

# MUHANDISLIK

## & IQTISODIYOT

ijtimoiy-iqtisodiy, innovatsion texnik,  
fan va ta'limga oid ilmiy-amaliy jurnal

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08.00.00 - Iqtisodiyot fanlar



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ИМЕНИ Г.В. ПЛЕХАНОВА  
ТАШКЕНТСКИЙ ФИЛИАЛ



# **muhandislik** **& iqtisodiyot**

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**Xolmirzayev Ulug'bek Abdulazizovich**, Iqtisodiyot fanlari doktori (DSc)

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05.01.01 – Muhandislik geometriyasi va kompyuter grafikasi. Audio va video texnologiyalari  
05.01.02 – Tizimli tahlil, boshqaruv va axborotni qayta ishlash  
05.01.03 – Informatikaning nazariy asoslari  
05.01.04 – Hisoblash mashinalari, majmualari va kompyuter tarmoqlarining matematik va dasturiy ta'minoti  
05.01.05 – Axborotlarni himoyalash usullari va tizimlari. Axborot xavfsizligi  
05.01.06 – Hisoblash texnikasi va boshqaruv tizimlarining elementlari va qurilmalari  
05.01.07 – Matematik modellashtirish  
05.01.11 – Raqamli texnologiyalar va sun'iy intellekt  
05.02.00 – Mashinasozlik va mashinashunoslik  
05.02.08 – Yer usti majmualari va uchish apparatlari  
05.03.02 – Metrologiya va metrologiya ta'minoti  
05.04.01 – Telekommunikatsiya va kompyuter tizimlari, telekommunikatsiya tarmoqlari va qurilmalari. Axborotlarni taqsimlash  
05.05.03 – Yorug'lik texnikasi. Maxsus yoritish texnologiyasi  
05.05.05 – Issiqlik texnikasining nazariy asoslari  
05.05.06 – Qayta tiklanadigan energiya turlari asosidagi energiya qurilmalari  
05.06.01 – To'qimachilik va yengil sanoat ishlab chiqarishlari materialshunosligi  
05.08.03 – Temir yo'l transportini ishlatish  
05.08.06 – "G'ildirakli va gusenisali mashinalar va ularni ishlatish" (texnika fanlari)  
05.09.01 – Qurilish konstruksiyalari, bino va inshootlar  
05.09.04 – Suv ta'minoti. Kanalizatsiya. Suv havzalarini muhofazalovchi qurilish tizimlari  
10.00.06 – Qiyosiy adabiyotshunoslik, chog'ishtirma tilshunoslik va tarjimashunoslik  
10.00.04 – Yevropa, Amerika va Avstraliya xalqlari tili va adabiyoti  
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08.00.03 – Sanoat iqtisodiyoti  
08.00.04 – Qishloq xo'jaligi iqtisodiyoti  
08.00.05 – Xizmat ko'rsatish tarmoqlari iqtisodiyoti  
08.00.06 – Ekonometrika va statistika  
08.00.07 – Moliya, pul muomalasi va kredit  
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08.00.09 – Jahon iqtisodiyoti  
08.00.10 – Demografiya. Mehnat iqtisodiyoti  
08.00.11 – Marketing  
08.00.12 – Mintaqaviy iqtisodiyot  
08.00.13 – Menejment  
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08.00.16 – Raqamli iqtisodiyot va xalqaro raqamli integratsiya  
08.00.17 – Turizm va mehmonxona faoliyati

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# A METHODOLOGICAL FRAMEWORK FOR ASSESSING THE EFFICIENCY OF GREEN INNOVATIONS IN METALLURGICAL ENTERPRISES: EVIDENCE FROM NKMK JSC



**Shakhruza Bohodir qizi Makhkamova**

Doctoral Student

Tashkent State Technical University named after Islam Karimov

E-mail: [makhkamova.shakhruza.1995@mail.ru](mailto:makhkamova.shakhruza.1995@mail.ru)

