

Article

Research on the Construction of an ESG Evaluation System for Coal Enterprises from the Perspective of “New Three Modernizations”

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Abstract

During the 15th Five-Year Plan period, China’s coal industry urgently requires an ESG evaluation system that reflects its high carbon emissions, operational risks and technology-driven transformation. Existing frameworks are derived mainly from general international standards and do not fully capture these industry-specific features. Using grounded theory, this study conducted three-level coding of 45 core literature sources and 15 policy documents and extracted 12 categories. From the perspective of the “New Three Modernizations”—green transformation, intelligent transformation and integrated development—this study constructs an ESG evaluation indicator system for coal enterprises comprising three primary indicators, 12 secondary indicators and 34 tertiary indicators. The entropy weight method and the extension cloud model were then used to evaluate Group ZN from 2020 to 2024. The results show that Group ZN’s ESG performance improved from Medium (C) in 2020–2021 to Good (B) in 2022–2024. The environmental dimension remained the main constraint, whereas the social and governance dimensions improved more clearly. The proposed system integrates industry characteristics with national policy priorities and provides a practical tool for ESG diagnosis and governance improvement in coal enterprises.

Keywords: new three modernizations; coal enterprises; ESG evaluation; grounded theory; extensible cloud model

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1. Introduction

In October 2025, the Fourth Plenary Session of the 20th Central Committee of the Communist Party of China analyzed the international and domestic situation and formulated recommendations for the 15th Five-Year Plan for National Economic and Social Development. The “15th Five-Year Plan” sets out the development paths of green transformation, intelligent transformation, and integrated development. It aims to address the issue of unbalanced and inadequate development through technological innovation, transformation of development models, and coordinated development, thereby consolidating the foundation of the real economy and pointing the way forward for enterprises.

According to the China Mineral Resources Report (2024), coal accounts for 66.6% of China’s energy production structure, petroleum for 6.2%, natural gas for 6.0%, and non-

fossil energy sources such as hydropower, nuclear power, wind power, and photovoltaics for 21.2%. Coal remains the dominant energy source in China's energy consumption structure. As typical representatives of traditional industries, coal enterprises should follow the "New Three Modernizations" development path, promote the upgrading of traditional industries, and achieve high-quality development. Simultaneously, they should adhere to innovation-driven strategies, increase R&D investment and talent cultivation, and achieve innovation in both technology and management models. Coal enterprises should strengthen compliance management, meet regulatory requirements for green operations, actively participate in industrial chain collaboration, and create a safe, green, and intelligent operating environment.

ESG (Environmental, Social, and Governance) is an emerging investment philosophy and corporate evaluation standard that focuses on a company's environmental, social, and governance performance rather than solely its financial performance. It aligns highly with the development paths of "green production, intelligent construction, and coordinated development" advocated by the "New Three Modernizations." Over the past two decades, as interest in sustainable investing has grown, societal demand for non-financial information regarding ESG activities has rapidly increased [1]. KPMG's "2024 Survey of Sustainability Reporting" indicates that over 40% of large companies globally incorporate ESG performance into executive compensation. On 4 June 2024, the State-owned Assets Supervision and Administration Commission of the State Council issued the "Guiding Opinions on Central Enterprises Fulfilling Social Responsibilities with High Standards in the New Era," explicitly requiring central enterprises to fulfill ESG responsibilities with high standards and improve the quality and transparency of ESG information disclosure.

ESG has moved from a peripheral concern to a core element of corporate strategy. It is not only a reflection of corporate social responsibility but also essential for enhancing competitiveness and achieving long-term value. However, compared with mature international ESG performance evaluation systems, China's ESG system exhibits a lag, and the ESG information disclosure mechanism remains insufficiently systematized. There is also limited research that discusses the construction of an ESG governance effectiveness evaluation indicator system tailored to the high-pollution and high-energy consumption characteristics of coal enterprises. Therefore, this study, based on a comparative analysis of ESG evaluation indicators from eight major domestic and international rating agencies and considering the characteristics of ESG evaluation for coal enterprises, uses grounded theory to analyze 45 literature sources and 15 policy documents to construct an ESG evaluation indicator system for coal enterprises. Subsequently, the entropy weight method is used to determine the weights of each indicator, and an ESG comprehensive evaluation model for coal enterprises is constructed based on the extension cloud model. A major Chinese coal enterprise, Group ZN, is selected as a case study to evaluate its ESG governance effectiveness from 2020 to 2024. Finally, based on the performance of Group ZN in various ESG aspects and referencing DuPont analysis, targeted suggestions for improving Group ZN's ESG governance are proposed.

Compared with existing studies, this study makes three contributions. First, it constructs an ESG evaluation indicator system for coal enterprises in the Chinese context by integrating grounded theory with the "New Three Modernizations" perspective. This design reflects the sector's high carbon emissions, high operational risks and technology-intensive transformation needs. Second, it combines the entropy weight method with the extension cloud model, thereby preserving objective weighting while improving the treatment of fuzziness and uncertainty in ESG evaluation. Third, it applies the proposed framework to Group ZN from 2020 to 2024 and identifies practical improvement paths for green transformation, intelligent transformation and integrated development.

The remainder of this article is organized as follows: Section 2 is a literature review, systematically summarizing the research progress on ESG evaluation indicators and methods, identifying existing research gaps. Section 3 elaborates on the process of constructing the ESG evaluation indicator system for coal enterprises based on grounded theory, including data collection, three-level coding, and indicator optimization from the perspective of the “New Three Modernizations.” Section 4 takes Group ZN as a case study, using the entropy weight method to determine indicator weights and constructing an extension cloud evaluation model to empirically evaluate and analyze its ESG performance from 2020 to 2024. Section 5, based on the evaluation results, draws on the DuPont analysis framework to propose suggestions for improving ESG governance in coal enterprises from the three paths of green transformation, intelligent transformation, and integrated development. Section 6 concludes the study, outlining the main findings, limitations, and future research directions.

2. Literature Review

2.1. ESG Evaluation Indicators

The concept of ESG (Environmental, Social, and Governance) was systematically introduced in the 2004 report “Who Cares Wins” by the United Nations Global Compact [2], evolving from an extension of corporate social responsibility theory to a core element of corporate strategic management. Academic research on ESG evaluation indicators has undergone a process of evolution from constructing general frameworks to industry-specific adaptation, and from qualitative description to quantitative measurement.

At the level of international ESG evaluation frameworks, major rating agencies have established relatively mature indicator systems. MSCI’s (Morgan Stanley Capital International) ESG rating framework covers 10 themes and 37 key issues across the three dimensions of Environment, Social, and Governance, with its core innovation lying in the design logic of industry-specific indicators, achieving cross-industry comparability by identifying the most significant materiality issues for each industry [3]. Thomson Reuters’ ESG evaluation system includes over 400 company-level indicators, generating a composite score through standardization, with the system emphasizing the objectivity and verifiability of data [4]. Sustainalytics’ risk rating system focuses on material ESG issues for enterprises, placing governance issues in a fundamental position, and rating based on measuring unmanaged ESG risk exposure [5]. FTSE Russell’s ESG rating model integrates 14 secondary indicators and over 300 tertiary indicators, emphasizing alignment with the United Nations Sustainable Development Goals (SDGs) [6]. Berg et al. [7] analyzed ESG score data from six major rating agencies and found significant rating divergence among different agencies, primarily due to differences in indicator selection scope, weight setting, and measurement methods. This finding reveals the complexity of ESG evaluation and the necessity of industry-specific evaluation.

In industry-specific ESG research, the mining and coal industries have gradually become research focuses. Kurniawan and Gunawan [8], based on the International Council on Mining and Metals (ICMM) principles framework, conducted a content analysis of ESG performance in Indonesian coal and mineral companies. They found that occupational health and safety (75%), community engagement (68%), and environmental impact management (62%) were the indicators with the highest disclosure rates, while human rights issues (30%) and biodiversity conservation (28%) had relatively lower disclosure rates, revealing structural differences in ESG information disclosure among coal enterprises. Ch et al. [9] employed a mixed-method approach to identify key dimensions of ESG evaluation in coal enterprises, using Singareni Collieries Company in India as a case study. They identified carbon abatement, land reclamation, community engagement, occupational

health and safety, and board governance as core dimensions. Wang et al. [10] studied Chinese coal enterprises, constructing a sustainable development evaluation system from the ESG perspective. They found that environmental regulatory intensity has a positive moderating effect on market concentration among high-quality firms, with corporate environmental information disclosure quality playing a mediating role in this process. Fikru et al. [11] conducted a meta-analysis of ESG performance in the mining industry and found that the mine lifecycle stage is a key moderating variable influencing the importance of ESG issues, with early exploration stages focusing on community relations, while operational stages emphasize environmental management and occupational safety.

In cross-cultural comparative research on ESG evaluation in coal enterprises, Huang et al. [12] compared the ESG disclosure practices of coal enterprises in Indonesia and China, finding that the regulatory environment and investor pressure are dominant factors driving differences in disclosure levels. Baninla et al. [13] used fixed-effects models to examine the impact of ESG performance on corporate financial performance based on data from listed Chinese coal enterprises. They found a significant positive correlation between comprehensive ESG performance and return on assets (ROA), with the environmental dimension having the strongest effect, providing empirical support for the business value of ESG investment in coal enterprises. Hou et al. [14] employed grounded theory, the entropy weight method, and cloud models to construct a performance evaluation framework for coal enterprises encompassing four dimensions: Finance, Environment, Social, and Governance (FESG). Their research identified production safety, ecological restoration, and technological innovation as core elements of ESG evaluation in coal enterprises, emphasizing the crucial role of industry-specific indicators in the evaluation system.

In summary, international ESG research has formed a relatively systematic theoretical framework and methodological system, and research on ESG evaluation for coal enterprises has made progress in indicator identification. However, existing research still has the following shortcomings: First, the construction of ESG evaluation indicator systems for coal enterprises is mostly based on the adaptation of general ESG frameworks, with insufficient attention to the specific national energy transition context and the phased characteristics of the industry. Second, the indicator extraction process often relies on single-source data, lacking systematically integrated development of multi-source qualitative data (such as policy documents, industry reports, academic literature). Third, existing research rarely incorporates the dynamic requirements of industry transformation and upgrading (such as intelligent transformation and circular economy integrated development) into the ESG evaluation framework, making it difficult to fully reflect the governance needs of coal enterprises in the new development stage. These research gaps provide theoretical space for this study to construct an ESG evaluation indicator system for coal enterprises from the perspective of the “New Three Modernizations.”

2.2. ESG Evaluation Methods

The choice of ESG evaluation method directly affects the rigor and reliability of the results. Existing methods can be grouped into three main types: subjective weighting methods, objective weighting methods, and combined evaluation models.

Subjective weighting methods mainly include the Analytic Hierarchy Process (AHP), the Delphi Method, and Fuzzy Comprehensive Evaluation. The AHP proposed by Saaty [15] decomposes complex problems into a hierarchy of goals, criteria, and alternatives by constructing judgment matrices, suitable for multi-criteria decision-making scenarios. In the field of ESG evaluation, Baraibar-Diez and Odriozola [16] used AHP to evaluate the ESG performance of European utility companies, finding significant differences in stakeholder perceptions of the weights of different dimensions. Xu et al. [17] employed the

Delphi Method to integrate expert opinions, constructing a corporate sustainability evaluation framework comprising environmental innovation, social responsibility, and governance transparency. However, subjective weighting methods cannot entirely avoid the cognitive biases of decision-makers and the subjectivity of expert opinions, potentially leading to weights that deviate from objective reality [18].

Objective weighting methods are represented by the Entropy Weight Method and Principal Component Analysis (PCA). Shannon's [19] information entropy theory laid the foundation for the Entropy Weight Method, which measures the information content of an indicator based on the coefficient of variation in its data; the larger the coefficient of variation, the smaller the information entropy and the higher the indicator weight. Mao et al. [20] used the Entropy Weight Method to evaluate the ESG performance of Chinese power enterprises, finding that the environmental dimension's weight was significantly higher than those of the social and governance dimensions, reflecting the specificity of energy-intensive industries. Su et al. [21] combined the Entropy Weight Method with the TOPSIS method to construct a green innovation performance evaluation model for coal enterprises, verifying the applicability of objective weighting methods in resource-based industry evaluations. The advantage of objective weighting methods lies in eliminating subjective interference, making the weight setting entirely driven by data characteristics. However, their robustness may be affected when indicator data quality is poor or the degree of dispersion is small [22].

The development of combined evaluation models aims to balance the objectivity of the evaluation process with the interpretability of the results. Extension theory (Extenics) was proposed by Cai [23] in 2013. It uses the matter-element model to describe the quality and quantity characteristics of things and can effectively handle incompatibility issues in multi-indicator evaluation. Fülöp et al. [24] introduced extension theory into corporate environmental performance evaluation, verifying the method's advantage in handling non-linear relationships among evaluation indicators. The Cloud Model was proposed by Li et al. [25]. It uses three numerical characteristics—Expectation (Ex), Entropy (En), and Hyper-entropy (He)—to depict the randomness and fuzziness of qualitative concepts, possessing unique advantages in the conversion between qualitative and quantitative data. Zhu et al. [26] applied the cloud model to evaluate the ecological environment quality of mining areas, finding that the method effectively addresses the issue of uncertainty propagation during the evaluation process. Combining extension theory with the cloud model to form the extension cloud model compensates for the limitation of traditional matter-element extension models where the value (V) is fixed, and overcomes the strong subjective judgment of membership degrees inherent in fuzzy set theory [27]. Hu et al. [28] used the extension cloud model to assess safety risks in the mining industry, verifying the method's applicability in high-uncertainty environments. The ESG-grounded theory-entropy weight-cloud model framework constructed by Hou et al. [14] systematically described the operational path of "classifying indicator levels—standardizing indicator levels—calculating indicator-level membership—evaluating corporate performance level," providing a methodological reference for ESG evaluation in coal enterprises.

Regarding recent advancements in combined evaluation methods, machine learning approaches are gradually being introduced into the ESG evaluation field. Uddin et al. [29] used Random Forest and Gradient Boosting Tree algorithms to predict ESG rating divergence, finding that company size and industry attributes are key features for predicting rating discrepancies. Sariyer [30] applied deep learning models to evaluate the sustainable development of coal enterprises, verifying the advantages of Long Short-Term Memory (LSTM) networks in handling time-series ESG data. While these cutting-edge studies offer new directions for the evolution of ESG evaluation methods, the "black box" nature of machine learning methods limits the interpretability of their results to some extent, posing

issues in terms of applicability to the practical needs of management decision-making in coal enterprises [31].

