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ESG FACTORS OF STRUCTURAL MODERNIZATION OF KAZAKHSTAN'S ECONOMY: SECTORAL DIFFERENCES AND DEVELOPMENT PRIORITIES

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Abstract. The transition to sustainable industrial development increases the importance of environmental, social, and managerial factors in the economy's structural modernisation. The aim of the study is to identify sectoral differences in the ESG transformation of Kazakhstan's key industries and to determine priority areas for their modernization. The empirical basis consists of official statistical data, materials from the Kazakhstan Stock Exchange, and regulatory documents for 2015–2025. The analysis used 2025 indicators for the mining, manufacturing, and energy sectors. We propose a method for creating an industry-specific ESG profile without combining indicators into a single rating. The Environmental component captures environmental protection costs and environmental investments; the Social component covers wages, their dynamics, and occupational safety; and the Governance component covers ESG disclosure, environmental monitoring, and sustainable financing mechanisms. Significant heterogeneity in industry ESG transformation has been identified. In the energy sector, environmental investments accounted for 87.9% of environmental expenditures and 11.08% of capital investments; in the manufacturing industry, they accounted for 35.2% and 0.18%, respectively; in the mining sector, they accounted for 9.8% and 0.52%, respectively. Despite the highest wages, the real wage index in the mining sector was 98.4%, compared to 102.5% in the manufacturing industry and 104.4% in the energy sector. The results substantiate the need for a differentiated ESG policy: for the extractive industry, technological environmental investments are a priority;

for the manufacturing industry, green innovations, deepening of processing, and digitalisation are priorities; for the energy sector, decarbonization, energy efficiency, and infrastructure renewal are key. The proposed approach makes it possible to account for sector-specific features when developing instruments of state regulation and investment policy, and when assessing the sustainability of structural transformations in the national economy.

Keywords: ESG, structural modernisation, industry, mining sector, manufacturing industry, energy, sustainable development, green investments, corporate governance, Kazakhstan

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ҚАЗАҚСТАН ЭКОНОМИКАСЫН ҚҰРЫЛЫМДЫҚ ЖАҢҒЫРТУДЫҢ ESG-ФАКТОРЛАРЫ: САЛАЛЫҚ АЙЫРМАШЫЛЫҚТАР МЕН ДАМУ БАСЫМДЫҚТАРЫ

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Аннотация. Тұрақты өнеркәсіптік дамуға көшу экономиканы құрылымдық жаңғыртудың экологиялық, әлеуметтік және басқару факторларының маңызын арттырады. Зерттеудің мақсаты-Қазақстанның базалық салаларының ESG-трансформациясының салалық айырмашылықтарын анықтау және оларды жаңғыртудың басым бағыттарын айқындау. Эмпирикалық негізді ресми статистикалық деректер, Қазақстан қор биржасының материалдары және 2015-2025 жылдарға арналған нормативтік құжаттар құрады. Көрсеткіштерді бірыңғай рейтингке біріктірмей салалық ESG-бейінін қалыптастыру әдісі

ұсынылды. Environmental - компонент табиғатты қорғау шығындары мен экологиялық инвестицияларды сипаттайды; Social-компонент – жалақы, оның нақты динамикасы және өндірістік қауіпсіздік; Governance-компонент – ESG-ақпаратты ашу, экологиялық мониторинг және тұрақты қаржыландыру тетіктері. Салалық ESG-трансформациясының айтарлықтай гетерогенділігі анықталды. Энергетикада экологиялық Инвестициялар табиғатты қорғау шығындарының 87,9% – и және күрделі салымдардың 11,08%–., өңдеу өнеркәсібінде тиісінше 35,2 және 3,18% –., тау-кен өндірісінде 9,8 және 0,52% -. құрады. Ең жоғары жалақыға қарамастан, өндіруші сектордағы нақты жалақы индексі 98,4%, өңдеу өнеркәсібіндегі 102,5% және энергетикадағы 104,4% құрады. Нәтижелер сараланған ESG саясатының қажеттілігін негіздейді: өндіруші сала үшін технологиялық экологиялық Инвестициялар, өңдеу саласы үшін – жасыл инновациялар, өңдеуді тереңдету және цифрландыру, Энергетика үшін – декарбонизация, энергия тиімділігі және инфрақұрылымды жаңарту басымдыққа ие. Ұсынылған тәсіл мемлекеттік реттеу, Инвестициялық саясат құралдарын әзірлеу және ұлттық экономиканың құрылымдық өзгерістерінің тұрақтылығын бағалау кезінде салалық ерекшеліктерді ескеруге мүмкіндік береді.

Түйін сөздер: ESG, құрылымдық жаңғырту, өнеркәсіп, тау-кен өндірісі, өңдеу өнеркәсібі, энергетика, тұрақты даму

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ESG-ФАКТОРЫ СТРУКТУРНОЙ МОДЕРНИЗАЦИИ ЭКОНОМИКИ КАЗАХСТАНА: ОТРАСЛЕВЫЕ РАЗЛИЧИЯ И ПРИОРИТЕТЫ РАЗВИТИЯ

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Аннотация. Переход к устойчивому промышленному развитию повышает значение экологических, социальных и управленческих факторов структурной модернизации экономики. Цель исследования – выявить отраслевые различия ESG-трансформации базовых отраслей Казахстана и определить приоритетные направления их модернизации. Эмпирическую основу составили официальные статистические данные, материалы Казахстанской фондовой биржи и нормативные документы за 2015–2025 гг. Межотраслевой анализ проведён по показателям 2025 г. для горнодобывающей, обрабатывающей промышленности и энергетики.