**Abstract.** This article explores the theoretical and methodological foundations for assessing the efficiency of green innovations in metallurgical industry enterprises and presents a practical analysis based on the case of NKMK JSC. The study substantiates the importance of a comprehensive approach to evaluating green innovations in metallurgical enterprises, emphasizing that assessment should encompass not only economic outcomes but also environmental, social, and institutional indicators. The author proposes a generalized methodological framework based on a system of indicators for evaluating the efficiency of green innovations. Using the example of NKMK JSC, the research highlights key achievements and priority areas related to energy efficiency, rational resource utilization, waste reduction, environmental sustainability, and production performance enhancement. The study identifies the most significant criteria for evaluating green innovative activities and demonstrates their contribution to enterprise development. The findings provide valuable practical insights for strengthening sustainable development strategies, enhancing innovation management practices, and accelerating green transformation processes in metallurgical industry enterprises.

**Keywords:** Green innovations, metallurgical industry, NKMK JSC, efficiency assessment, environmental and economic efficiency, resource conservation, energy efficiency, sustainable development, innovation management, industrial enterprise.

**Annotatsiya.** Mazkur maqolada metallurgiya sanoati korxonalarida yashil innovatsiyalar samaradorligini baholashning nazariy va uslubiy asoslari tadqiq etilib, "NKMK" AJ misolida amaliy tahlil amalga oshirilgan. Tadqiqotda metallurgiya korxonalarida yashil innovatsiyalarni baholash faqat iqtisodiy natijalar bilan cheklanmasdan, ekologik hamda ijtimoiy-institutsional ko'rsatkichlarni ham qamrab oluvchi kompleks yondashuv asosida amalga oshirilishi muhimligi asoslab berilgan. Muallif tomonidan yashil innovatsiyalar samaradorligini baholash uchun ko'rsatkichlar tizimiga tayanuvchi umumlashtirilgan metodik yondashuv taklif etilgan. "NKMK" AJ misolida energiya samaradorligini oshirish, resurslardan oqilona foydalanish, chiqindilarni qisqartirish, ekologik barqarorlikni ta'minlash hamda ishlab chiqarish samaradorligini yuksaltirish bilan bog'liq ustuvor yo'nalishlar tahlil qilinib, yashil innovatsion faoliyatni baholashning muhim mezonlari aniqlangan. Tadqiqot natijalari metallurgiya sanoati korxonalarida barqaror rivojlanish strategiyalarini takomillashtirish, innovatsion boshqaruv samaradorligini oshirish va yashil transformatsiya jarayonlarini jadallashtirish uchun muhim amaliy ahamiyat kasb etadi.

**Kalit so'zlar:** yashil innovatsiyalar, metallurgiya sanoati, "NKMK" AJ, samaradorlikni baholash, ekologik-iqtisodiy samaradorlik, resurs tejamkorligi, energiya samaradorligi, barqaror rivojlanish, innovatsion boshqaruv, sanoat korxonasi.

**Аннотация.** В данной статье исследованы теоретические и методологические основы оценки эффективности зелёных инноваций на предприятиях металлургической промышленности, а также проведён практический анализ на примере АО «НГМК». В исследовании обоснована важность комплексного подхода к оценке зелёных инноваций, при котором учитываются не только экономические результаты, но и экологические, социальные и институциональные показатели. Автором предложен обобщённый методический подход, основанный на системе показателей оценки эффективности зелёных инноваций.

На примере АО «НГМК» рассмотрены перспективные направления, связанные с повышением энергоэффективности, рациональным использованием ресурсов, сокращением отходов, обеспечением экологической устойчивости и ростом производственной эффективности, а также определены ключевые критерии оценки зелёной инновационной деятельности. Полученные результаты обладают высокой практической значимостью для совершенствования



стратегий устойчивого развития, повышения эффективности инновационного управления и ускорения процессов зелёной трансформации на предприятиях металлургической промышленности.

**Ключевые слова:** зелёные инновации, металлургическая промышленность, АО «НГМК», оценка эффективности, эколого-экономическая эффективность, ресурсосбережение, энергоэффективность, устойчивое развитие, инновационное управление, промышленное предприятие.