In summary, existing research on ESG evaluation methods has formed a relatively complete methodological system covering subjective weighting, objective weighting, and combined evaluation. The extension cloud model offers unique advantages in handling uncertainty. However, current research still has the following gaps: First, the application of evaluation methods often remains at the methodological level, lacking theoretically integrated development with the construction of the indicator system. Second, case studies mostly focus on static evaluation at a single point in time, insufficiently revealing the dynamic evolution patterns of ESG performance. Third, the presentation of evaluation results is often limited to composite scores, lacking in-depth diagnosis of structural relationships between dimensions. Based on this, this study aims to integrate grounded theory coding with the extension cloud model from the perspective of the “New Three Modernizations” to construct a full-process framework for ESG evaluation in coal enterprises. Through dynamic evaluation of the ESG performance of a typical case enterprise over a five-year period, it will reveal the evolution patterns and structural characteristics of ESG governance.

3. Construction of ESG Evaluation Index System for Coal Enterprises Based on Grounded Theory

3.1. Data Collection

Following the principles of objectivity, comprehensiveness, importance, accessibility, suitability, and systematicity, this study applies grounded theory to construct an ESG evaluation indicator system for coal enterprises. The original materials were collected from three main sources: ESG rating agency indicators, relevant academic literature, and supplementary policy documents. To improve the transparency and traceability of the data collection process, explicit inclusion and exclusion criteria were applied during material screening.

3.1.1. Domestic and International ESG Rating Agency Indicators

To identify the core issues in mainstream ESG evaluation frameworks, this study systematically reviewed eight representative domestic and international ESG rating or evaluation systems. These include MSCI's three dimensions, ten themes, and 33 issues; the secondary and tertiary indicators of the Thomson Reuters evaluation system; the three modules of Sustainalytics (Morningstar), namely Corporate Governance, Material ESG Issues, and Company-Specific Issues; FTSE Russell's 14 secondary indicators and corresponding tertiary indicators; the China Securities Index ESG evaluation system with 16 secondary indicators and 44 tertiary indicators; SynTao Green Finance's three-level indicator system and industry model; the indicator system developed by the International Institute of Green Finance at the Central University of Finance and Economics based on national policy documents; and the ESG indicator system established by China Securities Index using official database resources. These evaluation frameworks provided important references for extracting the initial indicators from both qualitative and quantitative perspectives.

During the screening process, indicators closely related to coal enterprises' production and operation, environmental governance, employee responsibility, production safety, social responsibility, and corporate governance were retained. Indicators applicable mainly to industries such as finance, internet services, and consumer goods, or indicators weakly related to resource extraction, energy use, and pollutant emissions in coal

enterprises, were excluded. Through this procedure, an initial indicator pool was formed and used as one of the reference sources for open coding.

3.1.2. Relevant Literature Materials

To ensure a solid theoretical foundation for the indicator system, this study searched literature published in the past ten years using keywords such as “ESG evaluation of coal enterprises,” “high-quality development of coal enterprises,” “sustainable development of coal enterprises,” and “quality and efficiency improvement of coal enterprises.” The inclusion criteria were as follows: (1) the research topic was directly related to ESG evaluation, sustainable development, high-quality development, or green and low-carbon transformation of coal enterprises; (2) the article was published in a core journal or had relatively high academic influence; (3) the article contained extractable evaluation indicators, influencing factors, or governance dimensions; and (4) the research content reflected the characteristics of the coal industry. The exclusion criteria were as follows: (1) the research object was weakly related to coal enterprises; (2) the article only provided macro-level policy commentary without involving evaluation indicators; (3) the indicators were highly repetitive and did not provide additional conceptual information; and (4) the data sources were unclear or the research quality was relatively low.

After considering topic relevance, publication date, journal quality, and citation influence, 45 articles were selected as the literature basis for grounded theory analysis. Among them, 42 articles were used for open coding, while the remaining three articles were used for theoretical saturation testing.

3.1.3. Supplementary Policy Documents

To reflect policy orientation and the characteristics of the coal industry, this study also collected policy documents and disclosure guidelines related to ESG information disclosure, green and low-carbon transformation, clean and efficient utilization, corporate social responsibility, and sustainable development. These include the “Content and Format Guidelines for Information Disclosure by Companies Offering Securities to the Public No. 2—Content and Format of Annual Reports” issued by the China Securities Regulatory Commission, the “China Corporate Social Responsibility Reporting Guide (CASS-ESG 5.0)” issued by the Chinese Academy of Social Sciences, the “Guidelines for Sustainability Reporting by Listed Companies (Trial Implementation)” issued by the Shenzhen Stock Exchange, and the “Environmental, Social and Governance Reporting Guide” issued by the Hong Kong Stock Exchange.

Meanwhile, to highlight the industrial attributes of coal enterprises, this study selected 15 representative policy documents issued in recent years as supplementary materials for grounded theory analysis, including the “Evaluation Indicator System for Cleaner Production in the Coal Mining and Washing Industry,” the “Opinions on Strengthening the Clean and Efficient Utilization of Coal,” and the “Opinions on Improving the Systems, Mechanisms, and Policy Measures for Green and Low-Carbon Energy Transformation.” The inclusion criteria for policy documents were as follows: (1) the document was directly related to green and low-carbon transformation, clean production, resource recycling, production safety, or social responsibility of coal enterprises; (2) the document was issued by national ministries, stock exchanges, or authoritative research institutions; and (3) the document could provide policy support for the setting of ESG indicators for coal enterprises. Documents with a low policy level, weak relevance to the coal industry, or high overlap with selected documents were excluded from the coding process.

3.2. Grounded Theory Coding

3.2.1. Open Coding

NVivo 11 was used to organize and code the original materials, which improved the efficiency and traceability of data processing. The grounded theory coding process included three stages: open coding, axial coding, and selective coding. To standardize the coding process, the literature materials and policy documents were coded separately. Literature materials were coded as W_n, where n represents the literature number, and policy documents were coded as Z_n, where n represents the policy document number. For example, W1 refers to the first article, and Z1 refers to the first policy document.

Open coding is the process of analyzing original materials sentence by sentence and paragraph by paragraph to extract initial concepts. In this study, 42 articles and 15 policy documents were first open-coded. Keywords, indicator expressions, and governance issues related to ESG evaluation of coal enterprises were identified from the original texts, and similar concepts were summarized through constant comparison. A total of 553 initial coding statements were obtained, from which 84 initial concepts were further extracted. Examples of open coding are shown in Table 1.

Table 1. Example of open coding for ESG indicators.

Sources of Original Materials (Selected Examples)	Conceptualization	Category
W1: unit coal consumption and unit energy consumption; W13: improving the comprehensive conservation and utilization of mineral resources; W24: the raw coal production energy consumption of large coal enterprises decreased from 17.1 kg tce/t to 9.7 kg tce/t; W25: energy input measured by the total energy consumption of the enterprise in the current year; W26: comprehensive energy consumption per 10,000 yuan of output value	Comprehensive energy consumption per 10,000 yuan of output value; energy consumption; energy consumption per unit output value	Energy consumption intensity
W20: total water consumption; W34: water consumption per unit mining output value (m ³ /10,000 yuan); W39: water consumption per 10,000 yuan of industrial added value; Z1: basic information on water resource use, including but not limited to total water consumption measured in tons and water use intensity, such as per unit of output; Z14: cumulative reduction in water consumption per unit of GDP by 28%	Water consumption in raw coal production; water resource use; water consumption per unit mining output value	Water consumption intensity
W5: reducing greenhouse gas emissions; W32: greenhouse gas emissions from the coal industry account for more than 40% of the national total; Z1: reporting entities should disclose Scope 1 and Scope 2 greenhouse gas emissions	Greenhouse gas emissions; greenhouse gas emission reductions	Greenhouse gas emissions
W15: sulfur dioxide emission performance; W17: sulfur dioxide emissions; W34: SO ₂ emissions per unit mining output value (kg/10,000 yuan); W40: combustion of 1 ton of coal produces 16 kg of sulfur dioxide; Z2: exhaust gas emissions include nitrogen oxides and sulfur oxides; Z5: emission intensity of major pollutants in key industries should be reduced by more than 20%	SO ₂ emissions per unit output value; exhaust gas emissions; pollutant emissions; SO ₂ generation per unit output value	SO ₂ emission intensity
W25: “pollutant emissions,” such as NO _x , are included as outputs; W39: nitrogen oxide emission rate; Z2: exhaust gas emissions include nitrogen oxides and sulfur oxides; Z6: nitrogen oxides should be reduced by more than 10% compared with 2020	NO _x emissions per unit output value; exhaust gas emissions; pollutant emissions; NO _x generation per unit output value	NO _x emission intensity
W1: wastewater discharge; W3: wastewater discharge; W16: zero wastewater discharge technology; W24: chemical wastewater management	Wastewater discharge; wastewater management	Wastewater discharge intensity
W15: mine water utilization rate; W16: resource utilization of coal mine water; W21: water resource utilization; W24: comprehensive mine water utilization rate increased from 62.0% to 79.3%; W32: comprehensive mine water utilization rates were 79.0%; Z3: improving resource utilization efficiency	Comprehensive resource utilization rate; resource utilization of mine water; mine water utilization rate	Mine water utilization rate

3.2.2. Axial Coding

Axial coding, also known as relational coding, involves comparing and analyzing the conceptual sub-categories formed during open coding to clarify their conceptual meanings, thereby identifying logical relationships and revealing the associations between different text segments in the source data. Through continuous comparison, classification, and integrated development of categories, more abstract main categories can be gradually extracted, while simultaneously revealing the structural relationships between the main categories and sub-categories.

Focusing on the research theme of ESG in coal enterprises, the 31 sub-categories obtained from open coding were compared to examine their associations. The main categories were refined, resulting in 12 main categories, as shown in Table 2. These include Resource Consumption, Emissions, Resource Utilization Rate, Environmental Protection, Employee Responsibility, Production Safety, Social Responsibility, Market Responsibility, Governance Structure, Governance Decision-Making, Governance Construction, and Technological Innovation.

Table 2. Main axis code.

Main Category	Corresponding Sub-Categories
Resource Consumption	Resource Consumption Intensity Water Consumption Intensity
Emissions	Greenhouse Gas Emission Reduction SO ₂ Emission Intensity NO _x Emission Intensity
Resource Utilization Rate	Mine Water Utilization Rate Coal Gangue Utilization Rate
Environmental Protection	Environmental Investment Intensity Clean Energy Use Ecological Restoration Area
Employee Responsibility	Employee Diversity Employee Turnover Rate Employee Training
Production Safety	Occupational Health Investment Intensity Safety Production Investment Intensity Intelligent Construction
Social Responsibility	Tax Contribution Ratio Donation Investment Intensity
Market Responsibility	Rural Revitalization Investment Intensity Customer Satisfaction Supplier Management
Governance Structure	Independent Directors Board Diversity
Governance Decision-Making	Number of Board Meetings Held Number of Information Disclosure Documents Party Organization Construction
Governance Construction	Anti-bribery and Anti-corruption Construction Risk Management System
Technological Innovation	R&D Investment Intensity R&D Personnel Ratio Number of Patents Obtained

3.2.3. Selective Coding

Selective coding builds on axial coding and analyzes the logical relationships among the main categories to extract a core category that comprehensively summarizes all main

categories. The core category and main categories are then linked along these relationships to develop an integrated explanation. Focusing on the 12 main categories—Resource Consumption, Emissions, Resource Utilization Rate, Environmental Protection, Employee Responsibility, Production Safety, Social Responsibility, Market Responsibility, Governance Structure, Governance Decision-Making, Governance Construction, and Technological Innovation—this study identified “Coal Enterprise ESG Evaluation” as the core category.

After reviewing the textual data and the coding process, the results still conformed to the above structural framework, and no new concepts or categories emerged. Therefore, the grounded theory analysis results are considered to pass the saturation test.

3.3. Analysis of Coal Enterprise ESG Evaluation Indicators from the Perspective of the “New Three Modernizations”

The 20th National Congress of the Communist Party of China, focusing on building a modern industrial system, clearly identified green transformation, intelligent transformation, and integrated development as the core directions for high-quality development of the real economy during the “15th Five-Year Plan” period. As a typical representative of traditional industries undergoing upgrading and transformation, the coal industry urgently needs to be guided by these “New Three Modernizations” to reshape its competitiveness. In this context, green transformation is the cornerstone of sustainable development, requiring enterprises to deepen environmental management and low-carbon transformation throughout the entire lifecycle; intelligent transformation is the driving force, leveraging technologies like big data and artificial intelligence to achieve precise production decision-making and agile risk response; integrated development is the key path, encompassing vertical integrated development within the coal-electricity-chemical industry chain and horizontal innovation of “eco + business” models. The organic coupling of these three elements forms the foundation for the sustainable development of coal enterprises. Given the high alignment between ESG principles and the connotations of the “New Three Modernizations,” this study uses this as an innovative perspective to construct an ESG evaluation indicator system tailored to the characteristics of the coal industry.

3.3.1. Theoretical Logic of the “New Three Modernizations” and ESG

Green transformation, intelligent transformation, and integrated development are key directions for the construction of a modern industrial system and provide policy guidance and an analytical lens for the transformation and upgrading of traditional industries, as shown in Figure 1. For coal enterprises, green transformation emphasizes low-carbon transformation, resource conservation, and ecological restoration, and is closely associated with the environmental dimension of ESG. Intelligent Transformation emphasizes the enabling role of digital technologies, intelligent equipment, and information systems in production safety, operational management, and governance decision-making, and is closely related to production safety in the social dimension and technological innovation in the governance dimension. Integrated Development emphasizes industrial chain extension, circular economy construction, and cross-sectoral coordinated development, thereby reflecting the capability of coal enterprises in resource recycling, ecological value transformation, and sustainable business model innovation.

Therefore, this study uses the “New Three Modernizations” as a supplementary theoretical lens and indicator refinement framework for constructing the ESG evaluation indicator system for coal enterprises. First, grounded theory coding extracts general ESG evaluation indicators from rating frameworks, academic literature, and policy documents. Second, the “New Three Modernizations” perspective is used to examine and refine

whether the preliminary indicators adequately reflect the characteristics of coal enterprises in green and low-carbon transformation, intelligent upgrading, and industrial integrated development. Based on this logic, the preliminary indicator system obtained through grounded theory is further analyzed from the perspectives of intelligent transformation, green transformation, and integrated development.

