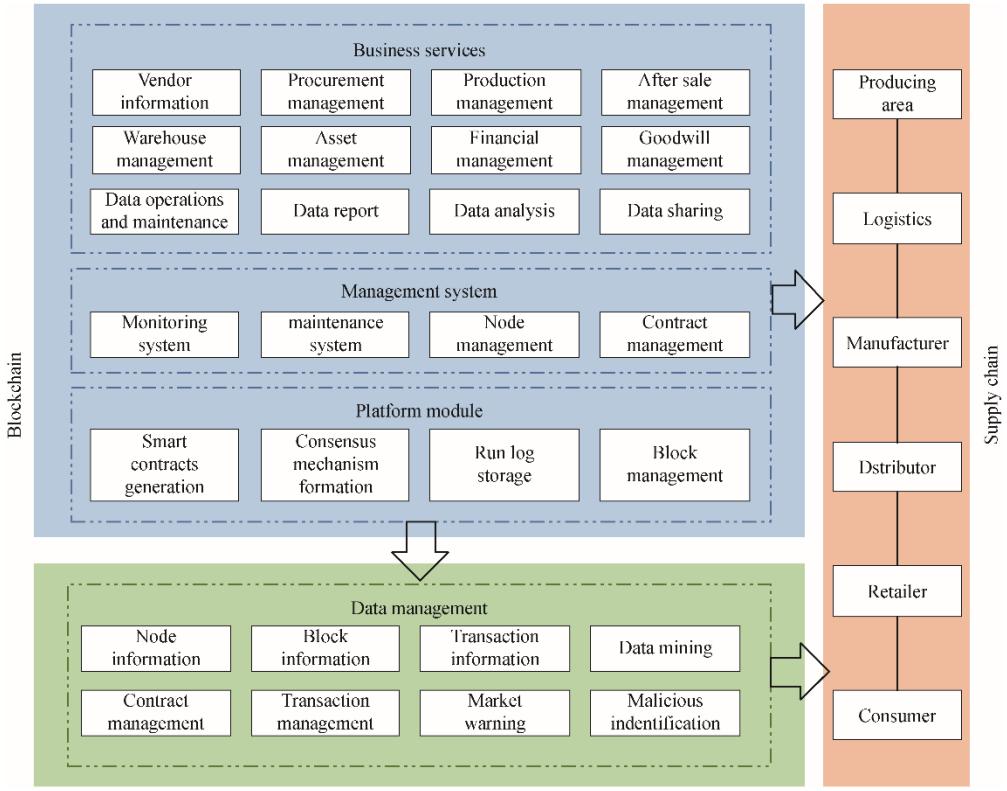

Fig. 4. New ideas for energy and mining supply chain management based on blockchain.

4 Application of new-generation information technology in energy and mining fields

Energy mining is a large and complex operation system that includes five aspects: energy production, energy transportation, energy consumption, energy market, and government supervision. The relationships among these components are shown in Fig. 5.

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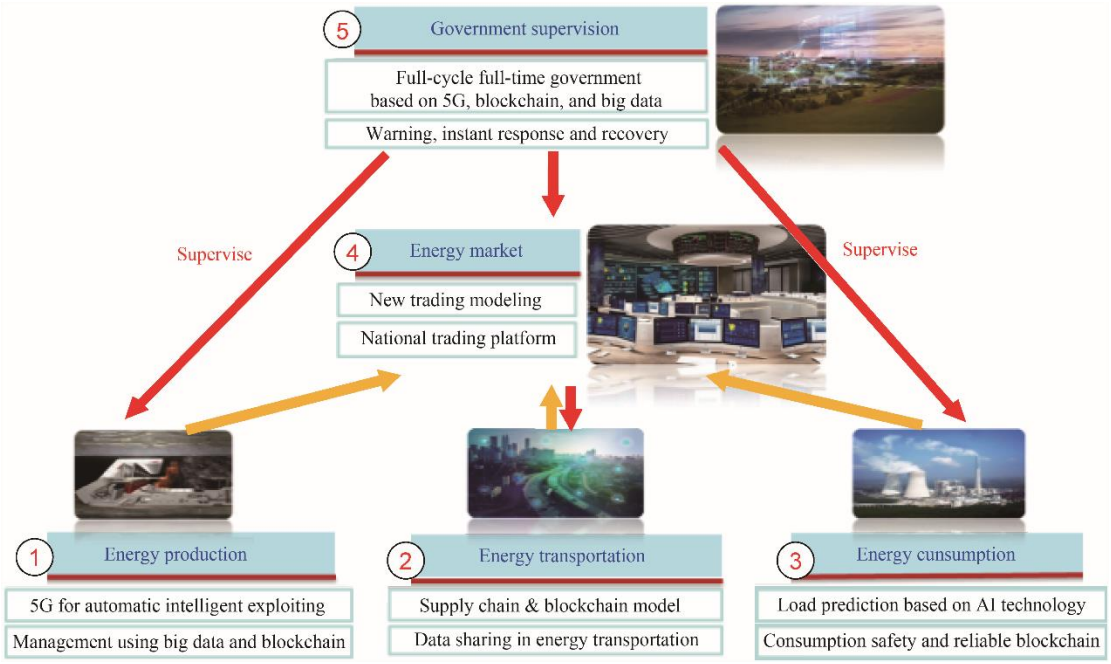