## INTRODUCTION

In the global economy, the ecological modernization of industrial production, efficient resource utilization, waste reduction, and carbon footprint minimization have become key priorities of sustainable development [1]. In particular, the metallurgical industry plays an important role in economic growth and industrial development, while simultaneously offering significant opportunities for improving resource efficiency, enhancing environmental performance, and implementing innovative green technologies. Therefore, the introduction of green innovations in this sector is increasingly recognized as an effective instrument for strengthening both environmental sustainability and economic competitiveness [2].

In the metallurgical industry, green innovations encompass technological, organizational, and managerial improvements aimed at implementing energy-efficient technologies, resource-saving production processes, advanced waste recycling systems, rational water resource management, low-emission equipment, and modern environmental monitoring mechanisms [3]. The benefits of these innovations extend beyond traditional economic outcomes, contributing to improved environmental quality, operational efficiency, and long-term sustainable development. Consequently, evaluating their effectiveness requires consideration of environmental, social, and institutional dimensions alongside economic indicators [4].

From this perspective, the development of a comprehensive, multi-criteria, and systemic framework for assessing the efficiency of green innovations in metallurgical enterprises represents an important scientific and practical objective. In this regard, the experience of Navoiy Mining and Metallurgical Company JSC (NKMK JSC), one of the leading mining and metallurgical enterprises in Uzbekistan, provides a valuable basis for examining the practical application of such an approach and identifying promising directions for sustainable industrial development [5].

The purpose of this article is to develop a comprehensive methodological approach for assessing the efficiency of green innovations in metallurgical industry enterprises and to demonstrate its practical applicability through the case of NKMK JSC.

## LITERATURE REVIEW

Issues related to green innovations and the assessment of their efficiency have attracted considerable attention from both international and domestic scholars. In particular, M. Porter and C. van der Linde demonstrated that environmental innovations serve as an important driver of enterprise competitiveness and long-term value creation [3]. K. Rennings examined the economic and environmental dimensions of the concept of eco-innovation and highlighted its significant contribution to sustainable development objectives [4]. Research conducted by OECD and UNIDO has emphasized the role of institutional mechanisms in promoting resource efficiency, energy conservation, and effective environmental management within industrial enterprises [6; 8].

The works of Uzbek researchers have made a valuable contribution to understanding the development of innovative activities in national industry, the modernization of the metallurgical sector, and the strengthening of environmental sustainability. Furthermore, official reports and analytical materials related to NKMK JSC demonstrate the successful implementation of energy-efficient technologies, waste recycling systems, and ESG principles within the enterprise, reflecting its commitment to sustainable industrial development [13].

At the same time, the existing body of literature presents significant opportunities for further expanding methodological approaches to evaluating green innovation efficiency. While many studies primarily focus on economic outcomes, growing attention is being directed toward the integration of environmental and social-institutional indicators into assessment frameworks. In this context, the present research contributes to the literature by proposing a comprehensive methodological approach based on the integrated evaluation of economic, environmental, and social-institutional indicators in metallurgical enterprises and by demonstrating its practical applicability through the case of NKMK JSC.

Theoretical and Methodological Foundations for Assessing the Efficiency of Green Innovations

## RESEARCH METHODOLOGY

Assessing the efficiency of green innovations in metallurgical enterprises requires a clear understanding of the economic essence of the concepts of “green innovation” and “efficiency.” Green innovations can be defined as a system of innovative solutions aimed at improving resource efficiency, enhancing environmental performance, increasing energy efficiency, promoting waste recycling, and supporting the transition toward sustainable production models [6].