Предложен метод формирования отраслевого ESG-профиля без объединения показателей в единый рейтинг. Environmental-компонент характеризует природоохранные затраты и экологические инвестиции; Social-компонент – заработную плату, её реальную динамику и производственную безопасность; Governance-компонент – раскрытие ESG-информации, экологический мониторинг и механизмы устойчивого финансирования. Установлена существенная неоднородность отраслевой ESG-трансформации. В энергетике экологические инвестиции составили 87,9% природоохранных затрат и 11,08% капитальных вложений, в обрабатывающей промышленности – 35,2 и 3,18%, в горнодобывающей – 9,8 и 0,52% соответственно. Несмотря на наиболее высокую оплату труда, индекс реальной заработной платы в добывающем секторе составил 98,4%, против 102,5% в обрабатывающей промышленности и 104,4% в энергетике. Результаты обосновывают необходимость дифференцированной ESG-политики: для добывающей отрасли приоритетны технологические экологические инвестиции, для обрабатывающей – зелёные инновации, углубление переработки и цифровизация, для энергетике – декарбонизация, энергоэффективность и обновление инфраструктуры. Предложенный подход позволяет учитывать отраслевую специфику при разработке инструментов государственного регулирования, инвестиционной политики и оценке устойчивости структурных преобразований национальной экономики.

Ключевые слова: ESG, структурная модернизация, промышленность, горнодобывающий сектор, обрабатывающая промышленность, энергетика, устойчивое развитие, зелёные инвестиции, корпоративное управление, Казахстан

Introduction. Structural modernisation increasingly extends beyond resource reallocation and manufacturing growth. Technological innovation, climate regulation, sustainable finance, and non-financial reporting requirements are reshaping industrial competitiveness. Consequently, Environmental, Social, and Governance (ESG) factors have evolved from investment risk assessment tools into components of industrial, technological, and investment policies.

Research demonstrates the relationship between ESG performance and technological innovation. Improved ESG practices can reduce financial constraints and stimulate green innovation, while technological advances enhance environmental performance (Zhang et al., 2024; Yang et al., 2024). These effects vary across industries and depend on technological capabilities. Digital transformation similarly improves carbon performance through green innovation, particularly in technology-intensive manufacturing (Li et al., 2024).

Mining industries face specific ESG challenges related to emissions, resource consumption, occupational safety, community relations, and corporate governance, despite their strategic importance for the energy transition (Fikru et al., 2024).

Sectoral differentiation is particularly relevant to Kazakhstan. In 2025, industrial output reached KZT 62.6 trillion, with mining accounting for 44.3% and manufacturing for 49.1%, jointly representing over 93% of industrial production (Bureau of National Statistics, 2026). Industrial enterprises also generated 94.5% (KZT 768.9 billion) of national environmental protection expenditures totalling KZT 813.3 billion.

However, environmental expenditure levels do not necessarily indicate technological modernisation. Distinguishing current environmental costs from capital investments is essential for evaluating structural transformation. Similarly, the social dimension of ESG requires assessing real wages, occupational safety, value-added distribution, and human capital. At the same time, governance indicators should reflect environmental monitoring, disclosure, integrated permits, and Best Available Techniques (BAT).

The study aims to identify sectoral differences in ESG-driven structural modernisation of Kazakhstan's economy and determine transformation priorities for mining, manufacturing, and energy. The research systematises ESG influence mechanisms, develops comparable sectoral indicators, evaluates environmental and social performance, examines governance institutions, and identifies differentiated transformation models. The scientific novelty lies in developing sector-specific ESG profiles rather than aggregate ratings. This approach accounts for technological differences and prevents compensation between fundamentally distinct indicators: higher wages cannot offset insufficient environmental investment. In contrast, substantial environmental expenditures do not necessarily reflect technological modernisation.

Literature Review. The contemporary understanding of Environmental, Social, and Governance (ESG) is gradually expanding beyond the traditional boundaries of corporate finance and investment analysis. A growing body of research treats ESG as a driver of technological innovation, a mechanism for alleviating financial constraints, and a factor shaping corporate development models.

Using a sample of companies, Zhang et al. (2024) show that stronger ESG performance positively influences both the quantity and quality of green innovations. The authors identify three principal mechanisms underlying this relationship: resource allocation, managerial improvements, and innovation-related capabilities.

Cabaleiro-Cerviño and Mendi (2024) show that aligning innovation strategies with ESG practices can simultaneously influence both innovation-related and non-innovation performance indicators. This finding suggests that ESG should not be viewed merely as an external constraint on production activities but rather as an integral component of strategic management aimed at promoting technological development.

Yang et al. (2024) identify a positive relationship between green technological innovation and ESG performance in manufacturing enterprises. Their findings

further indicate that market-based environmental regulatory instruments can strengthen this relationship, with reductions in carbon intensity as one underlying mechanism.

A distinct stream of research focuses on the shift from end-of-pipe solutions, which treat pollutants after they are generated, to pollution prevention at the source through production-process modifications. Empirical studies suggest that ESG mechanisms can encourage a shift in green innovation toward source control, thereby promoting changes in production technologies themselves (Zhang et al., 2024).

This distinction is particularly important for analysing industrial modernisation in Kazakhstan. When an enterprise increases its operating expenditures on filtration systems, waste treatment, and compensation for environmental damage, it may improve compliance with environmental regulations without fundamentally transforming its underlying production technology. Structural modernisation, however, occurs when investments lead to changes in energy sources, production processes, raw material composition, processing intensity, or resource management systems.

In the manufacturing sector, green production development is also closely linked to digitalisation. Existing research indicates that intelligent manufacturing and digital technologies can enhance ESG performance by improving transparency, increasing resource efficiency, stimulating green innovation, and optimising supply chains.