Fig. 5. Relationship among each aspect in energy and mineral industries.

4.1 New-generation information technology promotes energy and mining production

Energy production includes energy mining exploration, mining, deep processing of mineral resources, and the current emerging renewable clean energy power generation based on wind power, photovoltaics, and other stages. Among them, the main problems encountered in the mining of mineral resources are mining disasters and the absence of fully automated, intelligent, and efficient mining systems. The imperfection of monitoring and early warning mechanisms are the root causes of mining disasters. The deep processing of mineral resources is associated with problems such as high cost and difficulty in waste discharge supervision. Renewable new energy power generation is affected by wind and solar energy curtailment caused by source–load mismatch.

4.1.1 New-generation information technology can assist in the exploration of energy and mineral resources.

Geological information forms the basis for the development of mineral resources. Owing to the limitations of geological exploration and deduction technology, the requirements of geological exploration and deduction technology cannot be satisfied easily. Applying AI allows detection robots to intelligently control the detection process, thereby significantly reducing human labor. Using intelligent perception technology, various types of sensors can be used to automatically perceive detection information such as drilling and geophysical exploration. The lithology, structure, and other information of rock formations can be intelligently identified using algorithms, such as via machine learning and deep learning. Using the 5G communication network allows one to upload geological detection information in real time, use big data to perform geological deduction for the detection information, and construct a high-precision geological model, thereby providing geological information for the development of energy and mineral resources.

4.1.2 New-generation information technology supports intelligent green mining.

Restricted by the conventional management mode of mining enterprises, the informatization degree of mineral resource mining is low, and unified data interfaces, standards, and information exchange channels between systems do not exist, resulting in the formation of many “information islands,” which hinders the construction of intelligent green mines. The unique advantages of large bandwidth, low latency, and wide connection of 5G communication will provide a unified and high-quality communication network for each system of the mine, thereby effectively improving the equipment interconnection and human–computer interaction capabilities during mining and achieve an efficient and intelligent mining of mineral resources [29]. In addition, 5G-based precise real-time positioning and device-to-device IoT communication can realize precise directional mining, thereby improving the quality of mineral resource mining [30], as shown in Fig. 6.