Efficiency, in this context, reflects the relationship between the economic, environmental, and social benefits generated through the implementation of green innovations and the resources invested in these initiatives. Therefore, the efficiency of green innovations is most effectively evaluated through a comprehensive framework that incorporates the following three interrelated dimensions (Figure 1):

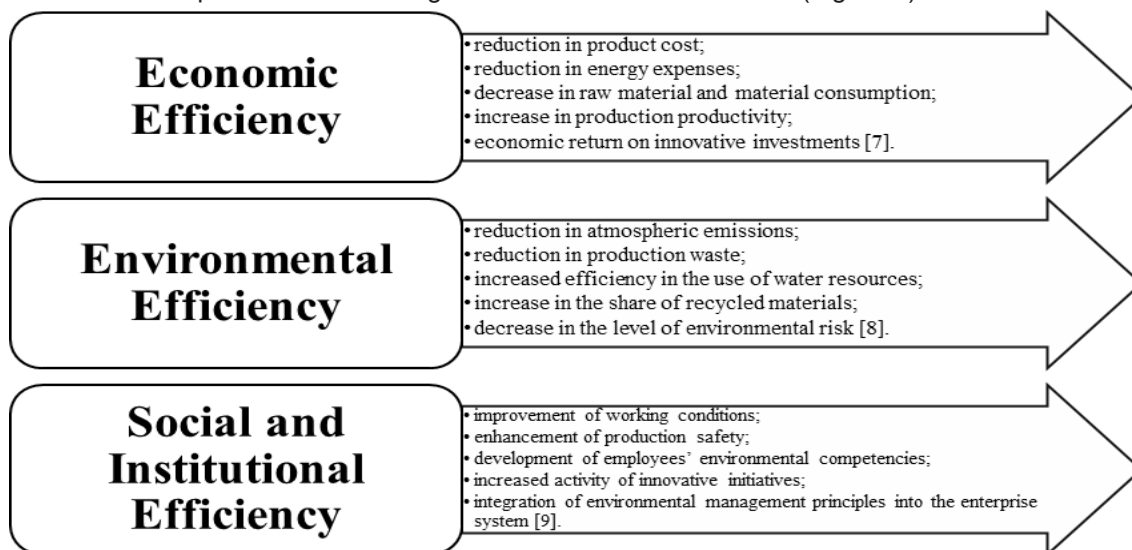


Figure 1. Key Dimensions for Assessing the Efficiency of Green Innovations in Metallurgical Enterprises

Thus, the assessment of the efficiency of green innovations in metallurgical enterprises should be based on a comprehensive multi-criteria evaluation system that integrates financial, environmental, and social-institutional indicators. Such an approach enables a more complete understanding of the overall contribution of green innovations to sustainable enterprise development.

Methodological Approach to Assessing the Efficiency of Green Innovations in Metallurgical Industry Enterprises

Within the framework of this study, a comprehensive methodological approach is proposed for assessing the efficiency of green innovations in metallurgical industry enterprises. This approach is based on the integrated evaluation of economic, environmental, and social-institutional dimensions of enterprise performance and includes the following stages:

### 1. Defining the Purpose of Assessment

The main objectives of the assessment are:

- to evaluate the effectiveness of implemented green innovations;
- to compare alternative innovation projects and identify their potential benefits;
- to determine investment priorities for sustainable development;
- to support strategic management decision-making and long-term enterprise growth [10].

### 2. Formation of the System of Indicators

To assess the efficiency of green innovations, the indicators are grouped into three interrelated categories (Table 1):



Table 1  
System of Indicators for Assessing the Efficiency of Green Innovations in Metallurgical Enterprises

A. Economic Indicator Block	B. Environmental Indicator Block	C. Social-Institutional Indicator Block
Energy costs per unit of output	Degree of reduction in atmospheric emissions	Occupational safety indicators
Degree of reduction in product cost	Reduction in waste volume	Employees' environmental competencies
Resource-saving coefficient	Reduction in water consumption	Number of innovative initiatives
Return on innovative investments	Increase in recycling share	Level of compliance with environmental standards
Payback period of expenditures	Reduction in environmental burden	Degree of integration of environmental principles into enterprise management

### 3. Systematization of Indicators and Comparative Analysis

To bring indicators expressed in different units of measurement into a unified analytical framework, they should be presented in relative, comparative, or index form. This approach enables effective monitoring of indicator dynamics, comparison with the base period, and benchmarking against industry standards [11]. As a result, the assessment process becomes more objective, comprehensive, and suitable for strategic decision-making.