The situation in the mining industry is more complex. The global energy transition is increasing demand for certain mineral resources while simultaneously intensifying concerns about the environmental and social consequences of extraction activities. Consequently, the ESG performance of mining companies is increasingly determined not only by emissions levels but also by water consumption, land reclamation, occupational safety, engagement with local communities, and transparency in corporate governance.

Thus, the sector-specific characteristics of ESG factors can be conceptually represented as follows:

$$ESG_i = f(E_i, S_i, G_i, T_i)$$

where E_i , S_i , and G_i represent the environmental, social, and governance dimensions of industry i , respectively, while T_i denotes its technological characteristics.

The technological dimension is particularly important because it explains why identical quantitative ESG indicators may have different economic and structural implications across industries. Accordingly, ESG performance should be interpreted within each sector's technological and institutional context rather than assessed exclusively through standardised aggregate indicators.

Materials and Methods. This study's methodological framework uses a comprehensive approach to assessing the structural and technological modernisation of Kazakhstan's industrial sector, incorporating environmental, social, and governance (ESG) criteria. The study covers 2015–2025, while the primary cross-sectoral analysis uses 2025 data, reflecting differences in publication frequency and the level of detail in official statistical information. For indicators reflecting long-term structural changes, dynamic analysis is employed where comparable time-series data are available.

The empirical foundation of the study comprises official statistical publications of the Bureau of National Statistics of the Republic of Kazakhstan, data from the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan, analytical reports of the Kazakhstan Stock Exchange (KASE), regulatory and legal documents concerning environmental regulation and sustainable finance, and findings from international studies addressing ESG transformation, green innovation, and industrial modernization (Cabaleiro-Cerviño & Mendi, 2024; Fikru et al., 2024; Li et al., 2024; Yang et al., 2024).

The study focuses on three major industrial sectors: mining and quarrying; manufacturing; and electricity, gas, steam, hot water, and air conditioning supply. In addition, selected comparative assessments incorporate indicators related to water supply, wastewater management, and waste treatment. We selected these sectors because of differences in capital intensity, environmental impacts, technological characteristics, and socioeconomic operating conditions.

The research methodology involves developing comparative sectoral ESG profiles that combine quantitative environmental and social indicators with a qualitative assessment of institutional corporate governance mechanisms. The environmental (E), social (S), and governance (G) dimensions are examined separately, without artificially aggregating them into a single composite index.

The environmental dimension (E) is assessed using indicators of environmental protection expenditures and investment activity. The first indicator measures the share of capital investment in environmental protection within total environmental protection expenditures:

$$E_{1,i} = \frac{I_i^{\text{env}}}{C_i^{\text{env}}} \times 100 \quad (1)$$

where I_i^{env} represents fixed capital investment in environmental protection in industry i ; C_i^{env} denotes total environmental protection expenditures in industry i , including current environmental protection expenditures and capital investments, provided that their statistical accounting is comparable.

The second indicator measures the environmental investment intensity of the industry:

$$E_{2,i} = \frac{I_i^{\text{env}}}{I_i^{\text{total}}} \times 100 \quad (1)$$

where I_i^{total} represents the total volume of fixed capital investment in the respective industry. In addition, the analysis examines growth rates of capital investment and industrial production volume indices, allowing comparison of investment activity with changes in industrial output.

The social dimension (S) is assessed using average monthly nominal wages, the real wage index, the share of employee compensation in gross value added, and occupational injury indicators. To assess relative wage levels across industries, the following coefficient is calculated:

$$WR_i = \frac{W_i}{W_{\text{economy}}} \quad (3)$$

where W_i - средн represents the average monthly wage of employees in industry i , and W_{economy} denotes the average monthly wage across Kazakhstan's economy. A coefficient greater than one indicates that the industry's average wage exceeds the national average, whereas a value below one indicates a relatively lower wage level.

The governance dimension (G) is analysed using a qualitative institutional approach. The assessment considers the development of ESG disclosure practices, environmental permitting mechanisms, the implementation of Best Available Techniques (BAT), automated emissions monitoring systems, the application of the green taxonomy, and the development of sustainable finance infrastructure, including financial instruments and information resources provided by the Kazakhstan Stock Exchange (KASE). The decision not to construct a hypothetical quantitative governance index is justified by the lack of standardised sectoral data needed to ensure comparability of corporate governance assessments. Similarly, environmental and social indicators are not aggregated using arbitrarily assigned weighting coefficients. In the final stage, a comparative cross-sectoral analysis identifies differences in environmental investment activity, social characteristics, and institutional readiness for ESG transformation. The findings are subsequently used to determine priorities for the structural and technological modernisation of Kazakhstan's key industrial sectors, taking into account sustainable development requirements.

Thus, the proposed methodology provides a comprehensive yet differentiated assessment of industrial ESG dimensions while maintaining transparent calculations and acknowledging the limitations of available statistical data.

Results. Assessing the dynamics of environmental protection expenditures constitutes an important stage in examining the financial and economic mechanisms underlying environmental sustainability and the implementation of ESG principles in Kazakhstan. The volume and composition of environmental

protection expenditures reflect how public authorities and business entities address environmental challenges by modernising production processes, introducing resource-efficient technologies, and reducing the adverse environmental impacts of economic activities. Analysing these indicators makes it possible to identify major trends in environmental financing, assess the consistency of investment priorities, and evaluate changes in the financial resources allocated to the economy's environmental modernisation.

During 2020–2025, environmental protection expenditures in Kazakhstan exhibited uneven dynamics, highlighting the need to examine their changes in relation to prevailing economic conditions, environmental regulatory requirements, and government policy priorities. To identify key trends and assess the scale of financing allocated to environmental protection measures, Table 1 presents the dynamics of these expenditures over the study period.