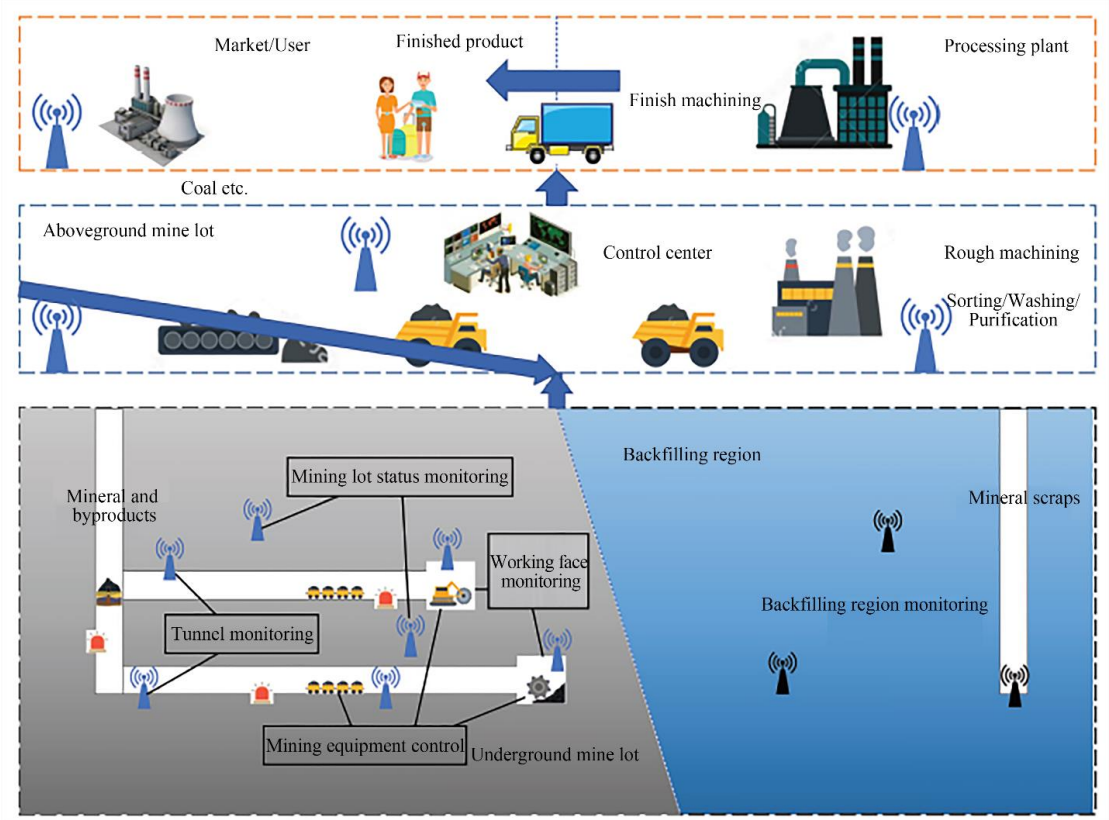

Fig. 6. Intelligent green mine based on new-generation information technology.

4.1.3 IoT, big data, and AI can improve pit safety production.

Accidents such as those associated with gases and roofs remain challenging in pit safety production [31]. The narrow and closed underground tunnel environment and dynamic movement of various types of equipment render pit safety monitoring and early warning more difficult. Using IoT and big data will effectively realize real-time, multidimensional security monitoring; additionally, through the integrated application of AI algorithms, hidden security risks can be determined from massive monitoring data, thereby providing early warning and eliminating security risks. Using digital twin and virtual reality technology to build aboveground and underground intelligent mines, as well as fully applying intelligent technology to replace manual operations with mining robots, real-time linkage and efficient collaborative automatic operations of human–machine–environment–management information can be realized.

4.1.4 Blockchain and big data technologies can facilitate environmental protection supervision and deep processing inspection of mineral resources.

Deep processing technology is an important method for improving the low-carbon and efficient utilization of mineral resources. For example, coal deep processing primarily includes washing and coking technology, gasification and liquefaction technology, coal–water slurry technology, blast furnace injection pulverized coal technology, briquette and coal blending technology, and clean coal integrated gasification combined cycle technology [32,33]. However, the conventional coal deep processing process is not environmentally friendly, resulting in significant amounts of waste liquid, waste gas, and waste residue with complex components and high treatment difficulty. Blockchain and big data technologies can facilitate environmental supervision and the deep processing inspection of mineral resources. To reduce the manpower and material cost associated with supervision and inspection, the decentralization, information sharing, and data immutability characteristics of the blockchain are utilized to ensure the openness and fairness in the entire supervision process. In addition, the application of AI in the deep processing of mineral resources will effectively improve the intelligence level of large mechanical systems, such as those for gangue collection and gangue discharge [34,35].

4.1.5 AI predicts clean energy power generation and can assist in the construction of a new power system that operates primarily on clean energy.