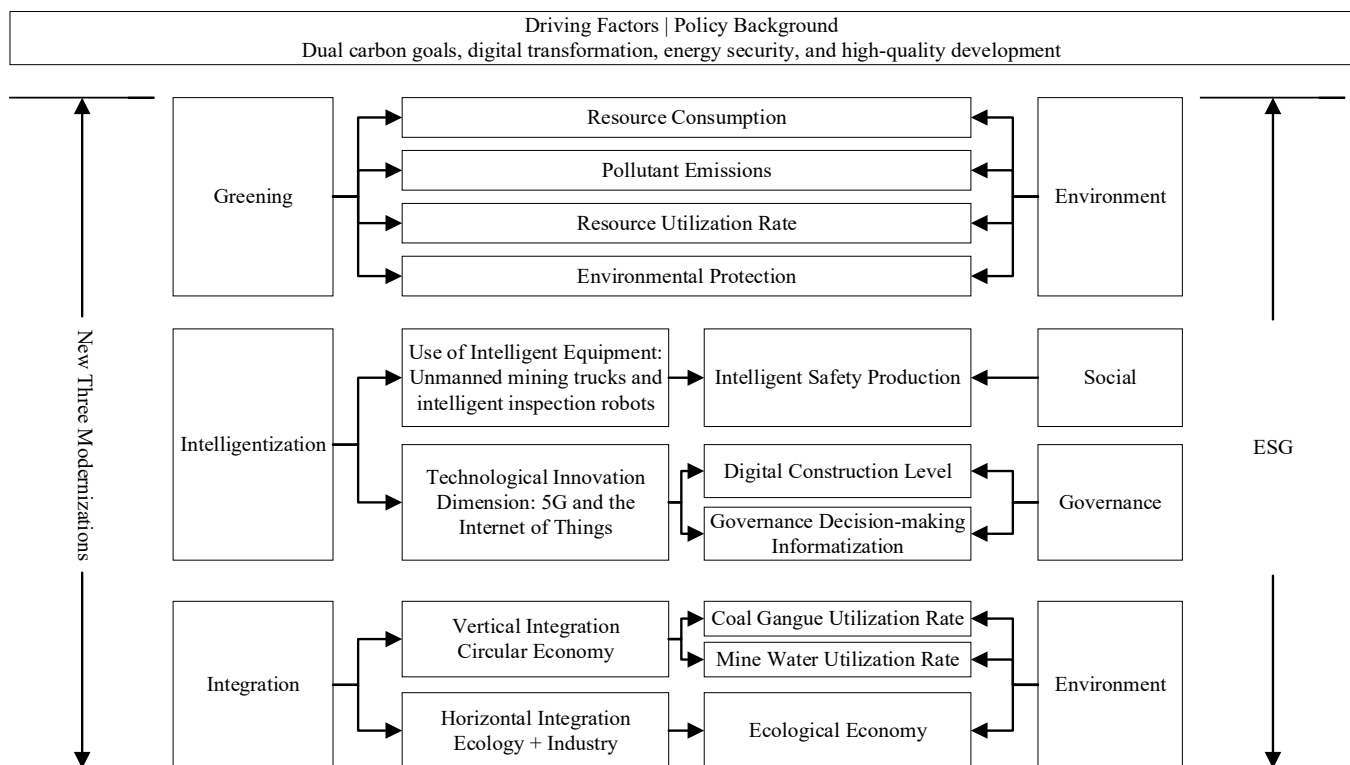


Figure 1. The relationship between the New Three Modernizations and ESG.

3.3.2. Intelligent Transformation

Intelligent Transformation is an important driving force for coal enterprises to improve production safety, operational efficiency, and governance capacity. Its core meaning is not limited to mechanization or automation in production, but involves embedding digital technologies such as big data, cloud computing, 5G, artificial intelligence, and the Internet of Things into the whole process of production, management, and decision-making, thereby improving risk identification, production control, and resource allocation.

Based on grounded theory coding, the preliminary qualitative indicator “intelligent construction” was obtained to measure whether coal enterprises have carried out intelligent development. This includes intelligent operation practices such as facial recognition, Beidou positioning, and three-dimensional modeling, as well as intelligent engineering management practices such as AI visual inspection, remote control, intelligent inspection, and intelligent fault identification. After expert discussion, “intelligent construction” was further divided into two tertiary indicators: “intelligent equipment usage” and “digital construction level.” Specifically, “intelligent equipment usage” reflects the application of unmanned mining trucks, intelligent inspection robots, and intelligent monitoring equipment in production safety, and is incorporated into the production safety indicator under the social dimension. “Digital construction level” reflects the application of 5G, the Internet of Things, data platforms, and information management systems in enterprise operation and management, and is incorporated into the technological innovation indicator under the governance dimension. Through this refinement, the intelligent transformation perspective is embedded into the ESG indicator system to reflect the supporting role of

digital technologies in improving production safety and governance capacity in coal enterprises.

3.3.3. Green Transformation

Green Transformation is the foundation of sustainable development for coal enterprises. It emphasizes reducing resource consumption and environmental impacts throughout resource extraction, transportation, processing, utilization, and ecological restoration. Coal enterprises are characterized by strong resource dependence, high energy consumption intensity, significant pollutant emission pressure, and heavy ecological restoration responsibilities. Therefore, green transformation is highly consistent with the environmental dimension of ESG.

Based on the grounded theory coding results, this study considers that the four secondary indicators in the environmental dimension—resource consumption, emissions, resource utilization, and environmental protection—can comprehensively reflect the main contents of green transformation in coal enterprises. Resource consumption reflects the enterprise's performance in energy and water conservation. Emissions reflect the enterprise's performance in greenhouse gas, exhaust gas, and wastewater control. Resource utilization reflects the recycling level of mine water, coal gangue, and other resources. Environmental protection reflects the enterprise's performance in ecological restoration, clean energy use, and ecological economy development. Therefore, from the green transformation perspective, this study does not add a separate indicator; instead, green transformation is used as an important basis for setting and interpreting the environmental indicators, thereby strengthening the ability of the indicator system to reflect low-carbon transformation, efficient resource utilization, and ecological governance performance in coal enterprises.

3.3.4. Integrated Development

Integrated Development is an important path for coal enterprises to move beyond the traditional single mining model and achieve industrial chain extension and value transformation. For coal enterprises, integrated development mainly includes vertical industrial chain integrated development and horizontal business integrated development.

Vertical industrial chain integrated development emphasizes breaking the single business model of coal mining and sales, and promoting coordinated development among coal mining, coal power conversion, solid waste resource utilization, new energy, new materials, and high-value product research and development. For example, the coal gangue utilization rate and mine water utilization rate not only reflect the resource utilization efficiency of enterprises, but also represent the effectiveness of waste resource utilization and water reuse in the circular economy industrial chain. Therefore, this study uses the coal gangue utilization rate and mine water utilization rate as important indicators for evaluating vertical integrated development and circular economy development in coal enterprises.

Horizontal business integrated development emphasizes the expansion of diversified industrial forms based on ecological restoration, thereby promoting coordination among mining area governance, ecological protection, and industrial development. For example, coal enterprises can develop photovoltaic power generation, ecological agriculture, fruit tree planting, cultural tourism, and study tour projects based on coal mining subsidence area governance and reclaimed land use, thereby promoting the integrated development of "ecology + industry." Based on this, this study incorporates "ecological economy" into the indicator system to measure the practical effectiveness of coal enterprises in horizontal industrial integrated development, ecological value transformation, and sustainable development model innovation.

3.4. Coal Enterprise ESG Evaluation Indicator System

This study constructs an ESG evaluation indicator system for coal enterprises by integrating grounded theory and the “New Three Modernizations” perspective. First, based on multi-source materials, including authoritative domestic and international ESG rating frameworks, core journal literature, and coal industry-related policy documents, grounded theory was used to conduct open coding, axial coding, and selective coding. Through this process, the core categories and preliminary indicators for ESG evaluation of coal enterprises were extracted. Second, the perspectives of green transformation, intelligent transformation, and integrated development were introduced to test and refine the industry adaptability of the preliminary indicators. Green Transformation mainly corresponds to indicators in the environmental dimension, including resource consumption, pollutant emissions, resource utilization, and environmental protection. Intelligent Transformation mainly supplements indicators related to intelligent equipment usage and digital construction in production safety and technological innovation. Integrated Development mainly strengthens indicators reflecting circular economy and industrial integrated development, such as mine water utilization rate, coal gangue utilization rate, and ecological economy. Finally, the indicator system was screened and optimized according to indicator importance, data availability, and quantification requirements.

Through the above procedures, this study finally developed an ESG evaluation indicator system for coal enterprises consisting of three primary indicators, 12 secondary indicators, and 34 tertiary indicators. The primary indicators include Environment, Social, and Governance. The secondary indicators include resource consumption, emissions, resource utilization, environmental protection, employee responsibility, production safety, social responsibility, market responsibility, governance structure, governance decision-making, governance construction, and technological innovation. The explanations and quantification methods of the indicators are shown in Table 3.

Table 3. Final result table of ESG evaluation indicators.

Primary Indicator	Secondary Indicator	Tertiary Indicator	Unit	Attribute
Environment (E)	E1 Resource Consumption	Energy Consumption Intensity	tce/million CNY	–
		Water Consumption Intensity	ton/10,000 CNY	–
	E2 Emission	Greenhouse Gas Emission Intensity	ton/10,000 CNY	–
		SO ₂ Emission Intensity	ton/100 million CNY	–
		NO _x Emission Intensity	ton/100 million CNY	–
		Wastewater Discharge Intensity	ton/10,000 CNY	–
	E3 Resource Utilization Rate	Mine Water Utilization Rate	%	+
		Coal Gangue Utilization Rate	%	+
	E4 Environmental Protection	Environmental Investment Intensity	%	+
		Clean Energy Use	Qualitative	+
		Ecological Restoration Area	km ²	+
		Ecological Economy	Qualitative	+
Social (S)	S1 Employee Responsibility	Proportion of Female Employees	%	+
		Employee Turnover Rate	Qualitative	–
		Employee Training Coverage Rate	%	+
		Occupational Health Investment Intensity	%	+
	S2 Production Safety	Safety Production Investment Intensity	%	+
		Intelligent Equipment Usage	Qualitative	+
	S3 Social Responsibility	Tax Contribution Ratio	%	+
		Social Donation Investment Intensity	%	+
		Rural Revitalization Investment Intensity	%	+
	S4 Market Responsibility	Customer Satisfaction	%	+

Governance (G)	G1 Governance Structure	Supplier Management	Qualitative	+
		Board Independence	%	+
		Board Diversity	%	+
	G2 Governance Decision-Making	Number of Board Meetings Held	Times	+
		Number of Information Disclosure Documents	Count	+
	G3 Governance Construction	Party Organization Construction	Qualitative	+
		Anti-bribery and Anti-corruption Construction	Qualitative	+
		Risk Management System	Qualitative	+
	G4 Technological Innovation	R&D Investment Intensity	%	+
		R&D Personnel Ratio	%	+
		Number of Patents Obtained	Count	+
		Digital Construction Level	Qualitative	+

4. Empirical Study of ESG Evaluation in Group ZN

4.1. Sample Selection and Data Sources

This study selects Group ZN as the subject of the empirical study. Group ZN is a comprehensive energy enterprise primarily engaged in coal mining and circular economy industries. Its business structure, resource utilization pattern, and environmental governance pressure are highly representative of coal enterprises. The evaluation is based on ESG-related data of Group ZN over five consecutive years from 2020 to 2024. The data are mainly obtained from the group's publicly disclosed annual reports, corporate social responsibility reports, and internal management information. Publicly disclosed documents are used to ensure the traceability and verifiability of the data, while internal information is used mainly for supplementary verification of selected indicators.

It should be noted that the ESG evaluation indicator system constructed in this study includes both quantitative and qualitative indicators. For quantitative indicators with directly available numerical data, standardized processing is conducted based on the original values. For qualitative indicators that are difficult to measure directly but can reflect the company's management practices and fulfillment of responsibilities through textual disclosure, this study refers to the graded scoring approach commonly used in ESG disclosure assessment, corporate social responsibility report content analysis, and sustainability disclosure index studies. The scoring is based on the degree and quality of information disclosure. Existing sustainability reporting frameworks and ESG data evaluation methods generally emphasize the completeness, comparability, and verifiability of publicly disclosed corporate information. Quantitative information usually provides stronger evidence than purely qualitative descriptions. Therefore, this study adopts a three-level scoring method based on "no disclosure–qualitative disclosure–combined qualitative and quantitative disclosure" to reduce the influence of purely subjective judgment on the evaluation results.

The specific scoring rules are as follows. First, if the company's annual report, corporate social responsibility report, or other documents provide both qualitative descriptions and quantitative data for a given indicator, indicating that the company discloses not only relevant management practices but also verifiable performance results, a score of 2 is assigned. Second, if the documents provide only qualitative descriptions of the indicator without specific data support, indicating that the company discloses relevant actions or management directions but with relatively limited completeness and verifiability, a score of 1 is assigned. Third, if the documents do not mention the indicator at all, the indicator is regarded as lacking a public disclosure basis for that year, and a score of 0 is assigned.

Taking the indicator of "ecological economy" as an example, if Group ZN's corporate social responsibility report states that "the ecological agricultural park achieved operating

revenue of XX million yuan and received XX tourists,” thereby providing both qualitative descriptions and quantitative results, the indicator is assigned a score of 2. If the report only states that the company “actively develops ecological agriculture and ecological tourism” without providing specific data such as revenue, number of tourists, or project scale, the indicator is assigned a score of 1. If the report contains no information related to ecological agriculture, ecological tourism, or other ecological economy activities, the indicator is assigned a score of 0. Through this rule, qualitative indicators are transformed into comparable ordinal variables, which improves the transparency and reproducibility of the evaluation process while maintaining the operability of the indicator system.

4.2. Determination of Indicator Weights

This study uses the entropy weight method to determine the weights of the evaluation indicators. Common weighting methods include subjective weighting methods, such as the analytic hierarchy process (AHP), and objective weighting methods, such as the entropy weight method and the CRITIC method. AHP can reflect expert judgments regarding the relative importance of indicators. However, it requires pairwise comparisons among indicators, and when the number of indicators is large, the scoring process becomes complicated and the results may be affected by subjective judgment and differences in expert composition. Since the ESG evaluation system constructed in this study contains multiple hierarchical levels and a relatively large number of tertiary indicators, relying entirely on expert scoring may increase subjectivity and operational difficulty in the weighting process. Therefore, the entropy weight method is adopted to improve the objectivity and reproducibility of weight determination.

