

INNOVATION SCIENCE AND TECHNOLOGY



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ISSUE 6

 **Acceptance of papers June, 2025**



**Acceptance of
papers**

Published monthly



Topics

economics,
technology, social
sciences



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AGENCY FOR INFORMATION AND MASS
COMMUNICATIONS (AOKA) OF THE
REPUBLIC OF UZBEKISTAN, EFFECTIVE
FROM OCTOBER 9, 2024.

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WAYS AND METHODS OF USING RENEWABLE ENERGY SOURCES IN INDUSTRIAL ENTERPRISES



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Abstract: This article analyzes the efficiency of using renewable energy sources in industrial enterprises. The study examines the methods of utilizing solar, wind, and biogas energy, along with their economic and environmental advantages. The introduction of advanced technologies, state incentives, and energy-saving strategies are discussed. The findings highlight the importance of renewable energy sources in ensuring sustainable industrial development.

Key words: renewable energy, industrial enterprises, energy efficiency, economic analysis, environmental sustainability.

INTRODUCTION

In Uzbekistan, systemic reforms are being implemented in order to modernize outdated infrastructure in economic sectors, social facilities, and industry, as well as to meet the growing demand of consumers for energy resources. In particular, a number of improvements have been made to the laws “On the Rational Use of Energy” and “On the Use of Renewable Energy Sources” with the aim of increasing energy efficiency in economic and social sectors, promoting energy conservation, introducing renewable energy sources, and supporting the population in this regard. A series of Presidential decrees have also been adopted to support the development of this direction.

According to Presidential Decree No. PQ-4422 of August 22, 2019, “On urgent measures to improve energy efficiency in economic sectors and the social sphere, introduce energy-saving technologies, and develop renewable energy sources,” Uzbekistan has set a goal to increase the share of renewable energy sources to more than 25 percent of total electricity generation by 2030. As of 2020, this figure stood at 10 percent.

Furthermore, Presidential Decree No. PQ-436 of December 2, 2022, “On measures to improve the effectiveness of reforms aimed at transitioning the Republic of Uzbekistan to a ‘green’ economy by 2030,” outlines the task of “increasing energy efficiency in the industrial sector by at least 20 percent.”

As a result of effective short-term activities, by the end of the first half of 2022, savings of 817.16 million cubic meters of natural gas, 447.0 million kWh of electricity, and 8.3 thousand tons of oil products were achieved. In this context, conducting scientific research aimed at developing effective mechanisms for achieving energy efficiency in industrial enterprises and improving the transition to renewable energy is considered one of the key directions.

LITERATURE REVIEW ON THE TOPIC

Numerous studies have been conducted by both local and international scholars on achieving energy efficiency and improving the effectiveness of energy use in the industrial sector. This is due to the fact that reducing energy costs and increasing energy efficiency are directly linked to the level of economic development and competitiveness of industrial enterprises.

In research conducted by global scholars—particularly the work of R.A. Burganov and others—a methodology has been proposed for calculating indicators of energy saving and energy efficiency within a

company. This methodology takes into account all types of energy used in company operations, including electrical, thermal, mechanical, lighting, human, and others.¹

In the research conducted by L.G. Giraudet, it is emphasized that managing information flows is one of the most crucial directions in reducing energy consumption.²

In the studies conducted by W. Mao and others, scientific proposals have been developed on calculating and reducing energy consumption in industrial enterprises based on the use of Internet of Things (IoT) technologies.³

In the studies by N.R. Kelchevskaya, E.V. Shirinkina, and I.V. Atlasov, the energy management factors that determine the success or failure of implementing energy efficiency measures in industrial enterprises have been identified.

In the research of I.M. Galyautdinov, methods for increasing the economic efficiency of enterprises in the oil and gas industry are proposed through the implementation of energy-saving measures.

M. Abdullayeva and S. Shodmonov have conducted studies on reducing production costs by lowering energy consumption.

M.N. Mamatyusup and S. Mutallibjonov have analyzed the main reforms implemented in Uzbekistan aimed at improving energy efficiency, as well as providing guidance on the effective use of domestically produced electricity.

The research of A. Yusupov focuses on the analysis of energy consumption balance, key quality indicators of the energy sector and ways to improve them, and energy saving through optimizing the operation of technical equipment and electrotechnological systems, along with increasing the power factor.