Distributed power generation technology, represented by wind power, photovoltaics, biomass, and other clean

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and renewable energy sources, can effectively alleviate the shortage of energy reserves, adjust the unreasonable energy structure, and achieve sustainable development goals. Wind and photovoltaic power generation are significantly affected by climatic conditions and environmental factors, as well as exhibits significant randomness, intermittency, and volatility. Regional inconsistencies are evident in the distribution of wind power, photovoltaic reserves, and energy consumption across China. The intensification of renewable energy development may result in severe wind and solar energy curtailment, which is primarily due to source–load mismatch. Meanwhile, using AI, the long- and short-term power generation of clean energy under the effects of complex factors can be predicted; consequently, source–load mutual assistance can be achieved by the power system, and a new power system operated primarily using grid-connected clean energy can be realized [36,37].

4.2 New-generation information technologies assist in energy and mining transportation

Owing to the unique characteristics of the reverse distribution of China's energy production bases and major consumer markets, the energy transportation patterns of North-to-South Coal Transportation, West-to-East Gas Transmission, and West-to-East Power Transmission in China will exist for a long period; as such, the support of an effective and efficient energy and mining transportation system will be required. The energy and mining comprehensive transportation channel system primarily includes railways, highways, shipping, oil and gas pipelines, and high-voltage level long-distance transmission networks, and its transportation efficiency significantly affects the development of the national economy. New-generation information technologies such as 5G, big data, AI, and blockchain are applied to energy and mining transportation, which will facilitate the new energy transportation pattern of delivery, loading and unloading, warehousing, distribution, and information integration.

4.2.1 Supply chain and blockchain fusion technology improves energy and mining transportation efficiency.

The vast areas in the north and west of China are energy-abundant areas, whereas the consumption areas are primarily in the economically developed eastern and southern coastal areas, which generate a significant deviation in terms of supply and demand. Additionally, the energy demand varies significantly by season. Therefore, smooth, efficient, adaptive, safe, and reliable modern energy and mining supply chain systems must be established. Blockchain will empower the supply chain and create a "supply chain–blockchain" dual-chain fusion technology system in the energy and mining fields [38], thereby effectively solving the current outstanding problem of supply–consumption time and space dislocation in China. (1) By examining the information acquisition and transmission of different parties in the upstream and downstream of energy and mining, chain data block structure and peer-to-peer network construction, as well as the distributed architecture and storage of supply chain information, new information sharing and collaboration mechanisms in energy and mining companies can be formed. (2) By standardizing the development environment and interface standards, a system autonomy, division of labor, sharing and collaboration mechanism can be developed for double-chain integration, whereas technical standards and legal guarantees can be amplified for double-chain integration. (3) By examining the dual-chain collaboration model in the energy and mining fields, a resource and capability guarantee mechanism as well as a performance improvement mechanism can be established; additionally, a logistics, information flow, and capital flow system based on the "supply chain–blockchain" double-chain integration technology can be developed.

4.2.2 5G and big data sharing technology can alleviate the high cost of energy mining transportation, warehousing, loading, and unloading.

Coal, oil, natural gas, and other energy raw materials are associated with numerous problems, such as severe transportation hazards, high storage costs, and significant losses and waste in the logistics loading and unloading processes [39]. These technologies can support the existing logistics enterprises, which are typically not equipped with timely and complete information acquisition technologies on both the supply and demand sides, do not adopt scientific transportation and warehousing management, and exhibit a low level of mechanization and intelligence in loading and unloading. Hence, an energy and mining transportation management information platform should be established through 5G, big data sharing, and blockchain to ensure the accuracy, timeliness, and traceability of information of all parties in logistics and transportation, realize collaborative optimization transmission with mandatory trust and transparency of the entire transportation process, and improve system efficiency and safety quality.