### 4. Formulation of a Generalized Assessment Conclusion

At the final stage of assessment, the results obtained from the economic, environmental, and social-institutional indicator blocks are analyzed in an integrated manner. This approach facilitates a comprehensive evaluation of the effectiveness of green innovations based on the principle of multi-criteria aggregated assessment. In the methodology developed by the author, the composition of indicators, assessment criteria, and the mechanism for drawing generalized conclusions are substantiated, while the detailed calculation algorithm will be further elaborated in subsequent stages of dissertation research.

## ANALYSIS AND RESULTS

### Institutional and Practical Foundations for the Implementation of Green Innovations at NKMK JSC

Navoiy Mining and Metallurgical Company JSC (NKMK JSC) is one of the strategically significant industrial enterprises of Uzbekistan and represents a technologically advanced mining and metallurgical production system with substantial resource utilization [12]. The scale of the company's operations, the complexity of production processes, and the diversity of technological chains create broad opportunities for the effective implementation of environmental and innovation management practices.

In recent years, NKMK JSC has consistently implemented organizational and technological measures aimed at production modernization, enhancement of energy efficiency, reduction of technological losses, expansion of waste recycling practices, and strengthening of environmental sustainability [13]. These initiatives serve as important components of the company's green innovation strategy and contribute to sustainable industrial development.

### 4. Practical Analysis of Assessing the Efficiency of Green Innovations: The Case of NKMK JSC

In the case of NKMK JSC, assessing the efficiency of green innovations requires a comprehensive analysis of economic, environmental, and social-institutional indicators that reflect the company's production characteristics. Such an approach enables a balanced quantitative and qualitative evaluation of green transformation processes and supports the development of effective strategic management decisions.

#### 1. Analysis in the Economic Dimension

From an economic perspective, indicators such as energy resource consumption, product cost, technological efficiency, raw material utilization, and production productivity play a key role in assessing the effectiveness of green innovations at NKMK JSC. The introduction of energy-efficient technologies, modernization of equipment, and automation of production processes contribute to more efficient resource utilization and enhanced operational performance.

Over the long term, these improvements support the optimization of production costs, more rational energy consumption, increased productivity, and greater operational sustainability [14].

Furthermore, the assessment of innovative projects should focus on investment returns, reductions in operating costs, and the potential generation of additional economic value. At NKMK JSC, these benefits are particularly evident in projects involving the commissioning of new production capacities, modernization of technological lines, and implementation of resource-saving equipment [15].

### 2. Analysis in the Environmental Dimension

Environmental performance represents one of the most important criteria for evaluating green innovations in metallurgical enterprises. In the case of NKMK JSC, relevant indicators include atmospheric emission reduction, increased waste recycling rates, efficient water resource utilization, reduction of environmental impact, and enhancement of environmental safety.

Continuous improvement of environmental monitoring systems, implementation of resource-efficient technologies, and development of technogenic waste processing initiatives contribute significantly to environmental performance enhancement. In particular, the use of waste as a secondary resource, modernization of water circulation systems, and deployment of low-emission technologies support the company's commitment to sustainable environmental management.

### 3. Analysis in the Social-Institutional Dimension

Social and institutional factors also play an important role in evaluating the effectiveness of green innovations. At NKMK JSC, this dimension encompasses occupational safety, production reliability, employees' environmental competencies, the development of environmental culture, and the integration of sustainable development principles into corporate management.

The ongoing modernization and automation of production processes contribute to improved workplace safety, reduced exposure to potentially harmful factors, and increased labor productivity. Simultaneously, the incorporation of environmentally oriented management approaches into strategic planning strengthens the company's innovation capacity and supports its long-term sustainable development objectives.