The entropy weight method is based on the principle of information entropy and measures the amount of information provided by an indicator according to the dispersion of its data. In general, the greater the variation in an indicator across evaluated objects or evaluation periods, the smaller its information entropy, indicating that the indicator contains more information and should be assigned a higher weight. Conversely, when an indicator shows limited variation, its information entropy is larger, indicating that it provides less information and should receive a lower weight. Compared with subjective weighting methods, the entropy weight method does not rely on direct expert scoring of indicator importance; instead, it determines weights according to the variation characteristics of the data itself, thereby reducing subjective bias to some extent.

It should be noted that the empirical analysis in this study is based on five consecutive years of data for Group ZN from 2020 to 2024. Therefore, the weights obtained in this study are mainly used for longitudinal comparison and governance diagnosis within the sample enterprise, rather than for establishing fixed industry-wide weights applicable to all coal enterprises. For a single enterprise, continuous five-year data can reflect dynamic changes in environmental governance, production safety, social responsibility, governance construction, and technological innovation. If an indicator fluctuates substantially over the five-year period, it suggests that the company’s governance performance in this area is relatively unstable and that the indicator is more sensitive to the overall ESG evaluation result. If an indicator remains relatively stable, its explanatory power for annual differences in ESG performance is comparatively limited. Therefore, using temporal dispersion to determine indicator weights is consistent with the research objective of identifying the key fluctuating factors and improvement priorities in Group ZN’s ESG governance.

In terms of data quality, the five-year indicator data used in this study were obtained from Group ZN’s publicly disclosed annual reports, social responsibility reports, sustainability reports, and relevant internal materials. The data sources are relatively consistent,

the statistical standards are generally comparable, and no obvious missing values or abnormal jumps are observed. These conditions provide the necessary basis for data completeness and comparability in entropy weight calculation. For these reasons, this study adopts the entropy weight method to determine indicator weights, and the resulting weights are interpreted as the relative contributions of different indicators to ESG performance variation within Group ZN during the study period, rather than as universal weights for the coal industry. The calculation steps of the entropy weight method are as follows:

- (1) Construct the original matrix. Data can be collected based on different time periods or objects to form an original matrix with m rows and n columns. (For this study, n represents the number of years, and m represents the number of indicators.)

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

- (2) Perform dimensionless processing on the data. To enhance data comparability and eliminate the impact of differences in data magnitude and units, it is necessary to standardize positive and negative indicators separately, ultimately obtaining the standard matrix $R = [r_{ij}]_{m \times n}$.

For positive indicators:

$$r_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (2)$$

For negative indicators:

$$r_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (3)$$

- (3) Calculate the weight of each indicator. Determine the proportion of the i -th indicator in the sum of all indicators for a given year.

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^m r_{ij}} \quad (4)$$

- (4) Calculate the entropy value e_j and the coefficient of variation g_j for the j -th indicator. Here, $k = \frac{1}{\ln(m)}$. A larger coefficient of variation g_j indicates smaller information entropy, meaning the indicator provides more information and should be assigned a larger weight.

$$e_j = -k \sum_{i=1}^m p_{ij} \ln(p_{ij}) \quad (5)$$

$$g_j = 1 - e_j \quad (6)$$

- (5) Calculate the weight w_j .

$$w_j = \frac{g_j}{\sum_{j=1}^n g_j} \quad (7)$$

The weights of the ESG evaluation indicators for Group ZN determined by the entropy weight method are shown in Table 4.

Table 4. Weights of each index by entropy weight method.

Primary Indicator	Weight	Secondary Indicator	Weight	Tertiary Indicator	Weight
Environment (E)	34.65%	E1 Resource Consumption	3.97%	E11 Energy Consumption Intensity	2.31%
				E12 Water Consumption Intensity	1.66%
		E2 Emissions	9.22%	E21 GHG Emission Intensity	3.62%
				E22 SO ₂ Emission Intensity	1.78%
				E23 NO _x Emission Intensity	1.85%
				E24 Wastewater Discharge Intensity	1.98%
		E3 Resource Utilization Rate	6.62%	E31 Mine Water Utilization Rate	4.26%
				E32 Coal Gangue Utilization Rate	2.36%
		E4 Environmental Protection	14.84%	E41 Environmental Investment Intensity	4.30%
				E42 Clean Energy Use	3.77%
				E43 Ecological Restoration Area	5.12%
				E44 Ecological Economy	1.65%
Social (S)	30.67%	S1 Employee Responsibility	13.12%	S11 Proportion of Female Employees	2.53%
				S12 Employee Turnover Rate	2.53%
				S13 Employee Training Coverage Rate	5.96%
				S14 Occupational Health Investment Intensity	2.09%
		S2 Production Safety	4.26%	S22 Safety Production Investment Intensity	2.61%
				S23 Intelligent Equipment Usage	1.65%
				S31 Tax Contribution Ratio	3.16%
		S3 Social Responsibility	7.85%	S32 Social Donation Investment Intensity	2.20%
				S33 Rural Revitalization Investment Intensity	2.48%
		S4 Market Responsibility	5.45%	S41 Customer Satisfaction	1.68%
				S42 Supplier Management	3.77%
Governance (G)	34.68%	G1 Governance Structure	6.69%	G11 Board Independence	4.26%
				G12 Board Diversity	2.44%
		G2 Governance Decision-Making	4.80%	G21 Number of Board Meetings Held	2.93%
				G22 Number of Info Disclosure Documents	1.87%
		G3 Governance Construction	12.18%	G31 Party Organization Construction	1.65%
				G32 Anti-bribery and Anti-corruption	3.77%
				G33 Risk Management System	6.76%
		G4 Technological Innovation	11.01%	G41 R&D Investment Intensity	1.97%
				G42 R&D Personnel Ratio	2.43%
				G43 Number of Patents Obtained	2.83%
				G44 Digital Construction Level	3.77%

From the perspective of the “New Three Modernizations” and the operational characteristics of coal enterprises, the weighting structure of this indicator system exhibits significant industry adaptability and practical rationality. First, at the primary indicator level, the weights of the three dimensions are balanced (E: 34.65%, S: 30.67%, G: 34.68%), reflecting the synergistic requirements of multiple operational objectives for coal enterprises. The coal industry, acting as the “ballast stone” for national energy security, faces the rigid constraints of carbon peaking and carbon neutrality while also bearing the social responsibility of ensuring stable supply and prices, all during a critical period of modern enterprise system construction. The balanced weight design avoids excessive dominance by a single dimension, aligning with the operational reality of coal enterprises needing to coordinate economic, social, and environmental benefits during the challenging energy transition period.

Second, at the secondary indicator level, the environmental dimension (E) focuses on end-of-pipe treatment and circular utilization, deeply aligning with green transformation imperatives and industry-specific pain points. The top three indicators by weight are Ecological Restoration Area (5.12%), Environmental Investment Intensity (4.30%), and Mine Water Utilization Rate (4.26%), reflecting historical legacies such as land subsidence and

water resource destruction caused by coal mining. The high weight of “Ecological Restoration” embodies the rigid constraint of green transformation on “end-of-pipe management,” while “Mine Water Utilization Rate” and “Coal Gangue Utilization Rate” (2.36%) reflect the resource utilization requirements under the circular economy paradigm, aligning with the green transformation concept of whole-process resource management.

The governance dimension (G) highlights risk prevention and innovation drive, meeting the demands of intelligent transformation and integrated development. The highest-weighted indicators are Risk Management System (6.76%), Digital Construction Level (3.77%), and R&D Investment Intensity (1.97%). The combined weight of technological innovation indicators reaches 11.01%. This reveals two core propositions for coal enterprise management: first, the need for refined risk control driven by high-risk operating environments; second, the reliance on technological empowerment for intelligent mine construction. Furthermore, the inclusion of Party Organization Construction (1.65%) as a distinctive indicator reflects the practical requirement for state-owned coal enterprises to integrate Party leadership with corporate governance.

The social dimension (S) emphasizes human capital upgrading and industrial chain coordination, fully reflecting the orientation towards intelligent transformation and integrated development. Employee Training Coverage Rate (5.96%) holds the highest weight, as the coal industry is at a critical juncture transitioning from labor-intensive to technology-intensive, demanding higher skill levels from its workforce. The weights assigned to Supplier Management (3.77%) and Rural Revitalization Investment (2.48%) reflect the social responsibility practice of coal enterprises leveraging their industrial advantages to drive local economic development and extend the industrial chain. Safety Production Investment (2.61%), combined with Intelligent Equipment Usage (1.65%), forms a complete chain of intelligent empowerment for improving intrinsic safety levels.

4.3. Extension Cloud Model for Coal Enterprise ESG Evaluation

4.3.1. Principles of the Extension Cloud Model

The matter-element extension model uses matter-elements as basic units to describe things, effectively solving the incompatibility problem in multi-indicator evaluation. However, the quantity value (V) in traditional matter-element extension models is often a fixed value, neglecting the randomness and fuzziness of uncertain problems and increasing the risk of information loss. In contrast, the cloud model fully considers the randomness and fuzziness of indicator grading, possessing unique advantages in converting between qualitative and quantitative data, thereby compensating for the shortcomings of the matter-element extension model. Therefore, this study introduces extension theory based on the cloud model to construct an extension cloud coupling model. This model can effectively address the randomness and fuzziness at indicator grade boundaries while overcoming limitations of traditional fuzzy set theory such as incompatibility and strong subjectivity in membership determination, enabling objective and accurate evaluation of objective matters [32]. The cloud matter-element matrix is:

$$R = (M, C, V) = \begin{bmatrix} M & c_1 & (Ex_1, En_1, He_1) \\ & c_2 & (Ex_2, En_2, He_2) \\ & \dots & \dots \\ & c_m & (Ex_m, En_m, He_m) \end{bmatrix} \quad (8)$$

where M is the name of the matter, C_i is the i -th indicator of the matter, and (Ex_i, En_i, He_i) are the three cloud characteristic values for the i -th indicator.

4.3.2. Determining the Evaluation Set and Grading Indicators

Referring to existing studies and expert recommendations [32], the comprehensive ESG evaluation results of coal enterprises are classified into five grades: Excellent (A), Good (B), Medium (C), Low (D), and Poor (E). To determine the grade boundaries of the tertiary indicators, this study integrates three types of evidence: policy standards, industry sample data, and expert discussion. The relevant policy documents were obtained from official government websites, the website of the China Coal Industry Association, and public documents issued by stock exchanges. Industry sample data were collected from the Qinglv Database, the CNRDS Database, and the 2024 corporate social responsibility reports and ESG reports publicly disclosed by 23 A-share listed companies in the coal mining and washing industry. For information that was not directly presented in a structured format, data extraction and manual text mining were used to obtain comparable industry-level information.

The grade boundaries were determined according to the following principles. If relevant policy documents provided explicit standards or benchmark values, these policy standards were used as the primary basis. If no explicit policy thresholds were available, the initial boundaries were determined based on the disclosed data of the 23 listed coal enterprises, considering the best value, worst value, mean value, and concentrated distribution range. For qualitative indicators and indicators that could not be fully classified based on policy standards or industry data, expert discussion was used to refine the boundaries, thereby improving the industry applicability and operational feasibility of the evaluation set.

(1) Environmental Dimension

The grade boundaries of the environmental indicators were mainly determined with reference to policy documents such as the Action Plan for Low-Carbon Transformation and Construction of Coal Power (2024–2027), the Opinions on Strengthening the Clean and Efficient Utilization of Coal, and the Evaluation Indicator System for Cleaner Production in the Coal Mining and Washing Industry. Publicly disclosed data from 23 listed coal enterprises in 2024 were also used. This study summarized the best value, worst value, mean value, concentrated distribution range, and number of companies with disclosed data for the tertiary environmental indicators, as shown in Table 5.

Table 5. Actual situation of tertiary environmental indicators for listed coal companies.

Indicator	Industry Best	Industry Worst	Mean	Concentration Range	Number of Companies with Disclosed Data
Energy consumption intensity	2.46 (Shaanxi Coal Industry)	224.59 (Suneng Co., Ltd.)	71.72	100–150	14
Water consumption intensity	0.65 (Huaibei Mining)	460.63 (Shanghai Energy)	7.38	5–10	9
Greenhouse gas emission intensity	0.038 (Pingmei Co., Ltd.)	9.19 (Xinji Energy)	2.95	1–4	9
SO ₂ emission intensity	0.14 (Jinkong Coal Industry)	933.15 (Huayang Co., Ltd.)	87.16	1–4	11
NO _x emission intensity	0.0007 (Pingmei Co., Ltd.)	14.13 (China Shenhua)	3.88	1–3	13
Wastewater discharge intensity	0.10 (Pingmei Co., Ltd.)	9.22 (Lanhua Sci-Tech)	3.45	2–4	10
Mine water utilization rate	100% (SPIC Industry-Finance Holdings)	46% (Lanhua Sci-Tech)	80.00%	80–95%	12

Coal gangue utilization rate	100% (Jizhong Energy, etc.)	63.1% (Shaanxi Coal Industry)	93.00%	95–100%	11
Environmental investment intensity	4.3% (Suneng Co., Ltd.)	0.29% (Hengyuan Coal and Electricity)	1.09%	0.5–1.5%	23
Ecological restoration area	5.26 (Haohua Energy)	0.13 (Huaibei Mining)	1.69	0.5–1	12

Among the environmental indicators, mine water utilization rate and coal gangue utilization rate have relatively explicit policy benchmarks. The Evaluation Indicator System for Cleaner Production in the Coal Mining and Washing Industry classifies these indicators into Level I, Level II, and Level III, where Level I represents the international leading level of cleaner production, Level II represents the domestic advanced level, and Level III represents the domestic general level. In this study, these benchmarks were used as the main basis for determining the grade boundaries of mine water utilization rate and coal gangue utilization rate, with further adjustments based on industry sample distributions and expert judgment. The relevant policy benchmarks are shown in Table 6.

Table 6. Resource utilization benchmarks in the cleaner production evaluation system for the coal industry.