4.2.3 AI facilitates the reliable and safe operation of electricity transmission and distribution systems.

Electricity offers the advantages of fast transmission speed, low environmental pollution during transportation,

and convenient distribution and dispatch. Hence, electricity is one of the most effective modes of energy transmission over a wide range. The stable operation of a transmission system is governed by the system safety and power reliability of both power generation and power consumption, and its importance has become increasingly prominent owing to the continuous increase in the voltage level. To ensure the safe and reliable transmission of electric energy, the full information measurement, accurate fault diagnosis, and rapid management methods of transmission lines [40] must be analyzed comprehensively to accurately identify fault types, determine fault locations, and rapidly eliminate faults such that the security of interconnected large power grids and the economy of system operation can be enhanced. AI will contribute significantly to fault analysis and processing, e.g., capturing the time characteristics of multisource data from the transmission and distribution process, to predict line trip faults in transmission systems [41]. Furthermore, the advantages of AI image recognition technology can be used to combine five types of remote operations of the power system (i.e., remote metering, remote signaling, remote control, remote tuning, and remote viewing) to achieve the multistate quantity monitoring and fault diagnosis of transmission corridor lines, transformers/converters, insulators, etc. [42].

4.3 New information technology increases energy and mining consumption

Energy is vital to the development of human society—its consumption and security are key components of national security. As the world's largest energy consumer, China is developing rapidly in terms of economy. Its total consumption of energy and mineral resources has increased significantly, and its consumption patterns have become increasingly diversified. The introduction of the national strategic goals of carbon peaking and carbon neutrality implies that China's energy consumption model will undergo revolutionary changes. In the future, based on new technologies such as big data, AI, 5G, and blockchain, energy and mining consumption will migrate from the stage of total expansion to a new stage, where quality and efficiency improvement characterized by intelligence and digitization will be prioritized.

4.3.1 Analysis of energy consumption model based on new-generation information technology

Certain energy and mineral resources in China are insufficient and have a limited reserve potential. To develop the energy industry and substitute industries scientifically and efficiently, China's future energy consumption patterns must be forecasted and analyzed more accurately. Using new-generation information technologies, significant amounts of energy consumption data can be obtained, stored, and analyzed, and advanced AI algorithms can be used to analyze energy consumption data more accurately. By examining the energy consumption pattern, we can decipher the implicit energy consumption behavior to perform macro prediction and provide consumption guidance for the development of the energy consumption pattern. For example, the energy consumption management system based on a big data platform can predict the trend of factory energy consumption [43]. Meanwhile, the load detection and decomposition technology of new-generation information technologies in energy and mineral resource consumption scenarios is gradually being promoted. This not only significantly benefits the development of the energy Internet, user-interactive services, demand response support, and user energy conservation, but also serves as a basis for smart energy use and energy-saving strategies [44].

4.3.2 AI improves upgrading of energy consumption patterns

New-generation information technologies can be used to analyze personas and energy consumption behavior of users. Personas, as virtual representatives of real users, are user models based on real big data as well as the basis for mining user requirements and values for classification and precise energy marketing. The 5G intelligent measurement terminal and non-intrusive load decomposition technologies can realize the real-time and high-density data acquisition of energy users [45]. Meanwhile, AI is used to analyze the autocorrelation and intercorrelation of these energy big data to analyze the users' energy consumption habits and behaviors [46]. The energy consumption characteristics established based on this information can be used to predict energy consumption and provide a basis for the demand-side response decision.

4.3.3 Multitechnology integration promotes intelligent development of energy-consumption platforms

Based on new-generation information technologies such as big data, 5G, and AI, a multimodal linkage energy consumption service platform can be constructed. The cooperation network between different regions and corporate entities will promote energy consumption information sharing and resource exchange among mining enterprises, ports, logistics parks, and other related enterprises.

(1) The intelligent energy-consumption platform will offer the functions of energy monitoring, analysis, management, transaction, and operation. By monitoring the energy transaction status, the dynamic display of the

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consumption panorama can be realized.

(2) An intelligent energy consumption platform will provide differentiated service strategies via creating personas. Through energy consumption settlement, it can satisfy the demands of various types of energy consumption as well as provide an operational platform and data support for energy transmission, sales, and other services.

(3) The intelligent energy consumption platform will monitor the uses' energy consumption data, such as heat, electricity, water, and gas in real time, as well as use big data to analyze regional energy consumption. By monitoring and comparing the energy consumption of the overall region, various industries, and various types of users, the government can dynamically perceive the regional energy supply and demand to perform energy conservation and optimize the energy consumption structure [47].