Table 1 — Dynamics of Environmental Protection Expenditures in Kazakhstan, 2020–2025

Year	Environmental Protection Expenditures, KZT billion	Change from Previous Year, %
2020	384.0	—
2021	417.0	+8.6
2022	444.5	+6.6
2023	610.3	+37.3
2024	456.1	–25.3
2025	813.3	+78.3

Source: Calculated based on data from the Bureau of National Statistics of the Republic of Kazakhstan.

In 2025, environmental protection expenditures were more than twice as high as in 2020. However, these expenditures were highly volatile, reflecting the implementation of large-scale investment projects and shifts in the composition of environmental expenditures.

Therefore, changes in total environmental protection expenditures alone cannot provide sufficient evidence of a continuous improvement in ESG performance. Changes in the expenditure structure are particularly significant. In 2025, of the total KZT 813.3 billion allocated to environmental protection, KZT 376.6 billion was capital investment, while KZT 436.7 billion was current expenditure. Thus, capital investment constituted 46.3% of total environmental protection expenditures (Bureau of National Statistics, 2026). Compared with 2024, expenditures on technology-related environmental measures increased sharply. Spending on energy-saving technologies and energy-efficiency improvements rose from approximately KZT 4.3 billion to KZT 127.5 billion. In contrast, expenditures associated with renewable energy sources reached KZT 179.3 billion (Bureau of National Statistics, 2026). These developments indicate a gradual shift in the environmental dimension of ESG, moving from predominantly compensatory environmental expenditures toward investments that could alter the technological characteristics of production.

The most substantial differences become evident when examining the sectoral structure of environmental investments.

Table 2 — Investment and Environmental Indicators of Kazakhstan's Key Industrial Sectors, 2025

Indicator	Mining and Quarrying	Manufacturing	Electricity, Gas and Heat Supply
Industrial production index, %	109.5	107.1	102.6
Fixed capital investment, KZT billion	3,348.8	2,981.3	2,226.1
Investment volume index, % of 2024	88.8	139.0	161.8
Total environmental protection expenditures, KZT billion	178.5	269.1	280.7
Environmental capital investment, KZT billion	17.4	94.8	246.6
Environmental investment as a share of total environmental protection expenditures, %	9.8	35.2	87.9
Environmental investment as a share of total sectoral fixed capital investment, %	0.52	3.18	11.08

Source: Authors' calculations based on data from the Bureau of National Statistics of the Republic of Kazakhstan.

Comparative analysis of Kazakhstan's key industrial sectors reveals substantial differences in environmental modernisation, particularly in the balance between current expenditures and capital investment. Three sector-specific transformation models can be identified, reflecting different levels of environmental investment intensity and integration into technological development.

Predominantly current environmental expenditures characterise mining and quarrying. In 2025, the fixed capital investment volume index declined to 88.8% of the previous year's level. Environmental protection expenditures totalled KZT 178.5 billion, including only KZT 17.4 billion in capital investment. Thus, approximately 90% represented current expenses, while environmental investment accounted for just 0.52% of total sectoral capital investment. This indicates limited investment intensity in environmental modernisation, although individual enterprises may implement large-scale projects.

Manufacturing demonstrates a more balanced transformation model. In 2025, industrial output rose 7.1%, while real fixed capital investment grew 39%. Environmental expenditures reached KZT 269.1 billion, including KZT 94.8 billion (35.2%) in capital investment, equivalent to 3.18% of total sectoral investment. These indicators suggest stronger integration of environmental objectives into industrial modernisation.

Manufacturing offers opportunities for structural transformation through deeper raw material processing, production digitalisation, and green technologies. Integrating these approaches can increase value added, improve resource efficiency, and reduce dependence on raw material exports. However, investment growth alone does not guarantee environmental improvements without coordinated industrial and environmental policies.

The electricity, gas, and heat supply sector demonstrates the strongest investment-oriented environmental transformation. In 2025, fixed capital investment increased by 61.8%, while environmental expenditures reached KZT 280.7 billion. Of this amount, KZT 246.6 billion (87.9%) represented capital investment, accounting for 11.08% of total sectoral investment.

This indicates substantial environmental modernisation efforts but does not necessarily confirm a transition to low-carbon energy. Investment effectiveness should also be assessed through emissions, energy intensity, generation technologies, and resource efficiency, since high expenditures may reflect accumulated infrastructure modernisation needs.

Overall, the sectors demonstrate distinct ESG transformation models: mining remains predominantly expenditure-oriented, manufacturing combines production growth with moderate environmental investment, and energy exhibits the highest capital investment intensity. These differences justify sector-specific ESG policies reflecting technological conditions and environmental risks.

Beyond environmental performance, the social dimension of ESG reflects how modernisation affects employment quality, wages, occupational safety, and human capital. Digitalisation and technological change increase workforce competency requirements, while productivity growth does not necessarily translate into improved working conditions or remuneration.

In 2025, Kazakhstan's average monthly nominal wage reached KZT 443.3 thousand, although substantial sectoral differences persisted. Table 3 compares key labour indicators to assess the social consequences of structural and technological modernisation across industrial sectors.

Table 3 — Social and Labour Characteristics of Kazakhstan's Key Industrial Sectors, 2025

Indicator	Mining and Quarrying	Manufacturing	Electricity, Gas and Heat Supply
Average monthly nominal wage, KZT	949,524	545,747	469,729
Ratio to the national average wage	2.14	1.23	1.06
Nominal wage index, %	109.6	114.2	116.4
Real wage index, %	98.4	102.5	104.4
Compensation of employees as a share of sectoral gross value added, %	22.5	27.2	43.1

Source: Compiled and calculated by the authors based on data from the Bureau of National Statistics of the Republic of Kazakhstan.