Primary Indicator	Secondary Indicator	Level I Benchmark	Level II Benchmark	Level III Benchmark
Comprehensive resource utilization	Comprehensive utilization rate of coal gangue generated in the current year (%)	≥85	≥80	≥75
Comprehensive resource utilization	Mine water utilization rate (%): water-scarce mining areas	≥95	≥90	≥85
Comprehensive resource utilization	Mine water utilization rate (%): general water-resource mining areas	≥85	≥75	≥70
Comprehensive resource utilization	Mine water utilization rate (%): water-rich mining areas	≥70	≥65	≥60

(2) Social Dimension

The grade boundaries of the social indicators were mainly determined with reference to documents such as the Coal Law of the People’s Republic of China and the Blue Book of Social Responsibility in the Coal Industry, as well as the 2024 corporate social responsibility reports and ESG reports of the 23 listed coal enterprises. The social dimension covers employee responsibility, production safety, social responsibility, and market responsibility, all of which show strong industry-specific characteristics. Therefore, the boundaries were determined based on the actual disclosure data of listed companies and refined through expert discussion. The industry sample statistics of the tertiary social indicators are shown in Table 7.

Table 7. Actual situation of tertiary social indicators for listed coal companies.

Tertiary Indicator	Industry Best	Industry Worst	Mean	Concentration Range	Number of Companies with Disclosed Data
Proportion of female employees	19.09% (Yankuang Energy)	3.48% (Xinji Energy)	13.66%	10–15%	11
Employee turnover rate	0.94% (Yankuang Energy)	4.1% (Lanhua Sci-Tech)	1.83%	1–1.5%	8
Employee training coverage	100% (Lu’an Environmental Energy, etc.)	5.4% (Zhengzhou Coal Industry)	87.95%	90–100%	8

Occupational health investment intensity	1.51% (Zhengzhou Coal Industry)	0.05% (Lanhua Sci-Tech)	0.50%	0.2–0.5%	7
Production safety investment intensity	14.47% (Zhengzhou Coal Industry)	1.35% (China Shenhua)	5.10%	3–7%	12
Tax contribution ratio	42.85% (Zhengzhou Coal Industry)	8.07% (Shanxi Coking Coal International Energy Group)	22.36%	15–30%	23
Social welfare investment intensity	0.74% (China Shenhua)	0.00% (Jinkong Coal Industry)	0.07%	0–0.1%	21
Rural revitalization investment intensity	0.38% (Panjiang Co., Ltd.)	0.00% (Jinkong Coal Industry)	0.07%	0.02–0.03%	21
Customer satisfaction	100% (Pingmei Co., Ltd., etc.)	90% (China Coal Energy)	98.06%	95–100%	9

(3) Governance Dimension

The grade boundaries of the governance indicators were mainly determined with reference to institutional documents such as the Guidelines for Sustainability Reports of Listed Companies, the Code of Corporate Governance for Listed Companies, and the Measures for the Administration of Information Disclosure by Listed Companies, together with public disclosure data from the 23 listed coal enterprises in 2024. The governance dimension includes governance structure, governance decision-making, governance construction, and technological innovation. Quantitative indicators, including board independence, board diversity, number of board meetings, number of information disclosure documents, R&D investment intensity, proportion of R&D personnel, and number of patents granted, were mainly determined based on industry sample distributions. Qualitative indicators, including Party organization construction, anti-bribery and anti-corruption construction, risk management system, and digital construction level, were determined based on the 0/1/2 scoring rule and expert discussion. The industry sample statistics of the tertiary governance indicators are shown in Table 8.

Table 8. Actual situation of tertiary governance indicators for listed coal companies.

Tertiary Indicator	Industry Best	Industry Worst	Mean	Concentration Range	Number of Companies with Disclosed Data
Board independence	50% (Shanghai Energy)	33.33% (Lu'an Environmental Energy, etc.)	38.30%	33–40%	23
Board diversity	33.33% (Shanghai Energy, etc.)	0 (Lanhua Sci-Tech, etc.)	13.35%	10–20%	23
Number of board meetings	19 (Pingmei Co., Ltd.)	5 (Haohua Energy)	9	7–10	21
Number of information disclosure documents	264 (China Coal Energy)	52 (Suneng Co., Ltd.)	110	100–150	11
R&D investment intensity	19.66% (Yankuang Energy)	0.44% (SPIC Industry-Finance Holdings)	3.78%	1–1.5%	19
Proportion of R&D personnel	31.83% (Jinkong Coal Industry)	0.45% (Pingmei Co., Ltd.)	6.79%	1–5%	14
Number of patents granted	637 (China Shenhua)	7 (Lanhua Sci-Tech)	127	50–100	19

In summary, this study determines the grade boundaries of the tertiary ESG indicators from the environmental, social, and governance dimensions based on policy standards, industry sample data, and expert discussion. This procedure reflects both the regulatory requirements of ESG governance in coal enterprises and the actual disclosure level

and distribution characteristics of listed coal enterprises. On this basis, the five-grade evaluation set for all tertiary indicators in the ESG evaluation system for coal enterprises is established, as shown in Table 9.

Table 9. Grade boundaries for coal enterprise ESG evaluation indicators.

Tertiary Indicator	Excellent (A)	Good (B)	Medium (C)	Low (D)	Poor (E)
E11 Energy Consumption Intensity	0–50	50–100	100–150	150–200	200–250
E12 Water Consumption Intensity	0–4	4–8	8–12	12–16	16–20
E21 GHG Emission Intensity	0–1	1–2	2–3	3–5	5–6
E22 SO ₂ Emission Intensity	0–1	1–2	2–3	3–4	4–5
E23 NO _x Emission Intensity	0–1	1–2	2–3	3–5	5–6
E24 Wastewater Discharge Intensity	0–1	1–2	2–4	4–6	6–10
E31 Mine Water Utilization Rate	100–95%	95–90%	90–85%	85–80%	80–75%
E32 Coal Gangue Utilization Rate	100–95%	95–90%	90–85%	85–80%	80–40%
E41 Environmental Investment Intensity	1.1–0.8%	0.8–0.5%	0.5–0.2%	0.2–0.05%	0.05–0%
E42 Clean Energy Use	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25
E43 Ecological Restoration Area	2–1.5	1.5–1	1–0.5	0.5–0.05	0.05–0
E44 Ecological Economy	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25
S11 Proportion of Female Employees	25–20	20–15	15–10	10–5	5–0
S12 Employee Turnover Rate	0–0.5	0.5–1	1–1.5	1.5–2	2–2.5
S13 Employee Training Coverage Rate	100–95%	95–90%	90–85%	85–80%	80–75%
S14 Occupational Health Investment Intensity	0.8–0.6%	0.6–0.4%	0.4–0.2%	0.2–0.05%	0.05–0%
S22 Safety Production Investment Intensity	2.5–2%	2–1.5%	1.5–1%	1–0.5%	0.5–0%
S23 Intelligent Equipment Usage	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25
S31 Tax Contribution Ratio	30–25	25–20	20–15	15–10	10–5
S32 Social Donation Investment Intensity	0.5–0.4%	0.4–0.3%	0.3–0.2%	0.2–0.1%	0.1–0%
S33 Rural Revitalization Investment Intensity	0.06–0.04%	0.04–0.03%	0.03–0.02%	0.02–0.01%	0.01–0%
S41 Customer Satisfaction	100–97%	97–94%	94–91%	91–88%	88–85%
S42 Supplier Management	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25
G11 Board Independence	54–47	47–40	40–33	33–26	26–19
G12 Board Diversity	25–20	20–15	15–10	10–5	5–0
G21 Number of Board Meetings Held	16–13	13–10	10–7	7–4	4–0
G22 Number of Info Disclosure Documents	250–200	200–150	150–100	100–50	50–0
G31 Party Organization Construction	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25
G32 Anti-bribery and Anti-corruption	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25

G33 Risk Management System	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25
G41 R&D Investment Intensity	2.5–2%	2–1.5%	1.5–1%	1–0.05%	0.05–0%
G42 R&D Personnel Ratio	13–9%	9–5%	5–1%	1–0.05%	0.05–0%
G43 Number of Patents Obtained	200–150	150–100	100–50	50–20	20–0
G44 Digital Construction Level	2.25–1.75	1.75–1.25	1.25–0.75	0.75–0.25	0.25–0.25

4.3.3. Constructing the Standard Cloud

After grading the ESG indicators in coal enterprises, they need to be normalized into cloud models. This involves calculating the cloud model numerical characteristics for each grade of each indicator: Expectation (Ex), Entropy (En), and Hyper-entropy (He), to prepare for constructing the cloud matter-element matrix. The specific formulas are as follows:

$$Ex = \frac{(c_{\max} + c_{\min})}{2} \quad (9)$$

$$En = \frac{(c_{\max} - c_{\min})}{2.355} \quad (10)$$

$$He = \rho \quad (11)$$

where $c_{\max}$ and $c_{\min}$ are the upper and lower bounds of the indicator grade, respectively, and ρ is a constant, generally taken as 0.1 [32]. According to the above formulas, the characteristic values $C_{ij}(Ex_{ij}, En_{ij}, He_{ij})$ for the i -th indicator C_i corresponding to the j -th grade C_{ij} can be obtained. Using the same formulas, a characteristic value matrix $C^* = [C_{ij}(Ex_{ij}, En_{ij}, He_{ij})]_{m \times n}$ can be obtained, forming the standard cloud for ESG evaluation in coal enterprises, as shown in Table 10.

Table 10. Cloud chart of ESG three-level indicators for the coal industry.

Tertiary Indicator	Excellent (A)			Good (B)			Medium (C)			Low (D)			Poor (E)		
	Ex	En	He	Ex	En	He	Ex	En	He	Ex	En	He	Ex	En	He
E11	25	14.783	1.478	75	14.783	1.478	125	14.783	1.478	175	14.783	1.478	225	14.783	1.478
E12	2	1.183	0.118	6	1.183	0.118	10	1.183	0.118	14	1.183	0.118	18	1.183	0.118
E21	0.5	0.296	0.030	1.5	0.296	0.030	2.5	0.296	0.030	4	0.591	0.059	5.5	0.296	0.030
E22	0.5	0.296	0.030	1.5	0.296	0.030	2.5	0.296	0.030	3.5	0.296	0.030	4.5	0.296	0.030
E23	0.5	0.296	0.030	1.5	0.296	0.030	2.5	0.296	0.030	4	0.591	0.059	5.5	0.296	0.030
E24	0.5	0.296	0.030	1.5	0.296	0.030	3	0.591	0.059	5	0.591	0.059	6.5	0.296	0.030
E31	97.5	1.478	0.148	92.5	1.478	0.148	87.5	1.478	0.148	82.5	1.478	0.148	77.5	1.478	0.148
E32	97.5	1.478	0.148	92.5	1.478	0.148	87.5	1.478	0.148	82.5	1.478	0.148	77.5	1.478	0.148
E41	0.95	0.089	0.009	0.65	0.089	0.009	0.35	0.089	0.009	0.125	0.044	0.004	0.025	0.015	0.001
E42	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
E43	1.75	0.148	0.015	1.25	0.148	0.015	0.75	0.148	0.015	0.275	0.133	0.013	0.025	0.015	0.001
E44	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
S11	22.5	1.478	0.148	17.5	1.478	0.148	12.5	1.478	0.148	7.5	1.478	0.148	2.5	1.478	0.148
S12	0.25	0.148	0.015	0.75	0.148	0.015	1.25	0.148	0.015	1.75	0.148	0.015	2.25	0.148	0.015
S13	97.5	1.478	0.148	92.5	1.478	0.148	87.5	1.478	0.148	82.5	1.478	0.148	77.5	1.478	0.148
S14	0.7	0.059	0.006	0.5	0.059	0.006	0.3	0.059	0.006	0.125	0.044	0.004	0.025	0.015	0.001
S22	2.25	0.148	0.015	1.75	0.148	0.015	1.25	0.148	0.015	0.75	0.148	0.015	0.25	0.148	0.015
S23	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
S31	27.5	1.478	0.148	22.5	1.478	0.148	17.5	1.478	0.148	12.5	1.478	0.148	7.5	1.478	0.148
S32	0.045	0.003	0.000	0.035	0.003	0.000	0.025	0.003	0.000	0.015	0.003	0.000	0.005	0.003	0.000
S33	0.045	0.003	0.000	0.035	0.003	0.000	0.025	0.003	0.000	0.015	0.003	0.000	0.005	0.003	0.000
S41	99	0.591	0.059	97	0.591	0.059	95	0.591	0.059	93	0.591	0.059	91	0.591	0.059

S42	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
G11	50.5	2.070	0.207	43.5	2.070	0.207	36.5	2.070	0.207	29.5	2.070	0.207	22.5	2.070	0.207
G12	22.5	1.478	0.148	17.5	1.478	0.148	12.5	1.478	0.148	7.5	1.478	0.148	2.5	1.478	0.148
G21	14.5	0.887	0.089	11.5	0.887	0.089	8.5	0.887	0.089	5.5	0.887	0.089	2	1.183	0.118
G22	225	14.783	1.478	175	14.783	1.478	125	14.783	1.478	75	14.783	1.478	25	14.783	1.478
G31	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
G32	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
G33	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015
G41	2.25	0.148	0.015	1.75	0.148	0.015	1.25	0.148	0.015	0.525	0.281	0.028	0.025	0.015	0.001
G42	11	1.183	0.118	7	1.183	0.118	3	1.183	0.118	0.525	0.281	0.028	0.025	0.015	0.001
G43	175	14.783	1.478	125	14.783	1.478	75	14.783	1.478	35	8.870	0.887	10	5.913	0.591
G44	2	0.148	0.015	1.5	0.148	0.015	1	0.148	0.015	0.5	0.148	0.015	0	0.148	0.015

4.3.4. Constructing the Matter-Element to Be Evaluated

The construction of the matter-element to be evaluated is based on the evaluation cloud. Raw data for coal enterprise indicators are obtained and transformed into a cloud model using the reverse cloud generator, generating evaluation cloud parameters that constitute the quantity value V of the matter-element extension model. The evaluation cloud parameters generate digital characteristic values (Ex , En , He) for the specific values of each coal enterprise indicator using the reverse cloud generator, yielding $V_i = Ex_i$, En_i , He_i , and subsequently the matter-element to be evaluated.

$$R = (M, C, V) = \begin{bmatrix} c_1 & (Ex_1, En_1, He_1) \\ M_j & c_2 & (Ex_2, En_2, He_2) \\ \cdots & \cdots \\ c_n & (Ex_n, En_n, He_n) \end{bmatrix} \quad (12)$$

where M_j represents the ESG performance of the coal enterprise in year j , c_1 to c_n represent a total of n indicators, and (Ex_i, En_i, He_i) represent the digital characteristic values corresponding to each indicator.