4.4 New-generation information technologies facilitate transactions in energy and mining markets

In the market segment, discussions are primarily conducted from the perspective of trading mechanisms, trading platforms, and quantitative assessments of market risks. Among them, the conventional trading mechanism of energy and mining is primarily based on the resource allocation method involving centralized optimization and decision-making, which cannot be applied easily to trading scenarios involving a significant number of distributed new energy and new mining industries. Meanwhile, the distribution of conventional trading platforms exhibits the clear characteristics of aggregation and regionality. Consequently, problems such as regional differentiation, compartmentalization of governance, and transaction information barriers are more prominent [48]. For the quantitative assessment of market risks, cross-regional market standardization, as well as standardized supervision and evaluation methods are not available. Furthermore, many illegal arbitrage spaces and cheating behaviors are indicated, which result in the loss of the market's self-optimizing and resource allocation ability and an increase in the systemic risk of the market [49]. Therefore, the problems above must be solved using new-generation information technologies to improve market awareness and supervision capabilities, manage the challenges arising from the continuously increasing instability and uncertainty in the market, and avoid significant losses caused by major emergencies.

4.4.1 New mechanism for energy and mining transactions based on blockchain

Owing to wide access to distributed energy, transactions of distributed energy are characterized by a significant number of participants, a small single transaction, and scattered locations, all of which increase the processing difficulty, risk, and operating cost of the transaction center. Furthermore, distributed energy trading necessitates the implementation of multisectoral and multilevel subsidy policies and the assessment of consumption responsibilities. Hence, the characteristics of blockchain, such as decentralization, transparency and traceability, and easy realization of smart contracts, can be utilized to establish a new mechanism for new energy and mining transactions as well as realize the automation of transaction initiation, reporting, order contract generation, settlement, and other sections in transactions to reduce the complexity and management costs of numerous new energy transaction processes. The blockchain platform provides a transparent and traceable access mechanism and uses unique digital encryption technology to provide a durable, two-way equal, and secure access mechanism [50]. In addition, conventional transaction reviews and public account book maintenance can be delegated to a third-party agencies certified by the relevant government department, and the traceability of blockchain can be used to realize the auxiliary supervision of each transaction, rapidly and accurately identify malicious nodes or hidden violations, and maintain good order in the energy and mining trading market.

4.4.2 Cross-industry energy trading platforms based on new-generation information technologies

The global energy composition structure is transforming from a single-fossil-energy-based structure to a multi-energy structure integrating fossil energy and clean energy. Different energy sources exhibit different characteristics of mutual penetration and integration in different segments, such as production, transportation, and consumption, as well as at different levels, such as physics and information. Therefore, an open, standardized, and secure multilevel international cross-industry energy trading platform must be constructed to achieve multi-energy interoperability, information sharing in various industries, as well as unbiased and open transactions. In this regard, 5G communication can be applied to realize the agile and reliable transmission of massive ledgers, images, videos, and text data generated in the energy transaction process, as well as to realize efficient and secure data interactions among various energy supply entities (coal, mining, electricity, natural gas, oil, and other operators) and end users [51]. Additionally, advanced data mid-end technology is used to obtain and process the detailed production,

transportation, warehousing, and consumption data of market participants on a platform that transforms massive, fragmented information into high-quality data assets. In addition, AI and big data analysis algorithms are used to mine the inherent laws of data and predict market trends, price trends, and other issues to provide the underlying data foundation for upper-level businesses [52].

4.4.3 Quantitative assessment of market risk based on big data and AI

Risk assessment of the energy and mining markets refers to the quantitative assessment of risks and consequences that may arise from potential problems. This assessment allows their severity to be determined, as well as preventive strategies and defensive measures to be implemented. Because of the complexity and diversity of risks encountered by the modern energy and mining market as well as the unpredictability of the future market, the following can be implemented: (1) establish a risk early warning system for different market entities; (ii) use big data and AI to quantify various loss indicators based on data generated by different risk trading processes; and (iii) perform the digital management and control of transactions on key and high-risk entities by using the predictive function of big data and the risk identification ability of AI, thus to proactively identify and correct illegal behaviors that disrupt the market order, and realize an active, dynamic, and whole-process supervision of the market.