The comparative analysis of Kazakhstan's key industrial sectors reveals substantial differences in wages, real income dynamics, and labour compensation shares in gross value added (GVA). These findings highlight the importance of assessing ESG social performance through multiple indicators, not nominal remuneration alone.

Mining and quarrying recorded the highest average monthly wages in 2025, more than double the national average. However, the real wage index reached

only 98.4%, indicating a 1.6% decline in purchasing power. Thus, high nominal remuneration does not necessarily improve employee welfare.

Manufacturing wages exceeded the national average by 23%, while real earnings increased by 2.5%. Combined with production and investment growth, these trends suggest relatively favourable social developments, although further assessment of productivity, employment structure, and wage disparities is required.

The electricity, gas, and heat supply sector recorded lower nominal wages than mining but achieved the strongest real wage growth of 4.4%. This coincided with substantial investment activity, although additional econometric analysis is needed to establish a causal relationship between investment and wage growth.

Labour compensation accounted for 22.5% of GVA in mining, 27.2% in manufacturing, and 43.1% in energy. Despite the highest wages, mining had the lowest compensation share, reflecting differences in capital intensity and value-added structures. Although this indicator does not independently measure social equity, it complements wage-based assessments of labour's participation in economic value distribution.

Overall, wage levels, purchasing power dynamics, and compensation shares show different sectoral patterns, confirming the need for a multidimensional ESG assessment that incorporates remuneration, productivity, and working conditions.

Occupational health and safety represents another essential social indicator, particularly in capital-intensive industries with hazardous production processes. In Kazakhstan, 2,328 occupational accidents were recorded in 2025, representing a 5.8% annual decline. Official statistics reported 255 injured workers in manufacturing and 130 in mining and quarrying (Bureau of National Statistics of the Republic of Kazakhstan, 2026).

Despite the overall improvement, occupational risks remain significant. However, absolute injury figures cannot provide objective intersectoral comparisons without accounting for employment levels and production characteristics. Therefore, a relative occupational injury rate is proposed for comparative ESG assessment, calculated as follows:

$$IR_i = \frac{N_i}{L_i} \times 1000$$

where IR_i - represents the occupational injury rate in industry i , expressed as the number of injured workers per 1,000 employees; N_i - denotes the number of employees injured in occupational accidents in industry i ; and L_i - represents the average annual number of employees in the respective industry.

The relative occupational injury rate improves intersectoral comparability, although comprehensive social sustainability assessment should also consider fatalities, lost working time, occupational diseases, and preventive measures. Digital technologies, including robotics, remote equipment control, the Industrial Internet of Things (IIoT), and intelligent monitoring, can reduce occupational risks

while improving productivity and operational safety. However, their effectiveness depends on technological reliability, employee competencies, and occupational risk management.

Thus, digital modernisation can generate economic and social benefits simultaneously. Incorporating occupational safety indicators into sector-specific ESG assessments enables consideration of technological transformation's effects on working conditions and human capital.

Unlike environmental and social indicators, the governance dimension (G) reflects institutional mechanisms supporting transparency, investment efficiency, and compliance with sustainability requirements. It encompasses corporate governance, ESG disclosure, environmental regulation, technological monitoring, and sustainable finance. These mechanisms operate at governmental, financial market, and corporate levels.

In Kazakhstan, governance infrastructure developed further in 2025. On June 9, the Kazakhstan Stock Exchange (KASE) launched its ESG Data Platform, providing centralised access to corporate sustainability reports, ESG bond information, methodological guidance, and educational resources (KASE, 2025). The platform improved information accessibility and transparency, building on previously established reporting recommendations rather than introducing mandatory ESG disclosure for all enterprises. Its effectiveness depends on data completeness, comparability, reliability, and practical use in investment decisions.

Another important mechanism is implementing Best Available Techniques (BAT) and integrated environmental regulation. By the end of 2025, BAT implementation measures covered 21 major industrial enterprises, while 22 applications for integrated environmental permits were under review. Automated emissions monitoring systems operated at 87 enterprises, including 81 transmitting data to the authorised government agency (Ministry of Ecology and Natural Resources of the Republic of Kazakhstan, 2026).

These developments indicate a transition towards technology-oriented environmental regulation, encouraging equipment modernisation, process improvements, and systematic monitoring. Digital environmental control increases data traceability and reduces information asymmetry. For capital-intensive industries, integrating BAT requirements into long-term investment programs is particularly important.

The national green taxonomy is another governance instrument that links environmental priorities with sustainable financing. Established by Government Resolution No. 996 of December 31, 2021, and amended by Resolution No. 215 of April 8, 2025, it defines criteria for projects eligible for green bonds and loans (Government of the Republic of Kazakhstan, 2025). Priority areas include energy efficiency, resource conservation, pollution reduction, climate mitigation, and adaptation.

However, taxonomy compliance does not automatically guarantee

environmental effectiveness, which depends on project selection, technical implementation, capital utilisation, and outcome monitoring.

Overall, Kazakhstan's governance transformation combines ESG information disclosure, technology-oriented environmental regulation, and sustainable investment classification. These mechanisms strengthen institutional conditions for industrial modernisation but do not ensure uniform effectiveness across sectors.

Synthesising the environmental, social, and governance findings reveals substantial intersectoral differences in environmental expenditure structures, investment intensity, real wages, value-added distribution, and institutional modernisation. These differences demonstrate the limitations of universal ESG ratings, which may obscure variations in capital intensity, technological characteristics, and environmental risks.