4.3.5. Constructing the Membership Matrix

By inputting the standard cloud and the matter-element matrix to be evaluated into Python 3.10 using PyCharm 2025.2.4, the membership degrees of the tertiary indicators for each grade can be obtained. The specific process involves treating the (Ex_i, En_i, He_i) of the indicator to be evaluated as a cloud droplet, generating a normal random number En' with mean En_i and standard deviation He_i , and then calculating the cloud membership μ between the evaluation indicator value x and the grade boundary cloud model. The calculation method is shown in Equation (13). After calculating the membership for all indicators, the membership matrix Z is obtained.

$$\mu(x) = e^{-\frac{(x-Ex)^2}{2En'^2}} \quad (13)$$

$$Z = \begin{bmatrix} \mu_1 & \cdots & \mu_{1m} \\ \vdots & \ddots & \vdots \\ \mu_n & \cdots & \mu_{nm} \end{bmatrix} \quad (14)$$

The raw indicator values for Group ZN from 2020 to 2024 were input into the reverse cloud generator to obtain the three characteristic values of the cloud model, forming the matter-element to be evaluated. Formula (13) was then used to determine the membership degrees of the indicators to each grade, resulting in the membership matrix. To avoid interference from randomness in the calculation, $N = 1000$ was set when using the formula to compute the membership matrix, meaning the calculation was repeated 1000 times to obtain the average membership degree of the indicator value belonging to different grades. Notably, if a positive (negative) indicator is greater than (less than) the upper (lower) bound of Excellent (A) or less than (greater than) the lower (upper) bound of Poor

(E), according to existing research, the membership degree for the Excellent (A) or Poor (E) grade is set to 1. The raw indicator data for Group ZN in 2024 were input into the grade membership function, and PyCharm software was used to repeat the calculation 1000 times, resulting in an average membership matrix, which was then normalized. The detailed results are shown in Table 11.

Table 11. The 2024 ZN group hierarchical indicator membership matrix.

Tertiary Indicator	Poor (E)	Low (D)	Medium (C)	Good (B)	Excellent (A)
E11 Energy Consumption Intensity	0.0000	0.0000	0.0104	0.7275	0.2620
E12 Water Consumption Intensity	0.0000	0.0000	0.0002	0.1110	0.8889
E21 GHG Emission Intensity	0.0007	0.9865	0.0128	0.0000	0.0000
E22 SO ₂ Emission Intensity	0.0000	0.0000	0.0482	0.8800	0.0718
E23 NO _x Emission Intensity	0.0000	0.1415	0.7791	0.0793	0.0001
E24 Wastewater Discharge Intensity	0.0361	0.2348	0.7291	0.0000	0.0000
E31 Mine Water Utilization Rate	0.9996	0.0004	0.0000	0.0000	0.0000
E32 Coal Gangue Utilization Rate	0.0934	0.0000	0.0005	0.1949	0.7112
E41 Environmental Investment Intensity	0.0000	0.0000	0.6342	0.3643	0.0015
E42 Clean Energy Use	0.0000	0.0000	0.0001	0.0623	0.9376
E43 Ecological Restoration Area	0.0000	0.1563	0.8251	0.0186	0.0000
E44 Ecological Economy	0.0000	0.0000	0.0001	0.0627	0.9372
S11 Proportion of Female Employees	0.0086	0.6945	0.2960	0.0010	0.0000
S12 Employee Turnover Rate	0.0000	0.0000	0.0006	0.2283	0.7711
S13 Employee Training Coverage Rate	0.0000	0.0000	0.0159	0.7917	0.1924
S14 Occupational Health Investment Intensity	0.0000	0.0000	0.1979	0.7869	0.0152
S22 Safety Production Investment Intensity	0.1192	0.8525	0.0282	0.0000	0.0000
S23 Intelligent Equipment Usage	0.0000	0.0000	0.0001	0.0633	0.9367
S31 Tax Contribution Ratio	0.0000	0.0000	0.0000	0.0026	0.9974
S32 Social Donation Investment Intensity	0.0000	0.0000	0.0062	0.6304	0.3634
S33 Rural Revitalization Investment Intensity	0.0000	0.0030	0.4676	0.4667	0.0628
S41 Customer Satisfaction	0.0000	0.0000	0.0001	0.0681	0.9318
S42 Supplier Management	0.0000	0.0000	0.0001	0.0623	0.9376
G11 Board Independence	0.0023	0.4323	0.5611	0.0043	0.0000
G12 Board Diversity	0.0000	0.0018	0.3929	0.6000	0.0053
G21 Number of Board Meetings Held	0.0001	0.0032	0.4968	0.4969	0.0031
G22 Number of Info Disclosure Documents	0.0000	0.0001	0.0981	0.8668	0.0350
G31 Party Organization Construction	0.0000	0.0000	0.0001	0.0629	0.9370
G32 Anti-bribery and Anti-corruption	0.0000	0.0000	0.0001	0.0623	0.9377
G33 Risk Management System	0.0001	0.0587	0.8818	0.0594	0.0001
G41 R&D Investment Intensity	0.0000	0.0031	0.0061	0.6295	0.3612
G42 R&D Personnel Ratio	0.0000	0.0000	0.8562	0.1436	0.0002
G43 Number of Patents Obtained	0.0000	0.0000	0.0000	0.0019	0.9981
G44 Digital Construction Level	0.0000	0.0000	0.0001	0.0623	0.9377

4.3.6. Determining the Evaluation Results

The indicator weight matrix $W\{(w_1, w_2, w_3, \dots, w_n)\}$ calculated by the entropy weight method is multiplied by the membership matrix $Z = (\mu_{ij})_{m \times n}$ to obtain the indicator membership matrix $B = W * Z = \{(b_1, b_2, b_3, \dots, b_m)\}$. From this, the membership matrices for secondary indicators, primary indicators, and the overall ESG performance can be calculated. Finally, the weighted average method is used to determine the grade of each indicator. A quantitative index j ($j = 1, 2, \dots, m$) is used to represent the quantification of the m grades. Formula (15) is used to calculate the characteristic variable value j^* for each indicator. The grade of the indicator is then determined by comparing j^* with the grade characteristic value intervals.

$$j^* = \frac{\sum_{j=1}^m j b_j}{\sum_{j=1}^m b_j} \quad (15)$$

This study divides the comprehensive ESG evaluation of coal enterprises into five grades: Excellent (A), Good (B), Medium (C), Low (D), and Poor (E), i.e., $m = 5$. The quantification for each grade is 1–5. Based on existing research, the characteristic value intervals for each grade are shown in Table 12.

Table 12. Variable characteristic value intervals for ESG comprehensive evaluation grades.

Overall Evaluation Grade	Grade Characteristic-Value Interval
Excellent (A)	1–1.5
Good (B)	1.5–2.5
Medium (C)	2.5–3.5
Low (D)	3.5–4.5
Poor (E)	4.5–5

When j^* is between 1 and 1.5, the ESG evaluation indicator grade in coal enterprises is Excellent (A); between 1.5 and 2.5, Good (B); between 2.5 and 3.5, Medium (C); between 3.5 and 4.5, Low (D); and between 4.5 and 5, Poor (E).

4.4. Analysis of Group ZN's ESG Evaluation Results

4.4.1. Analysis of Overall ESG Results

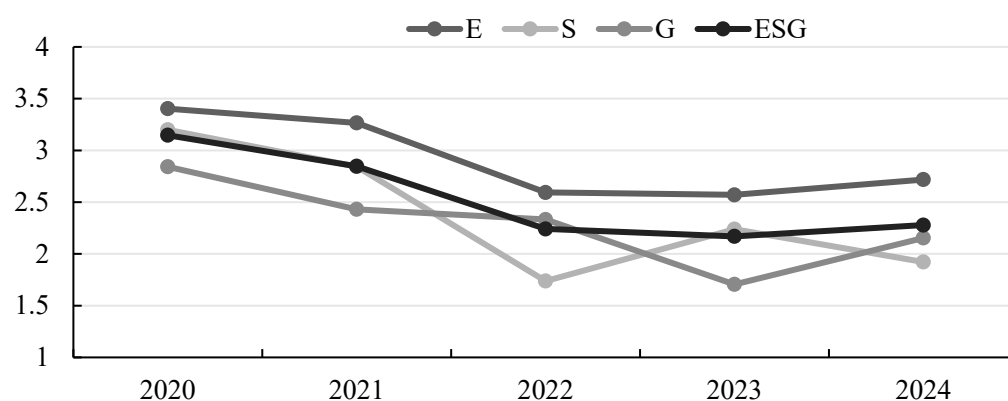
The characteristic values and grades of Group ZN's overall ESG performance and the three primary indicators, namely Environment, Social, and Governance, are shown in Table 13 and Figure 2. It should be noted that, in this evaluation system, grades range from Excellent (A) to Poor (E), corresponding to characteristic values from low to high. Therefore, a decline in the characteristic value or a movement from Grade C toward Grade B or Grade A indicates an improvement in ESG performance, while an increase in the characteristic value indicates relatively weaker performance.

The overall ESG results show that Group ZN improved from the Medium (C) level in 2020–2021 to the Good (B) level in 2022–2024, indicating an overall improvement in the company's ESG governance performance. The improvement was particularly evident from 2021 to 2022, while the overall ESG grade remained relatively stable at the Good (B) level from 2022 to 2024. This change was closely associated with the company's continuous implementation of the “dual carbon” strategy, green and low-carbon transformation, rural revitalization initiatives, and social responsibility practices. As the empirical analysis focuses on Group ZN, the following discussion examines the company-specific mechanisms underlying changes in ESG performance and provides case-based evidence for applying the evaluation framework to ESG governance diagnosis in coal enterprises.

For the three primary indicators, the environmental, social, and governance dimensions all showed varying degrees of grade improvement, but their improvement patterns were not fully consistent. The environmental dimension remained at the Medium (C) level throughout the five-year period, although its characteristic value declined to some extent. The social dimension improved from Medium (C) in 2020–2021 to Good (B) in 2022–2024. The governance dimension improved from Medium (C) in 2020 to Good (B) from 2021 to 2024. These results suggest that Group ZN's ESG governance remains uneven across dimensions. In particular, the environmental dimension lagged behind the social and governance dimensions, indicating the need to strengthen resource utilization, pollution reduction, and environmental investment stability.

Table 13. Overall ESG results.

Dimension	2020	2021	2022	2023	2024
E	3.4040 Medium	3.2658 Medium	2.5940 Medium	2.5709 Medium	2.7180 Medium
S	3.1998 Medium	2.8436 Medium	1.7384 Good	2.2391 Good	1.9220 Good
G	2.8423 Medium	2.4308 Good	2.3323 Good	1.7056 Good	2.1540 Good
ESG	3.1466 Medium	2.8467 Medium	2.2408 Good	2.1690 Good	2.2783 Good

**Figure 2.** Line chart of overall ESG evaluation results.

4.4.2. Evaluation of Environmental Dimension Performance

The evaluation results of the secondary and tertiary indicators in the environmental dimension are shown in Table 14 and Figure 3. Overall, the environmental dimension presents a structural pattern characterized by relatively good energy consumption performance, gradual improvement in emission control, insufficient resource utilization, and significant fluctuations in environmental protection investment. Although some indicators showed declining characteristic values and grade improvement, the environmental dimension remained at the Medium (C) level throughout the five-year period, indicating uneven internal improvement.

In terms of resource consumption, Group ZN performed relatively well. Energy consumption intensity remained at approximately 60–65 tons per million yuan over the five years, representing a relatively good industry level. Water consumption intensity decreased from 7.87 tons per 10,000 yuan of operating revenue in 2020 to 2.48 tons in 2024, with a decrease of 217.34%. This improvement was mainly attributable to the company's continuous implementation of full-process energy consumption diagnosis, introduction of energy-saving equipment, elimination of high-energy-consuming equipment, strengthening of water supply pipeline inspection, and application of water-saving facilities. In particular, in 2023, the company achieved important results in a preparation process technology project, which further supported energy conservation and resource management efficiency. This indicates that corporate governance measures have had a relatively direct positive effect on the improvement of energy and water consumption indicators.

In terms of emissions, Group ZN improved from the Low (D) level in 2020 to the Medium (C) level from 2021 to 2024. Wastewater discharge intensity decreased from 9.72 tons per 10,000 yuan in 2020 to 3.59 tons in 2024, representing a reduction of 63.07%. This improvement was mainly associated with the company's response to the "dual carbon" goals, promotion of green and low-carbon technologies, and implementation of water-

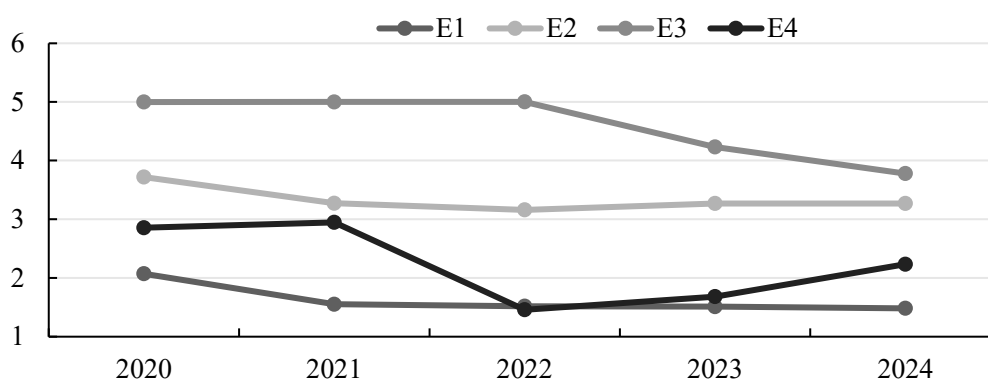
saving management. In 2024, the company further strengthened water-saving management and reclaimed water reuse projects, and achieved savings across water intake, use, and discharge through pipeline inspection, leakage repair, and water supply system optimization. However, greenhouse gas emission intensity remained relatively weak. This is partly related to the high-emission characteristics of coal mining and the energy structure of coal enterprises, while also indicating that further efforts are needed in deep emission reduction, carbon management technologies, and low-carbon process transformation.