#### Recommended System of Indicators for Assessing the Efficiency of Green Innovations at NKMK JSC

The following table presents the main recommended system of indicators for assessing the efficiency of green innovations at NKMK JSC (Table 2).

**Table 2**  
**Recommended System of Indicators for Assessing the Efficiency of Green Innovations at NKMK JSC**

Assessment Block	Main Indicators	Analytical Significance
<b>Economic Block</b>	Energy costs per unit of output; degree of reduction in product cost; resource-saving coefficient; return on innovative investments; optimization of operating costs	Characterizes the production efficiency, resource utilization effectiveness, and economic benefits generated by green innovations.
<b>Environmental Block</b>	Reduction in atmospheric emissions; reduction in waste volume; increase in recycling share; improvement in water-use efficiency; enhancement of environmental sustainability	Demonstrates the contribution of green innovations to environmental performance improvement and sustainable resource management.
<b>Social-Institutional Block</b>	Occupational safety indicators; production safety; employees' environmental competencies; compliance with environmental standards; integration of environmental principles into management	Reflects the positive influence of green innovations on organizational development, human capital enhancement, and long-term sustainability.

This system of indicators makes it possible to assess the efficiency of green innovations at NKMK JSC not only through individual indicators but also in a comprehensive manner by considering their interrelationships. Furthermore, this approach provides a solid methodological foundation for evaluating the level of sustainable development, the quality of resource utilization, and the effectiveness of environmental management within the enterprise.

#### Scientific Novelty and Practical Significance of the Research

The scientific novelty of this study lies in the systematization of existing approaches to assessing the efficiency of green innovations in metallurgical enterprises, the identification of opportunities for their further improvement, and the development of a comprehensive methodological approach that enables the integrated evaluation of economic, environmental, and social-institutional outcomes within a unified analytical framework.

The main scientific results of the study are as follows:

- a three-block conceptual model for assessing the efficiency of green innovations in metallurgical enterprises has been substantiated;
- a comprehensive system of indicators for evaluating the efficiency of green innovations has been developed;
- practical directions for assessing the effectiveness of green innovations have been clarified using the case of NKMK JSC;
- a methodological approach has been proposed to support the effective monitoring of green transformation



processes in enterprise management.

The practical significance of this study is reflected in its contribution to:

- improving the selection and prioritization of green innovation projects in metallurgical enterprises;
- supporting investment decision-making in alignment with environmental and economic objectives;
- enhancing the sustainable development strategy of the enterprise;
- facilitating the integration of ESG principles into production management;
- strengthening innovation management mechanisms at NKMK JSC.

## CONCLUSIONS AND RECOMMENDATIONS

The implementation of green innovations in metallurgical enterprises is increasingly becoming an important driver of environmental sustainability, efficient resource utilization, and enhanced production performance. Given the high level of resource consumption, energy demand, and environmental responsibility associated with this sector, the application of accurate, systematic, and comprehensive assessment approaches is of particular importance.

As a result of the study, a comprehensive methodological framework for assessing the efficiency of green innovations in metallurgical enterprises has been proposed. This framework enables the integration of economic, environmental, and social-institutional indicators into a unified analytical system, facilitates the evaluation of their interrelationships, and supports the formulation of comprehensive assessment conclusions.

The analysis conducted using the case of NKMK JSC demonstrates that production modernization, improvements in energy efficiency, the introduction of resource-saving technologies, expansion of waste recycling practices, and enhancement of environmental monitoring systems represent key directions for increasing the effectiveness of green innovations. In addition, further opportunities exist to strengthen the integration of environmental principles into enterprise management, align green transformation initiatives with strategic planning processes, and implement multi-criteria monitoring systems for innovative activities.

The scientific significance of the proposed methodological approach lies in its ability to expand traditional financial models of innovation assessment by incorporating environmental and social outcomes into the evaluation framework. Its practical significance is reflected in supporting the selection, prioritization, monitoring, and strategic management of green innovation projects in metallurgical enterprises, thereby contributing to their long-term sustainable development and competitiveness.

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