Accordingly, the study proposes a sector-specific ESG typology comparing environmental, social, and governance characteristics without combining heterogeneous indicators into a single composite score. The resulting matrix identifies distinct transformation models and modernisation priorities for mining, manufacturing, and energy, as presented in Table 4.

Table 4 — Sector-Specific Characteristics of ESG Transformation in Kazakhstan's Key Economic Sectors

Dimension	Mining and Quarrying	Manufacturing	Energy Sector
E: Nature of environmental impact	High resource intensity and environmental pressures	Varies considerably across subsectors	High carbon and energy intensity
E: Share of environmental capital expenditure	Low relative to current expenditures	Moderate	Very high
E: Main priority	Pollution prevention and resource efficiency	Green technologies and circularity	Decarbonization and modernisation of generation capacity
S: Wage levels	Significantly above the national average	Above the national average	Relatively close to the average industrial wage level
S: Real wage dynamics in 2025	Decline	Increase	Stronger increase
S: Main risk	Hazardous working conditions and skills transition	Occupational safety and shortages of technical personnel	Obsolescence of skills and infrastructure
G: Key mechanism	BAT, environmental monitoring, and ESG disclosure	Supply chain standards and ESG reporting	Tariff and investment mechanisms and BAT
Technological priority	Automation and reduced resource and energy intensity	Advanced processing and Industry 4.0	Low-carbon generation, power grids, and energy storage

Source: Developed by the authors.

The integrated sectoral ESG matrix reveals substantial differences in

how environmental, social, and governance factors influence structural and technological modernisation across Kazakhstan's key industries. These differences reflect sector-specific production technologies, capital intensity, environmental pressures, investment structures, and value-added generation, confirming the need for differentiated ESG transformation strategies.

Mining and quarrying require a transition from expenditure-oriented environmental compliance towards investment-driven technological modernisation. In 2025, environmental capital investment accounted for less than 10% of total environmental protection expenditures, indicating the predominance of current operating costs.

Priority measures include electrifying and automating mining equipment to reduce technological losses and emissions, introducing closed-loop water systems, processing industrial waste, and restoring disturbed land. Digital environmental monitoring can improve transparency and risk management. These measures should be combined with deeper mineral processing and domestic value-chain development to reduce resource intensity and dependence on raw material exports.

Manufacturing demonstrates opportunities to integrate ESG principles with technological innovation and economic diversification. In 2025, fixed capital investment increased by 39% in real terms, industrial output grew by 7.1%, and environmental capital investment represented 35.2% of environmental protection expenditures.

Key priorities include deeper raw material processing, resource-efficient and low-waste technologies, recycling, industrial automation, the Industrial Internet of Things, digital twins, energy-efficient equipment, and supply chain traceability. These innovations can improve productivity, increase value added, and reduce environmental impacts. Consistent with Yang et al. (2024), green technological innovation and reduced financial constraints can strengthen corporate ESG performance. Therefore, manufacturing ESG transformation should support structural diversification and international competitiveness through coordinated industrial and environmental policies.

The electricity, gas, and heat supply sector demonstrates the strongest environmental investment orientation, with capital investment accounting for 87.9% of environmental protection expenditures in 2025. However, this indicator may reflect accumulated infrastructure modernisation needs rather than an established low-carbon development model.

Priority areas include replacing carbon-intensive generation facilities, upgrading electricity and heating networks, reducing technical losses, expanding renewable energy, introducing energy storage and flexible generation capacity, and implementing digital demand-side management.

The energy sector's ESG transformation requires coordinating environmental investment with governance mechanisms. Long investment cycles and regulated operating conditions necessitate predictable regulation, appropriate cost-recovery

mechanisms, and long-term investment incentives. Assess effectiveness through emissions intensity, energy efficiency, supply reliability, and infrastructure flexibility rather than investment volumes alone.

Overall, three distinct ESG modernisation models emerge: mining prioritises resource efficiency and cleaner production; manufacturing focuses on green innovation, deeper processing, and diversification; and energy emphasises infrastructure renewal, decarbonisation, and power system flexibility. These findings substantiate the need for sector-specific ESG policies aligned with technological conditions, investment requirements, and long-term structural development objectives.

These pathways can be summarised as follows:

Mining and Quarrying

Environmental Compliance → Resource Efficiency → Cleaner Technologies

Manufacturing

Innovation → Advanced Processing → Green Competitiveness

Energy Sector

Infrastructure Modernisation → Decarbonization → Energy System Flexibility

The identified differentiation confirms that mechanically applying a uniform set of ESG indicators across industries is methodologically inappropriate.

Despite common sustainable development principles, performance indicators for structural and technological modernisation should reflect specific production processes, resource consumption patterns, and sectoral environmental risks.

For example, the share of renewable energy in the generation mix is directly relevant to the electricity sector. At the same time, more informative indicators for mining include specific energy and water consumption, mineral recovery rates, the extent of land reclamation, and industrial waste-management efficiency. For metallurgical production, priority indicators include specific pollutant and greenhouse gas emissions per tonne of output, the energy intensity of technological processes, the share of recycled raw materials, and the degree of processing. In mechanical engineering, relevant indicators include production equipment energy efficiency, automation levels, innovation activity, enterprise digital maturity, and supply chain sustainability. Therefore, the development of sector-specific ESG key performance indicators (KPIs) should be based on technological relevance, quantitative measurability, and the ability to assess actual modernisation outcomes.

The synthesis of the research findings provides a basis for distinguishing between economy-wide and sector-specific priorities for the structural and technological modernisation of Kazakhstan's economy. Economy-wide priorities establish the institutional, organisational, and economic conditions for ESG transformation, including improved sustainable financing mechanisms, the development of digital

monitoring infrastructure, increased corporate governance transparency, incentives for technological innovation, and enhanced workforce training systems.