4.5 New-generation information technologies facilitate government regulation

Energy and mining are basic industries that significantly affect the national economy and people's livelihoods. Furthermore, they are associated with high-investment, high-pollution, and high-risk industries. Therefore, comprehensive supervision by the government is necessitated to regulate enterprise behavior, ensure production safety, sustain orderly markets, and achieve specific policy objectives. In the energy and mining governance systems, new-generation information technologies have been piloted in the regulatory fields of safety, market, and environmental protection, where good results have been achieved in strengthening government supervision, expanding the supervision range, and promoting the informatization construction of supervision platforms [53,54].

4.5.1 New-generation information technologies promote intensive development of security supervision

In the production and transportation processes of the energy and mining industries, the equipment used are scattered, and the mobility of personnel and vehicles is high. To ensure the safe production of energy and mining, many monitoring sensors, RF terminals, high-definition cameras, and lidar systems must be installed. Consequently, the significant amount of sensing data generated by the various monitoring equipment in real time can be organized and analyzed to guarantee the reliable operation of production and transportation.

The 5G technology features a new network architecture that offers at least 10 times the peak rate of 4G, transmission delays in milliseconds, and a connection capacity of 100 billion; hence, it is an important technology for improving the response ability of energy and mining safety supervision [55]. AI can improve the intelligence level of systems and mechanical actuators, as well as replace human labor to complete the supervision of complex and hazardous scenarios in the entire process of energy and mining, accurately distinguish various potential hazards, and effectively improve the perception of safe production and transportation [56,57]. The application of big data and cloud computing in diversified information assets enables regulatory systems to rapidly integrate safety regulatory data between energy regulatory departments at different levels, thereby eliminating information islands, realizing information sharing, and facilitating the management of regulatory authorities from a global perspective [58], as shown in Fig. 7.

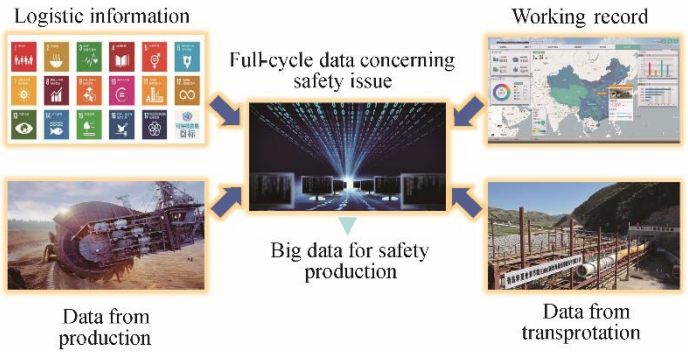

Fig. 7. Governance on production and transportation of energy and mining industries.

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4.5.2 Big data and blockchain improve regulatory capacity of energy trading market

The basic intent of reforming the energy system is to establish an energy and mining market system under the supervision of a government that separates administration from management to achieve unbiased competition, openness, orderliness, and healthy development. Strengthening the supervision of the energy and mining markets is important to promote the construction of this system. Therefore, a unified platform that allows the government to supervise the energy and mining markets must be established such that they can comprehensively and effectively supervise and restrict trading entities and energy prices. The platform can extract valuable information from the energy market supervision system via big data mining technology and monitor the effects of energy commodities and their derivatives on the financial market. Furthermore, it can aid the government in implementing the appropriate measures to avoid the manipulation or abuse of the energy market, prevent financial risks and energy price increase, and enhance the targeting and stability of energy market supervision [59]. Furthermore, blockchain can be used to improve the security of regulatory data, prevent the forgery of regulatory data, and ensure the government's supervision, review, and punishment of the transaction source [60].

4.5.3 IoT supports the effective implementation of environmental protection supervision

By integrating IoT, remote sensing imaging, and image analysis using AI, we can build an intelligent multidimensional perception system of environmental supervision to perceive environmental changes in real time during energy production, realize the real-time monitoring of the entire cycle and the full coverage of the energy production process, rapidly identify and respond to abrupt malignant events, and prevent environmental pollution during the production process of energy mining at the source.