Classical definitions of the terms “energy saving” and “energy efficiency” are addressed in the works of V.V. Bushuev, A.M. Belogoryev, E.A. Borgolov, and V.V. Timatkov. According to experts, energy efficiency refers to the rational use of energy resources—achieving economically efficient use of fuel and energy resources in line with current technological and environmental standards. Energy saving, in turn, is described as a set of measures aimed at improving energy performance. Efficiency is thus considered as a means of reducing costs to achieve beneficial outcomes.

RESEARCH METHODOLOGY

In this study, statistical data, practical experiences, and scholarly articles were analyzed to assess the potential for utilizing renewable energy sources. Existing strategies aimed at increasing energy efficiency in industrial enterprises were examined using a comparative method. The data were evaluated based on economic and environmental indicators to assess the effectiveness of these strategies.

ANALYSIS AND RESULTS

Improving energy efficiency in industry encompasses enhancing production processes, optimizing interactions among all elements of production, improving product quality, ensuring environmental sustainability, increasing management effectiveness, and developing the company’s intangible assets. Ultimately, this leads to increased production and ensures financial stability in industrial enterprises.

According to N.I. Suslov, energy efficiency is the income or output derived from the use of one unit of energy consumed in various forms—such as fuel, heat, or electricity.

Table 1. Comparative analysis of renewable energy sources in industrial applications.

Renewable Energy Source	Key Advantages	Suitable Locations	Impact on Cost Reduction	Environmental Benefit	Implementation Challenges
Solar Energy	Low maintenance, long lifespan	Sunny and hot regions	High (long-term)	High – Zero emissions	High initial investment
Wind Energy	Stable electricity generation	Open plains, coastal areas	Moderate to high	High – Reduces grid dependency	Requires specific geography

1 Burganov R.A. et al. On the need to improve the methodology for calculating energy saving and energy efficiency of enterprises //IOP Conference Series: Materials Science and Engineering. – IOP Publishing, 2020. – T. 791. – №. 1. – C. 012040.

2 Giraudet L. G. Energy efficiency as a credence good: A review of informational barriers to energy savings in the building sector // Energy Economics. – 2020. – T. 87. – C. 104698.

3 Mao W. et al. Energy-efficient industrial internet of things: Overview and open issues //IEEE Transactions on Industrial Informatics. – 2021. – T. 17. – №. 11. – C. 7225-7237.

Biogas Energy	Waste-to-energy, dual output (heat+power)	Areas with organic waste (e.g., food, agri-industries)	Moderate	High – Waste recycling	Complex setup, requires feedstock
Geothermal Energy	Reliable, constant heat source	Geologically active areas	Moderate	High – No combustion emissions	Limited to certain regions

The comparative analysis in Table 1 highlights the potential benefits and challenges of integrating various renewable energy sources into industrial operations. Each energy source offers distinct advantages depending on geographical, economic, and technological conditions.

Solar energy stands out due to its low maintenance costs and long operational lifespan, making it particularly suitable for regions with high solar irradiance, such as many areas in Uzbekistan. Despite a high initial investment, its long-term cost-effectiveness and zero-emission profile make it a strategic choice for energy-intensive enterprises aiming for sustainability.

Wind energy, on the other hand, provides stable and consistent electricity generation, especially in open plains and coastal areas. Its ability to reduce reliance on the national power grid makes it beneficial for remote or off-grid industrial facilities. However, its implementation is heavily dependent on geographic and meteorological conditions, which may limit its application in certain regions.

Biogas energy offers a dual advantage: it utilizes organic waste, thus contributing to waste management, and simultaneously generates both heat and electricity. This source is especially suitable for agro-industrial complexes and food-processing enterprises. The main challenge lies in its complex infrastructure requirements and the need for a constant supply of organic feedstock.

Geothermal energy provides a reliable and continuous source of heat, which can significantly support industrial heating needs. It is ecologically clean, as it does not involve combustion, and is ideal for geologically active areas. However, its application is geographically constrained, requiring careful geological assessments prior to implementation.

Overall, energy saving is a crucial direction in the development of industrial enterprises, as it aims to make more efficient use of energy resources while reducing environmental and social burdens. Energy saving in industry not only involves reducing energy consumption but also creating the conditions necessary for the efficient use of energy and enhancing the competitiveness of products. Energy consumption in industry can be divided into three main categories: electricity consumption, thermal energy use, and fuel combustion.

Modern energy-saving practices are based on three fundamental principles:

First, the rational use of fuel and energy resources, including the exploration and development of new, unconventional sources of energy supply.