In terms of resource utilization, the mine water utilization rate remained around 75% for a long period, making it a major weakness in the environmental dimension. This result should not be interpreted simply as insufficient awareness of resource recycling. It is also necessary to consider objective constraints such as hydrogeological conditions, differences in mine water quality, the spatial distribution of mining areas, the matching degree between reclaimed water and reuse scenarios, and the layout of existing treatment facilities. For mines with long operating histories and relatively dispersed mining areas, centralized collection, treatment, and reuse of mine water may involve a longer transportation radius, which can increase reuse costs and reduce utilization efficiency. Therefore, the resource utilization weakness of Group ZN is more accurately reflected in the insufficient development of regional treatment, quality-based utilization, and on-site reuse mechanisms under existing mining-area constraints. Meanwhile, the coal gangue utilization rate increased significantly after 2023, from 49.26% to 96.17%. This was mainly because the company strengthened full-process supervision of coal gangue and expanded its sales and utilization channels through field research and cooperation with high-tech enterprises. These results indicate substantial improvement in solid waste utilization, while mine water reuse, high-value solid waste utilization, and coordination within the circular economy industrial chain still require further enhancement.

In terms of environmental protection, the indicators fluctuated significantly. The ecological restoration area increased from 0.085 square kilometers in 2020 to 2.75 square kilometers in 2022, and then declined to 0.64 square kilometers in 2024. This change was closely related to the planning, construction, grid connection, and acceptance cycle of photovoltaic power generation projects. In 2022, the concentrated release of project outcomes contributed to the peak in ecological restoration area and the quantitative disclosure of clean energy use. After the phased completion of these projects, the growth of restoration area slowed, and environmental investment intensity declined. In addition, the ecological restoration area is also affected by the scale of reclaimable land, the progress of subsidence-area treatment, land-use planning, and the degree of historical mining disturbance. Therefore, its annual fluctuation should not be directly equated with changes in corporate willingness to engage in environmental governance. The company continuously disclosed ecological economy information from 2022 to 2024, indicating its exploration of integrated development involving ecological restoration, tourism, agriculture, and animal husbandry. Overall, the Medium (C) rating of Group ZN's environmental dimension reflects both objective constraints arising from resource endowment, mining-area conditions, and mining stage, and management-related improvement space in efficient mine water reuse, stable ecological restoration investment, and coordinated environmental governance. Future environmental governance should therefore focus on improving resource recycling efficiency and environmental investment stability while fully considering the objective conditions of the mining areas.

Table 14. Evaluation results of secondary environmental indicators.

Secondary Indicator	2020	2021	2022	2023	2024
E1 Resource Consumption	2.0723	1.5509	1.5169	1.5109	1.4825
	Good	Good	Good	Good	Excellent
E2 Emissions	3.7183	3.2729	3.1610	3.2683	3.2689
	Low	Medium	Medium	Medium	Medium
E3 Resource Utilization Rate	4.9968	4.9986	4.9998	4.2310	3.7779
	Poor	Poor	Poor	Low	Low
E4 Environmental Protection	2.8545	2.9472	1.4565	1.6805	2.2334
	Medium	Medium	Excellent	Good	Good

**Figure 3.** Line chart of evaluation results for environmental dimension.

4.4.3. Evaluation of Social Dimension Performance

The evaluation results of the secondary and tertiary indicators in the social dimension are shown in Table 15 and Figure 4. Overall, the social dimension improved from Medium (C) in 2020–2021 to Good (B) in 2022–2024, but internal indicators differed considerably. The social dimension can be characterized by fluctuating employee responsibility, the need for further improvement in production safety, and relatively strong performance in social responsibility and market responsibility.

In terms of employee responsibility, the indicator grade fluctuated to some extent. The employee turnover rate remained at a relatively excellent industry level, and occupational health management showed good results, with zero new occupational disease cases over the five-year period. Occupational health investment reached its highest level in 2024. However, employee training coverage fluctuated significantly, exceeding 95% in 2022, falling to 83% in 2023, and increasing again to 93.7% in 2024. The peak in 2022 was mainly related to company-wide centralized training, while the decline in 2023 was associated with the shift in training resources toward key frontline technical positions and targeted skills training. In 2024, the indicator rebounded under measures such as full coverage of new employee training. This indicates that Group ZN has established a foundation for employee training, but still needs to balance key-position training with overall training coverage.

In terms of production safety, the grade reached Good (B) in 2022 and then returned to Medium (C). This was mainly because, from 2021 to 2022, the company increased production safety investment to implement the Work Safety Law and related requirements. It upgraded old equipment, added safety devices, conducted safety technology transformation, and purchased safety monitoring systems, thereby improving production safety indicators. After 2022, large-scale capital investment gradually shifted to operation and maintenance investment, resulting in a decline in production safety investment intensity.

Meanwhile, the company continued to deploy intelligent equipment, including slope surface displacement monitoring systems, unmanned mining trucks, and intelligent inspection robots. No major equipment accidents or major casualties occurred during the five-year period, indicating that the company's safety risks were generally controllable. However, the off-peak pattern between production safety investment and environmental investment in some years suggests a certain coordination issue in ESG resource allocation, which requires stronger cross-issue management.

In terms of social responsibility, Group ZN performed relatively steadily and provided strong support for the social dimension. The tax contribution ratio increased from 24.84% in 2020 to 31.07% in 2024, an increase of more than six percentage points, making an important contribution to the improvement of the social responsibility score. In addition, the company continued to carry out industrial assistance, educational assistance, and volunteer service activities under the rural revitalization strategy, reflecting its capacity to fulfill social responsibilities.

In terms of market responsibility, Group ZN improved significantly and remained at the Excellent (A) level from 2022 to 2024. This was mainly due to the institutional breakthrough in supplier management in 2022. The company formulated supplier management measures and supplier performance management rules, and evaluated 184 suppliers, thereby promoting full lifecycle supplier management and responsible supply chain construction. In addition, customer satisfaction remained at a high level and reached 98.45% in 2024, further improving market responsibility performance.

Table 15. Evaluation results of secondary social indicators.

Secondary Indicator	2020	2021	2022	2023	2024
S1 Employee Responsibility	2.9650 Medium	3.0027 Medium	1.7530 Good	3.0994 Medium	2.1301 Good
S2 Production Safety	3.5065 Low	2.5927 Medium	2.3077 Good	2.8254 Medium	2.9202 Medium
S3 Social Responsibility	2.3161 Good	1.9192 Good	1.8582 Good	1.2277 Excellent	1.6281 Good
S4 Market Responsibility	4.7967 Poor	3.9873 Low	1.0861 Excellent	1.1665 Excellent	1.0642 Excellent

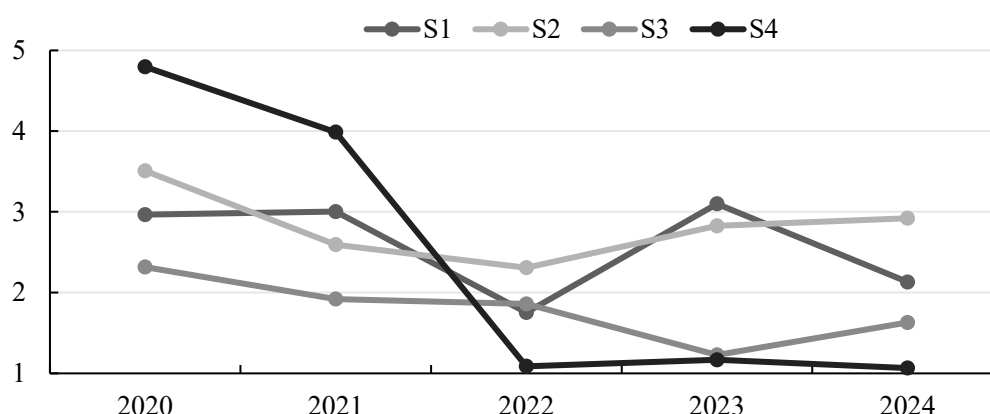


Figure 4. Line chart of social dimension evaluation results.

4.4.4. Evaluation of Governance Dimension Performance

The evaluation results of the secondary and tertiary indicators in the governance dimension are shown in Table 16 and Figure 5. Overall, the governance dimension improved from Medium (C) in 2020 to Good (B) from 2021 to 2024. However, the internal structure remained differentiated, with governance construction and technological innovation supporting the overall governance dimension, while governance structure and governance decision-making still required improvement.

In terms of governance structure, the grade fluctuated between Good (B) and Medium (C), mainly due to changes in board independence. Board independence decreased from 43.75% in 2020 to 33.33% in 2024. Although it rebounded in some intermediate years, its stability remained insufficient. At the same time, the proportion of female mid- and senior-level managers increased, suggesting improvement in management gender diversity. Overall, governance structure still needs further optimization in terms of board independence and structural stability.

In terms of governance decision-making, Group ZN remained at the Medium (C) level for five consecutive years. The number of board meetings remained at approximately seven to eight per year, indicating that the company maintained regular decision-making frequency for major issues. From 2020 to 2024, the company disclosed a total of 833 information documents, reflecting continuous improvement in transparency. However, the overall improvement in governance decision-making was limited, indicating that meeting frequency and disclosure quantity alone are insufficient to fully improve governance effectiveness. Further efforts are needed to strengthen decision implementation tracking and information-based management.

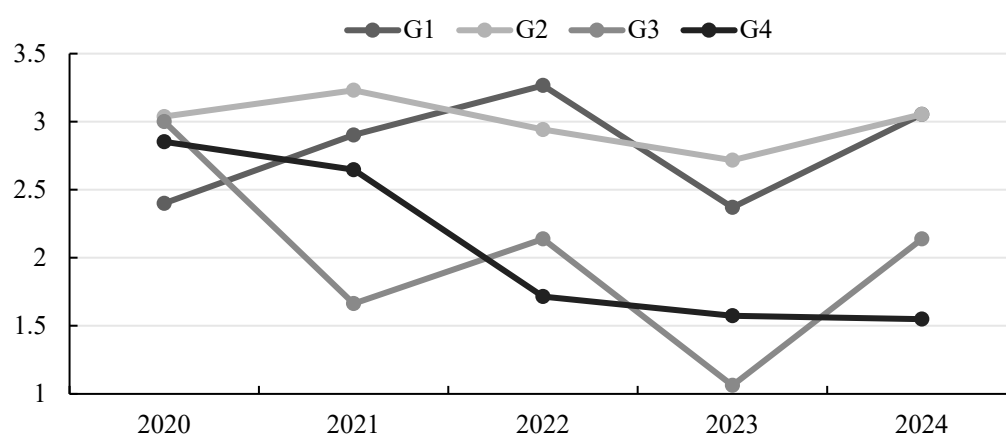
In terms of governance construction, Group ZN performed relatively well. The company continued to promote Party organization construction, anti-corruption initiatives, and risk management system development, and gradually increased quantitative disclosure related to integrity education, special training, and risk control. These measures are consistent with policy requirements for strengthening Party leadership in state-owned enterprises, improving internal control, and enhancing compliance management, which help reduce operational risks and strengthen governance foundations.

In terms of technological innovation, Group ZN improved from Medium (C) to Good (B), becoming an important driver of governance improvement. R&D investment intensity increased from 1.19% in 2020 to 1.95% in 2024, representing a growth rate of 63.87%. By 2024, the cumulative number of invention patents had reached 215, exceeding 200 for the first time. The company also established innovation performance studios and promoted the application of technologies such as smart mines, 5G, the Internet of Things, precise personnel positioning, remote control, and emergency command communication systems. In addition, digital technologies were integrated into financial management, human resource management, and data management. These technological and digital transformation measures enhanced governance capacity, although their synergy with environmental governance, production safety, and employee responsibility still needs to be further released.

In summary, the ESG evaluation results of Group ZN show that the company achieved overall grade improvement from 2020 to 2024, but the environmental dimension lagged behind, and some indicators in the social and governance dimensions still fluctuated. The annual changes in indicators were affected not only by internal management capacity but also by project construction cycles, policy implementation intensity, and the order of resource allocation. Based on the evaluation results of the sample enterprise, this study further identifies the main strengths, weaknesses, and formation mechanisms of Group ZN's ESG governance, thereby providing a basis for subsequent ESG governance optimization and further application of the evaluation framework.

Table 16. Evaluation results of secondary governance indicators.

Secondary Indicator	2020	2021	2022	2023	2024
G1 Governance Structure	2.3996	2.9015	3.2655	2.3698	3.0534
	Good	Medium	Medium	Good	Medium
G2 Governance Decision-Making	3.0372	3.2304	2.9415	2.7164	3.0534
	Medium	Medium	Medium	Medium	Medium
G3 Governance Construction	3.0002	1.6626	2.1380	1.0624	2.1378
	Medium	Good	Good	Excellent	Good
G4 Technological innovation	2.8517	2.6463	1.7146	1.5733	1.5487
	Medium	Medium	Good	Good	Good

**Figure 5.** Line chart of evaluation results for governance dimensions.

5. Suggestions for Improving ESG Governance in Group ZN

Based on the ESG evaluation results, the overall ESG performance of Group ZN shows a continuous upward trend, indicating that the company has made progress in implementing the “dual carbon” strategy, promoting energy transformation, and improving ESG governance. However, the evaluation results also show that the development of primary indicators remains uneven, and some secondary and tertiary indicators show relatively strong volatility. In particular, the environmental dimension remains at a medium level, with further room for improvement in resource utilization efficiency, environmental investment stability, and greenhouse gas emission intensity. Drawing on the decomposition logic of the DuPont analysis system, namely “overall objective–component factors–specific measures,” this study decomposes the ESG governance optimization objective of Group ZN into three paths: green transformation, intelligent transformation, and integrated development. Expected improvement targets are further set based on the evaluation results from 2020 to 2024 (as shown in Figure 6).

5.1. Green Transformation Path

The green transformation path mainly addresses the unbalanced development within the environmental dimension. The previous evaluation results show that Group ZN has achieved positive results in energy consumption control, wastewater reduction, coal gangue utilization, and ecological economy disclosure. Specifically, wastewater discharge intensity decreased by 63% over five years, and energy consumption intensity reached an excellent level in 2024. However, resource utilization efficiency remains below the industry average, while environmental investment and ecological restoration invest-

ment fluctuate significantly. As a result, the environmental dimension remains at a medium level. Therefore, the core objective of the green transformation path is to improve resource utilization efficiency and environmental investment stability while maintaining existing advantages in energy consumption and pollution control, so as to promote the environmental dimension from Grade C to Grade B.