5 New-generation information technologies support reconstruction of energy and mining governance systems

Owing to the rapid development of the national economy and the upgrading of the energy industry, conventional energy and mining systems and governance models have lagged behind the actual development of the industries and thus cannot accommodate the changes in the international political and economic arenas. New-generation information technologies will significantly enhance the monitoring, analysis, research, judgment, supervision, and governance capabilities of all segments in energy and mining systems.

By analyzing the characteristics of the entire industrial chain in the energy and mining fields, energy and mining governance systems can be reconstructed using new-generation information technologies, as follows:

(1) By forming a green energy consumption and governance system, the energy and mining consumption governance capability, energy utilization efficiency, and level of energy conservation and emission reduction can be improved.

(2) To realize the governance capability of energy and mining systems, the relevant parties must strengthen the restraint and governance of relevant aspects based on the current development status, provide a more solid foundation for their development, and provide a more favorable environment for the rational influx of international capital.

(3) The high governance capability of energy and mining technologies can promote the governance of environmental problems and global environmental pollution control. Furthermore, it promotes the systematization of the constituents of energy and mining governance systems and efficient governance.

(4) Effective energy and mining supply governance capabilities can guarantee the security of the national energy supply, as well as alleviate the adverse effect of the energy game on economic and social development.

(5) The purpose of realizing the external governance of energy and mining is to alleviate the contradiction between domestic energy supply and demand, promote the healthy development of the energy economy, and strengthen international discourse power to promote the establishment of a new national energy pattern and new order.

By improving the five governance capabilities above, we plan to develop a new model of energy and mining system governance that can comprehensively contribute to the national energy industry revolution.

6 Policy Proposal

6.1 Establishing national platforms for safe production and trading of energy and mining

The intelligent operation of the entire process of energy production and utilization can be realized by establishing a national-level intelligent platform for energy and mining safety production and incorporating

information regarding the main sources of energy production hazards, high-risk work positions, and safety production monitoring systems into the platform. Based on the "5G+ABCD" technology support, which implies the combination of 5G and new information technologies such as AI, blockchain, cloud computing, and big data, we plan to construct a four-level intelligent platform for coal production and trading at the mining company, group, provincial and national levels, as well as establish a modern energy and mining governance technology system. This will enable a comprehensive, timely, and reliable acquisition and supervision of all types of energy and mineral resource inventory information, consumption information, and transaction information. Additionally, the security of China's energy and mining resource transactions can be guarantee through barter transactions, digital currencies, and other methods.

6.2 Developing key basic theories, inadequate technologies, and equipment

It is necessary to establish specific basic research projects for the National Natural Science Foundation of China, major projects for scientific instruments, and key research and development programs. Basic theoretical research should be conducted including fusion analysis of massive multisource heterogeneous data, establishment of low-delay highly reliable communication standards for multiscenario massive large links, enhancement of weak stability and generalization ability of AI, and blockchain-based intelligent contract technology for energy mining transactions. Intelligent equipment should be included in the national intelligent manufacturing development plan, the research and application of high-end intelligent equipment and robots should be increased, and fiscal and taxation policy support should be provided.

6.3 Supporting new infrastructure and critical mineral resource reserves in energy and mining sectors

New infrastructure construction and key mineral resource reserves shall be included in the national strategic development plan. Infrastructure for 5G network deployment optimization technologies, mining data feature screening and fusion technologies, as well as blockchain for the fields of energy and mining should be further developed, and the security and management of key mineral resources should be prioritized to effectively safeguard the security of key mineral resources.

6.4 Strengthening policy support and financial guarantees

Based on the government-led, policy-driven, and enterprise-implemented principle from the national level, funds will be allocated to the energy and mining governance information platform. This will promote the top-level design and infrastructure construction of a nationally unified, sector-united, and industry-coordinated national-level intelligent platform for energy and mining safety production and trading, as well as support the intelligent transformation of information platforms of state-owned energy and mining enterprises. At the provincial level, the appropriate parties should introduce new infrastructure investment and industrial support policies for the energy and mining industries, actively pursue loans from financial institutions, increase the financing efforts of financial institutions, guide social capital to increase investment, harness the self-financing potential of enterprises, and enhance the degree of capital security for enterprises.

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