Second, the widespread use of household and industrial energy meters, along with the regulation of electricity and heat consumption.

Third, the introduction of advanced technologies in construction aimed at minimizing energy losses.

Most studies on energy saving focus on identifying energy-saving factors and examining the variables that directly influence energy efficiency. From an economic standpoint, the essence of energy saving lies in maximizing the ability to meet society's demand for energy services. Creating the necessary conditions for energy saving is considered a fundamental requirement. Therefore, all countries strive to achieve an effective balance between the volume of energy consumption and energy demand as a sufficient condition for successful energy saving.

The use of renewable energy sources in industrial enterprises is currently one of the key directions in ensuring energy security and reducing environmental challenges. The limited availability and rising cost of traditional energy resources are prompting industrial enterprises to adopt effective measures for utilizing alternative energy sources. In particular, the use of solar, wind, biogas, and geothermal energy offers the potential to partially or fully meet enterprises' energy needs.

Solar energy is considered one of the most promising sources for industrial enterprises, with its capacity and efficiency largely dependent on geographical location. In hot and sunny regions, generating electricity using photovoltaic panels proves to be economically beneficial for industrial facilities. Although the initial investment cost for solar panels is relatively high, their long operational lifespan and low maintenance costs make this technology attractive.

Wind energy is most suitable for industrial enterprises located in open plains and coastal areas. Wind turbines provide a stable source of electricity and reduce dependence on power grids.

Biogas technologies are also among the effective means of energy production in industrial enterprises. Organic waste generated during the production process can be converted into biogas, which is then used to produce heat and electricity. This approach not only contributes to the diversification of energy sources but also enhances environmental sustainability by promoting waste recycling.

Geothermal energy can be effectively applied in heat supply systems. This technology utilizes underground heat sources to increase the energy independence of industrial enterprises. The widespread implementation of renewable energy sources in industrial sectors requires the adoption of innovative technologies, improvement of state support programs, and expansion of financing opportunities. In addition, clear strategies for enhancing energy efficiency in industrial enterprises must be developed. These efforts, in the long term, contribute to increasing the competitiveness and ensuring the sustainable development of the industrial sector.

The key conditions for developing and implementing energy-saving projects in industrial enterprises include:

Minimizing the share of energy costs in the total cost of production;

Establishing an accounting system for energy resources throughout project operations.

The strategy for managing energy-saving processes in industrial enterprises involves achieving a high-tech level of energy consumption and efficient management of energy resources through the implementation of energy-saving projects. The core components of this mechanism.

Every industrial enterprise possesses untapped potential and reserves for improving energy efficiency, particularly in auxiliary processes. The proposed mechanism for organizing the management of energy-saving projects in industrial enterprises focuses initially on analyzing and forming an optimal portfolio of energy efficiency measures and selecting the most suitable projects. The implementation of this mechanism helps reduce inefficient resource expenditures and enhances overall performance by ensuring continuous resource availability.

In recent years, disruptions in the energy system have increasingly highlighted the need for all sectors, including industrial enterprises, to implement effective measures for reducing energy consumption and establishing efficient energy-saving systems. Achieving global standards in reducing fuel use for thermal energy production is viewed as a critical issue. Addressing these challenges requires analyzing international trends in the use of renewable energy sources (RES) in industrial enterprises and formulating flexible, strategic tasks that align with global practices.

CONCLUSION AND RECOMMENDATIONS

The use of renewable energy sources is one of the key factors in ensuring the sustainable development of industrial enterprises. The results of the study indicate that the efficient use of solar, wind, and biogas energy contributes to improving the energy efficiency of production processes, reducing operational costs, and minimizing negative environmental impacts.

To expand the use of renewable energy in industrial enterprises, it is essential to introduce advanced technologies, improve mechanisms for state-supported concessional loans and subsidies, and strengthen incentives for the production of energy-saving technologies.

It is also of great importance to establish a continuous professional development system for enterprise managers and specialists on the effective utilization of renewable energy sources. Widespread implementation of solar panels and wind generation systems in industrial zones, the use of energy storage equipment, and the integration of biogas production technologies into production processes could lead to significant positive transformations in the sector.

Additionally, it is necessary to develop clear energy efficiency strategies at the enterprise level and broaden the financing of innovative projects. These measures play a crucial role in promoting the development of the industrial sector.

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Proofreader: Zokir ALIBEKOV

Layout and Designer: Oloviddin Sobir ugli

2025. № 6

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