The green transformation path can be decomposed into four aspects: energy consumption optimization, pollution emission standardization, resource utilization improvement, and environmental investment stabilization:

Green Transformation Improvement = Energy Consumption Optimization + Pollution Emission Standardization + Resource Utilization Improvement + Environmental Investment Stabilization

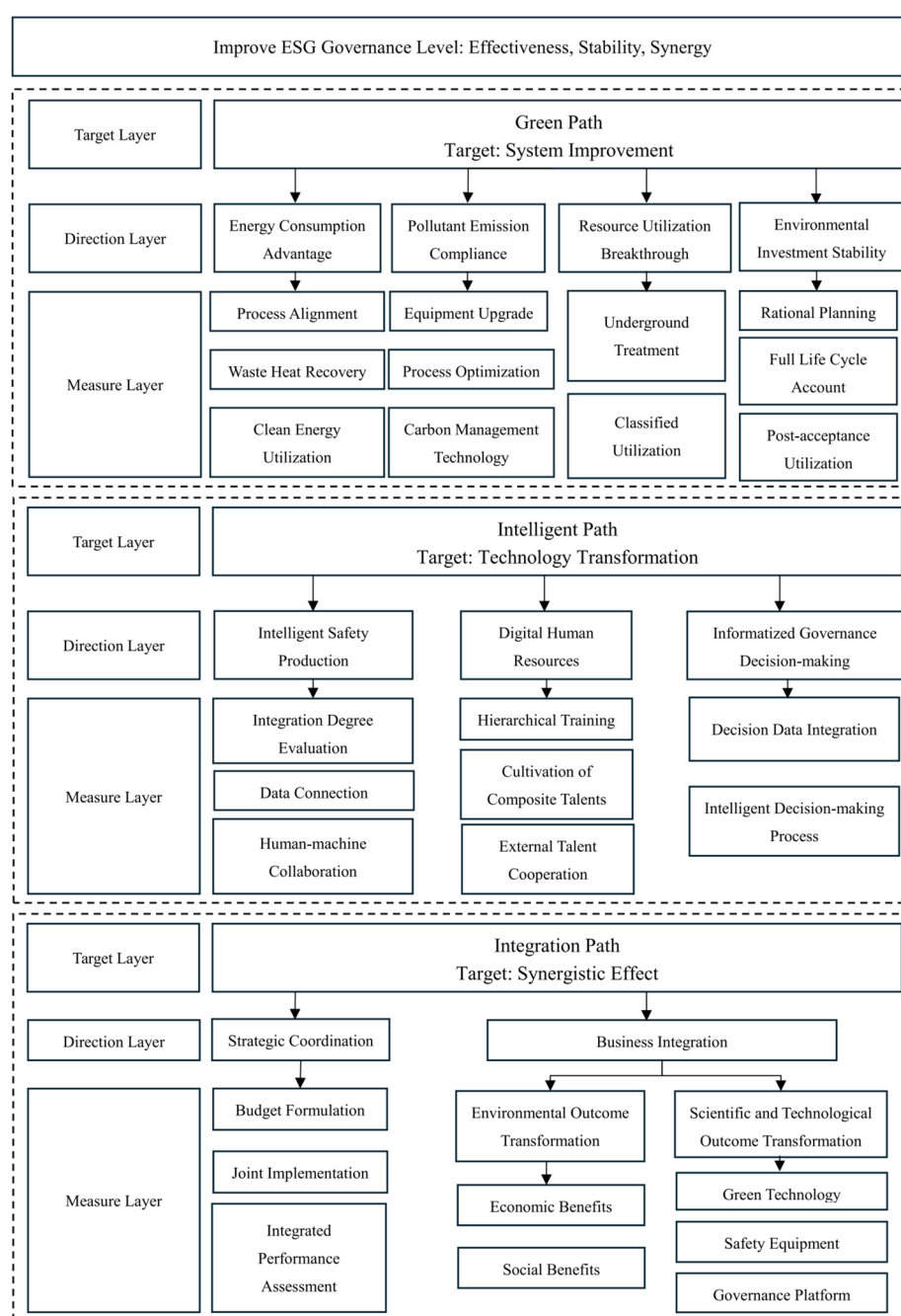


Figure 6. Suggestions for ESG governance improvement of ZN group.

In terms of energy consumption, Group ZN should continue to conduct energy consumption diagnosis for key processes and benchmark against advanced enterprises in the industry, focusing on high-energy-consuming processes such as coal washing, ventilation, and drainage. It should also promote waste heat recovery through ground-source heat pumps and develop photovoltaic power generation in mining areas. Through these measures, energy consumption indicators are expected to remain at a good level and achieve an additional improvement of approximately 3–5%.

In terms of pollution emissions, Group ZN should address the weakness of greenhouse gas emission intensity by promoting equipment upgrading, production process optimization, and carbon management technologies. By improving production equipment efficiency, optimizing coal washing and transportation processes, and exploring CCS/CCUS technologies, wastewater discharge intensity is expected to decline by a further 10–15% on the basis of the existing reduction, while greenhouse gas emission intensity is expected to improve gradually from a low level to a medium level.

In terms of resource utilization, Group ZN should focus on improving the mine water utilization rate. Mobile water treatment stations can be deployed to realize regional treatment and on-site reuse of mine water. Meanwhile, quality-based utilization should be implemented according to the water quality requirements of different scenarios, such as dust suppression, coal preparation, and ecological replenishment. For solid wastes such as coal gangue, backfill mining technology can be promoted to improve comprehensive utilization. Through these measures, the mine water utilization rate is expected to approach or reach the industry average, and resource utilization indicators are expected to improve from a relatively low level to a medium or higher level.

In terms of environmental investment, Group ZN should establish a full-lifecycle ledger for ecological restoration projects and include project approval, implementation, maintenance, and acceptance in unified management. The subsequent use of reclaimed land should also be included in acceptance criteria to reduce fluctuations caused by project cycles. Through these measures, the annual volatility of environmental protection investment is expected to decrease, and the stability of the environmental dimension score will be improved.

5.2. Intelligent Transformation Path

The intelligent transformation path mainly addresses the insufficient transformation of intelligent investment into governance performance. The evaluation results show that Group ZN has steadily increased R&D investment, achieved relatively rich technological innovation outputs, and applied intelligent equipment and digital technologies in production. As a result, the technological innovation score has continued to improve. However, indicators such as production safety, employee training coverage, board independence, and governance decision-making still fluctuate significantly, indicating that intelligent construction has not yet been fully converted into stable governance effectiveness. Therefore, the core objective of the intelligent transformation path is to promote the transformation from equipment investment to performance output and improve the stability of production safety, employee management, and governance decision-making.

The intelligent transformation path can be decomposed into three aspects: production safety intelligent transformation, human resource digitalization, and governance decision-making informatization:

$$\text{Intelligent Transformation Improvement} = \text{Safety Production Intelligent Transformation} + \text{Human Resource Digitalization} + \text{Governance Decision-making Informatization}$$

In terms of production safety, Group ZN should establish an evaluation mechanism for intelligent equipment application, incorporating equipment online rate, monitoring

data utilization rate, alarm information processing rate, and hidden-danger rectification rate into the annual safety assessment of mines. It should also connect production control systems with safety management systems and integrate monitoring data on gas, roof conditions, hydrology, and mine pressure to establish a unified safety perception platform. Through these measures, the annual volatility of production safety indicators is expected to decrease by approximately 20%, and safety governance performance will shift from phased improvement to stable improvement.

In terms of human resources, Group ZN should establish a hierarchical and categorized digital training system. Basic safety training and job-access training can be conducted through online courses and VR simulations to improve training coverage and record accuracy. Key skill training can be carried out through mentoring, practical exercises, and supplier-supported training. In addition, cooperation with universities and research institutions can be strengthened to cultivate interdisciplinary talents in “mining + information technology” and “mining + environmental protection.” Through these measures, employee training coverage is expected to remain at a relatively high level, and the volatility of employee responsibility indicators will be reduced.

In terms of governance decision-making, the previous results show that board independence decreased from 43.75% in 2020 to 33.33% in 2024, indicating the need to improve governance structure stability. Therefore, Group ZN should build an ESG indicator information platform to dynamically monitor energy consumption, safety warnings, environmental emissions, R&D investment, the proportion of independent directors, meeting attendance, and resolution completion. An online management system for board, supervisor, and executive meetings should also be established to record proposal submission, material distribution, meeting voting, resolution archiving, and implementation tracking. Through these measures, board independence is expected to gradually recover to around 40%, and the stability of governance decision-making indicators will be improved.

5.3. Integrated Development Path

The integrated development path mainly addresses the lack of coordination in resource allocation and the unsynchronized fluctuation of ESG indicators. The evaluation results show that the environmental, social, and governance dimensions of Group ZN are misaligned in some years, while indicators such as production safety investment and environmental protection investment also show certain time mismatches. This indicates that ESG governance still suffers from departmental fragmentation and resource competition. Therefore, the core objective of the integrated development path is to promote the shift from fragmented management to systematic governance through strategic coordination and business integrated development.

The integrated development path can be decomposed into two aspects: strategic coordination and business integrated development:

Integrated Development Improvement = Strategic Coordination + Business Integrated Development

In terms of strategic coordination, Group ZN should incorporate ESG issues such as production safety, environmental protection, technological innovation, employee training, and social responsibility into comprehensive budget management. A cross-departmental joint budgeting mechanism should be established to clarify departmental responsibilities and funding arrangements, thereby avoiding fragmented budgeting and repeated competition for resources. A joint budget execution and dynamic adjustment mechanism should also be established to track fund implementation, project progress, and expected benefits. Through these measures, the annual volatility of input indicators related to safety, environmental protection, technology, and human resources is expected to decrease by 15–20%, and the coordination among ESG dimensions will be improved.

In terms of business integrated development, Group ZN should promote the transformation of environmental governance results and technological innovation achievements into economic and social benefits. In the circular economy field, the company can improve project revenue contributions by stabilizing supply-demand relationships, expanding solid waste utilization scenarios, and deepening the high-value treatment of coal gangue. In the ecological economy field, the company can improve the continuous output capacity of ecological restoration projects through full-lifecycle project management, market-oriented operation, and ecological product value accounting. In terms of technological achievement transformation, ledgers should be established for technologies such as back-fill mining, water-preserved mining, gas reuse, slope monitoring, personnel positioning, and equipment status monitoring, with clear annual transformation targets and input–output evaluations. Through these measures, the transformation efficiency of technological achievements and the revenue contribution of circular economy projects are expected to increase gradually, further enhancing the internal driving force of ESG governance.

In summary, Group ZN should optimize ESG governance through the three paths of green transformation, intelligent transformation, and integrated development while maintaining its overall upward trend. The green transformation path focuses on promoting the environmental dimension from Grade C to Grade B; the intelligent transformation path focuses on reducing the volatility of production safety, employee responsibility, and governance decision-making indicators; and the integrated development path focuses on reducing the annual volatility of ESG input indicators and improving governance coordination. By setting measurable improvement targets, the proposed governance suggestions become more operational and enhance the practical value of the evaluation results.

6. Conclusions and Related Recommendations

6.1. Main Conclusions

In the context of heightened international and domestic attention to ESG, this study, grounded in sustainable development theory, stakeholder theory, and the triple bottom line theory, investigates the ESG governance effectiveness of coal enterprises. Using Group ZN as a case study, it constructs an ESG evaluation system applicable to the coal industry and employs the extension cloud model to comprehensively evaluate its ESG performance from 2020 to 2024. The main research conclusions are as follows.

First, this study develops an ESG evaluation indicator system adapted to the coal industry. The system consists of three primary indicators, 12 secondary indicators, and 34 tertiary indicators. While retaining the general logic of ESG evaluation, it incorporates industry-specific indicators related to resource consumption, pollutant emissions, mine water utilization, coal gangue utilization, production safety, intelligent equipment usage, ecological economy, and digital construction. This enhances the applicability of ESG evaluation to coal enterprises.

Second, this study establishes an extension cloud model for ESG evaluation in coal enterprises. Indicator weights are determined using the entropy weight method, and the five-grade evaluation set is constructed based on policy standards, industry sample data, and expert discussion. The model can process both quantitative and qualitative indicators, thereby improving the objectivity, interpretability, and operability of the evaluation process.

Third, the empirical results show that the comprehensive ESG grade of Group ZN improved from Medium (C) to Good (B) from 2020 to 2024, but the degree of improvement differed across the environmental, social, and governance dimensions. The environmental dimension remains the key constraint on further ESG improvement, while the social and governance dimensions performed relatively better overall, although some indicators still showed annual fluctuations. Based on the evaluation results, this study proposes three

optimization paths—green transformation, intelligent transformation, and integrated development—which provide practical directions for the subsequent improvement of ESG governance in Group ZN.

6.2. Limitations and Further Research Ideas

This study has several limitations that provide directions for further research. First, the ESG information disclosure system for Chinese coal enterprises is still being improved, and industry-specific mandatory disclosure requirements remain insufficiently detailed and standardized. As a result, environmental, social, and governance information disclosed by enterprises may differ in reporting scope, level of detail, and comparability. Due to data availability constraints, some evaluation indicators in this study still have room for further refinement and improvement. Future research can further optimize the indicator system as ESG disclosure standards for the coal industry become more complete, thereby improving industry adaptability and data comparability.

Second, the evaluation in this study is mainly based on corporate annual reports, social responsibility reports, ESG reports, and relevant database information. Although these data sources are accessible and traceable, publicly disclosed information may not fully capture the actual processes of environmental governance, internal management, and implementation effectiveness. Future studies can incorporate government regulatory data, industry association data, third-party rating data, field survey materials, and internal management data to construct a multi-source ESG evaluation database, thereby improving the completeness and robustness of the evaluation results.

Third, this study adopts a single-case design and evaluates Group ZN as the sample enterprise. This design helps reveal the dynamic characteristics and formation mechanisms of ESG governance performance in the sample enterprise. However, coal enterprises may differ substantially in resource endowments, mining-area locations, mining years, ownership structures, and development stages. Therefore, the external applicability of the findings still needs to be further examined using broader samples. Future research can conduct cross-sectional comparisons and longitudinal tracking studies of coal enterprises in different regions, types, and development stages to more comprehensively identify differences in ESG governance performance and their influencing factors.

Finally, this study mainly focuses on the construction of an ESG evaluation system and the measurement of ESG governance performance in coal enterprises, while the driving mechanisms and economic consequences of ESG performance are not examined in depth. Future research can use ESG evaluation results as explanatory or mediating variables to further investigate the relationships between ESG performance and enterprise value, operating performance, financing constraints, green innovation, and risk control. It can also examine the mechanisms through which green transformation, intelligent transformation, and integrated development contribute to ESG governance improvement. As ESG disclosure systems and digital management practices in coal enterprises continue to improve, future studies can combine dynamic evaluation models with long-term panel data to further reveal the impact mechanism of ESG governance on high-quality development.

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