At the same time, sector-specific priorities must reflect the particular characteristics of production processes, environmental pressures, capital investment structures, and labour relations. The proposed approach involves coordinating three interrelated objectives: improving technological efficiency, reducing adverse environmental impacts, and ensuring positive socioeconomic outcomes from modernisation. The selection of specific instruments should therefore be determined not only by the availability of investment resources but also by their capacity to generate measurable structural, environmental, and social improvements.

Based on the identified sectoral differences, a matrix of priority ESG modernisation measures has been developed, systematising the key technological transformations, implementation mechanisms, and expected outcomes for Kazakhstan's major economic sectors.

Table 5 — Matrix of Priority Areas for Structural and Technological ESG Modernisation in Kazakhstan's Key Economic Sectors

Sector / Area	Priority Measures	Expected Outcomes
Mining and Quarrying	Resource conservation, automation, waste recycling, environmental monitoring	Reduced resource intensity and environmental impacts
Manufacturing	Advanced processing, digitalisation, low-waste technologies, energy efficiency	Higher value added and improved green competitiveness.
Energy Sector	Modernisation of generation facilities and networks, renewable energy, energy storage, digital management	Reduced carbon intensity and increased power system flexibility
Cross-Sectoral Governance	ESG reporting, green taxonomy, sustainable finance, BAT implementation	Greater transparency and improved investment effectiveness
Social Modernization	Occupational safety, workforce upskilling, development of digital competencies	Improved employment quality and greater human capital resilience

Note: Developed by the author based on the research findings.

The analysis identifies common priorities for ESG modernisation across Kazakhstan's industrial sectors, including technological renewal, digital environmental monitoring, occupational safety, and transparent sustainability reporting. However, implementation approaches differ according to sector-specific technological and investment characteristics.

Mining requires deeper raw material processing, improved resource efficiency, and increased environmental investment. Manufacturing should prioritise green technologies, higher-value-added production, and technological competitiveness. The energy sector faces substantial capital requirements for modernising generation facilities, electricity networks, and low-carbon infrastructure.

Consequently, modernisation effectiveness depends not only on investment volumes but also on how they are allocated to productivity growth, environmental improvements, and social sustainability. The governance dimension (G) is particularly important because it connects environmental objectives with investment planning, resource allocation, monitoring, and performance evaluation.

Weak governance mechanisms, including insufficient ESG disclosure, unclear responsibilities, inadequate performance indicators, and limited independent verification, may reduce investment effectiveness and increase greenwashing risks.

In Kazakhstan, the KASE ESG Data Platform and national green taxonomy create opportunities to improve corporate transparency, standardise sustainable investment criteria, and reduce information asymmetry. However, their effectiveness depends on data reliability, methodological consistency, regular updates, and independent verification.

Therefore, governance improvements should prioritise comparable sector-specific ESG indicators and monitoring of actual investment outcomes. Key indicators include greenhouse gas emissions per unit of output, energy and water intensity, waste recycling rates, occupational injuries, and environmental capital investment.

The corresponding indicators can be expressed as follows:

$$ESG_{KPI} = \left\{ \frac{CO_{2e}}{Q}; \frac{E}{Q}; \frac{W}{Q}; R_w; IR; CAPEX_{ESG} \right\}$$

where CO_{2e} represents greenhouse gas emissions expressed in carbon dioxide equivalents per unit of output; E/Q denotes the energy intensity of production; W/Q represents water intensity; R_w is the proportion of recycled waste; IR is the occupat; $CAPEX_{ESG}$ denotes environmental capital investment. The proposed indicator system does not constitute a composite index. Instead, it provides complementary criteria for monitoring the environmental, social, and investment-related outcomes of modernisation.

Practical application requires considering sector-specific technologies, using comparable measurement units, and applying consistent calculation methodologies. Particular importance should be attached to shifting the emphasis from assessing absolute environmental protection expenditures toward evaluating the effectiveness of invested capital. This approach involves comparing environmental capital investment with observed changes in emissions intensity, energy and water consumption, waste generation and recycling volumes, and occupational safety indicators. For an accurate assessment of investment effectiveness, it is also necessary to account for the time lag between capital expenditure and the realisation of environmental benefits, since major technological projects may take several years to complete. Consequently, improvements in governance mechanisms should focus on establishing a transparent and measurable management system

for structural and technological modernisation that aligns investment decisions with sector-specific ESG priorities. Such a system can improve the justification and allocation of capital resources, strengthen investor confidence, and create the institutional conditions needed to shift from a predominantly expenditure-oriented environmental protection model to one focused on achieving specific technological, environmental, and socioeconomic outcomes.

Discussion. The findings confirm that Environmental, Social, and Governance (ESG) factors influence structural and technological modernisation differently across Kazakhstan's industrial sectors. These differences reflect environmental expenditure structures, production technologies, capital intensity, value-added distribution, and institutional governance mechanisms. Consequently, ESG assessment should consider not only expenditure volumes but also their investment orientation and technological outcomes.

The first finding concerns sectoral differences in environmental expenditure structures. In 2025, environmental capital investment accounted for 87.9% of environmental protection expenditures in the energy sector, compared with 35.2% in manufacturing and less than 10% in mining. This indicates distinct environmental modernisation models, ranging from current expenditure-oriented compliance to investment-driven technological renewal.

Although capital investment creates opportunities for equipment modernisation and resource-efficient technologies, it does not automatically guarantee environmental improvements. Similarly, current expenditures may support effective environmental protection. Therefore, assess investment structures alongside actual changes in emissions, energy intensity, water consumption, and productivity.

The second finding highlights differences in social performance. Despite the highest nominal wages, mining recorded a real wage index of 98.4% in 2025, while real wages increased by 2.5% in manufacturing and 4.4% in energy. Differences in employee compensation shares in gross value added further demonstrate variations in income distribution.

These results confirm that nominal wages alone cannot adequately measure ESG social performance. A comprehensive assessment should incorporate real earnings, occupational safety, employment quality, and workforce development. Digitalisation and automation can improve productivity and reduce occupational risks but also increase demand for new competencies, making retraining and human capital development essential.

The third finding concerns institutional governance. Kazakhstan's development of integrated environmental permitting, Best Available Techniques (BAT), automated emissions monitoring, ESG disclosure infrastructure, and green taxonomy strengthens the institutional foundations of sustainable industrial development.

However, these mechanisms do not automatically produce environmental or

social improvements. Their effectiveness depends on integrating ESG requirements into corporate investment strategies, risk management, and performance evaluation. Transparent, comparable, and verifiable indicators are necessary to assess actual outcomes, reduce information asymmetry, and prevent formal compliance and greenwashing.

The fourth finding demonstrates the importance of sector-specific ESG assessment. Consistent with Zhang et al. (2024) and Yang et al. (2024), the effects of ESG factors and green innovation depend on industry characteristics, technological capabilities, and financial resources.

For mining, priority indicators include resource efficiency, technological losses, land reclamation, and extraction-related environmental impacts. For manufacturing, relevant criteria include processing depth, energy intensity, secondary raw material utilisation, and green innovation. For energy, carbon intensity, infrastructure efficiency, generation technologies, and power system flexibility are particularly important.

Accordingly, ESG assessment should combine standardised indicators that ensure intersectoral comparability with industry-specific criteria that reflect technological and environmental differences. Universal composite ratings may obscure these characteristics and weaken investment decision-making.

The study's scientific significance lies in extending ESG assessment beyond environmental expenditure and formal reporting to an integrated analysis of investment orientation, technological performance, social sustainability, and institutional governance. This approach considers ESG transformation as a potential driver of resource efficiency, industrial diversification, higher value added, and long-term economic resilience.

Nevertheless, the findings are comparative and analytical rather than causal. Establishing the direct effects of ESG factors on structural modernisation requires further econometric analysis and enterprise-level empirical evidence.

Conclusion. This study identified sector-specific ways environmental, social, and institutional governance factors influence the structural and technological modernisation of Kazakhstan's key economic sectors. The findings indicate that ESG principles are becoming increasingly important in shaping investment priorities, upgrading production infrastructure, and improving mechanisms for sustainable industrial development. However, the nature and intensity of ESG transformation vary considerably by production technology, sectoral capital intensity, and investment allocation patterns.

The analysis established that industrial enterprises accounted for 94.5% of Kazakhstan's total environmental protection expenditures in 2025, although the composition of these expenditures differed substantially across sectors. The electricity sector showed the strongest investment orientation, with environmental capital investment accounting for 87.9% of total environmental protection expenditures and 11.08% of total fixed capital investment. The corresponding

figures were 35.2% and 3.18% in manufacturing, compared with 9.8% and 0.52% in mining and quarrying. These differences reflect distinct financing structures for environmental modernisation and highlight the importance of distinguishing current environmental expenditures from investments that could drive technological transformation.

The assessment of the social dimension of ESG also revealed heterogeneous sectoral outcomes. Although mining and quarrying maintained the highest absolute wage levels, exceeding the national average by more than twofold, real wages declined in 2025. By contrast, manufacturing and the energy sector recorded positive real wage dynamics. These findings confirm the need for a comprehensive assessment of the social outcomes of modernisation that considers not only wage levels but also purchasing power, occupational safety, professional skills development, and employment quality.

The study further established that the development of environmental regulatory mechanisms characterises the institutional governance dimension of ESG in Kazakhstan, the implementation of Best Available Techniques, the expansion of integrated environmental permitting, the digitalisation of emissions monitoring, improvements in the national green taxonomy, and the development of ESG disclosure infrastructure at the Kazakhstan Stock Exchange. These instruments create favourable conditions for greater investment transparency, improved corporate governance, and closer alignment between environmental requirements and technological development objectives. However, their effectiveness depends on how fully ESG criteria are incorporated into investment decisions and whether the resulting environmental and socioeconomic outcomes can be objectively measured.

The study's principal scientific contribution is justifying a differentiated approach to structural and technological ESG modernisation across key economic sectors. For mining and quarrying, the priority is to shift from predominantly current environmental protection expenditures toward increased investment in resource-efficient technologies, production automation, and advanced processing of mineral raw materials. In manufacturing, the main directions include adopting green innovation, digitalisation, circular production models, and a greater share of higher-value-added products. For the energy sector, key priorities include modernising capital-intensive infrastructure, gradually decarbonising electricity generation, improving energy efficiency, and ensuring reliable energy supply.

Based on these findings, the study proposes a methodological approach to assessing ESG transformation that combines standardised sustainable development principles, sector-specific performance indicators, and technologically oriented modernisation instruments. This approach accounts for differences in environmental impacts, investment requirements, and production processes, providing a more robust assessment of structural changes than applying universal ESG criteria alone.

In conclusion, Kazakhstan's structural and technological modernisation should

integrate common ESG principles with sector-specific technological characteristics and measurable investment outcomes. This approach can shift environmental management from a compliance- and expenditure-oriented model to an investment- and innovation-driven model of sustainable industrial development. Such a transition should focus on improving resource efficiency, expanding higher-value-added production, developing human capital, and strengthening the national economy's long-term competitiveness.

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