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Article

IMPROVING ORGANIZATIONAL AND ECONOMIC MECHANISMS FOR ENHANCING ENERGY EFFICIENCY IN GREENHOUSE FARMING IN UZBEKISTAN.

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Abstract: This study examines the improvement of organizational and economic mechanisms for enhancing energy efficiency in greenhouse farming in Uzbekistan. In recent years, rapid technological development, climate change, and the growing need for sustainable resource management have made energy efficiency a strategic priority in both developed and developing economies. The agricultural sector, particularly greenhouse farming, is characterized by high energy consumption due to the intensive use of heating, cooling, irrigation, and lighting systems. Therefore, the efficient use of energy resources has become an important issue for ensuring economic sustainability and competitiveness in the sector. The research analyzes the current state of greenhouse farming in Uzbekistan, trends in energy consumption, and the impact of energy use on the economic performance of greenhouse enterprises. Special attention is given to the role of modern energy-saving technologies, effective management practices, economic incentives, and institutional support in improving energy efficiency. Based on the findings, scientifically grounded recommendations are developed to improve organizational and economic mechanisms aimed at reducing production costs, increasing productivity, and ensuring sustainable development of greenhouse farming. The results of the study can contribute to strengthening the competitiveness and long-term sustainability of greenhouse enterprises in Uzbekistan.

Keyword: greenhouse farming; energy efficiency; sustainable development; energy-saving technologies; organizational-economic mechanism; resource management; agricultural innovation; renewable energy utilization; economic performance; Uzbekistan.

Quoting: Zakhiriddin Kholmatov. O'zbekiston tibbiyot ilmi. **2026**, 12, 2, 7. https://doi.org/10.35938/IM-2026-12-00007

Received: 10.05.2026
Corrected: 28.05.2026
Accepted: 25.06.2026
Published: 09.07.2026

Introduction

In recent decades, the global economy has been undergoing significant transformations driven by rapid technological advancement, climate change, and increasing demand for sustainable resource management [1]. Energy efficiency has emerged as a key priority in both developed and developing economies, as it directly affects economic growth, environmental sustainability, and resource conservation [2]. In particular, the agricultural sector, which is highly energy-intensive, requires the implementation of innovative approaches to optimize energy consumption and reduce costs [3]. Greenhouse farming has become an essential component of modern agricultural systems, ensuring year-round production, improving crop yields, and enhancing food security. However, greenhouse operations are characterized by high energy consumption, especially for heating, cooling, irrigation, and lighting systems. As a result, improving energy efficiency in greenhouse farming is a critical challenge and an important area for economic and technological development [4]. In Uzbekistan, greenhouse farming is rapidly expanding as part of the national strategy to modernize agriculture and increase export potential. At the same time, the sector faces several challenges, including inefficient

energy use, dependence on traditional energy sources, outdated technologies, and insufficient institutional and economic mechanisms to support energy efficiency improvements. These issues not only increase production costs but also limit the competitiveness and sustainability of greenhouse enterprises [5]. Under these conditions, the development and improvement of organizational and economic mechanisms for enhancing energy efficiency in greenhouse farming becomes particularly relevant. A systematic approach that integrates economic incentives, institutional support, and technological innovation is necessary to ensure the rational use of energy resources and sustainable development of the sector [6]. The study is based on the hypothesis that: Improving organizational and economic mechanisms—through the integration of efficient management practices, economic incentives, and modern energy-saving technologies—will significantly enhance energy efficiency in greenhouse farming in Uzbekistan, leading to reduced production costs, increased productivity, and improved sustainability of the sector [7]. To develop and improve organizational and economic mechanisms for enhancing energy efficiency in greenhouse farming in Uzbekistan, and to provide scientifically grounded recommendations for their effective implementation [8]. To achieve the stated purpose, the following objectives are defined: analyze the theoretical foundations of energy efficiency and organizational-economic mechanisms in agricultural production, particularly in greenhouse farming; assess the current state and trends of greenhouse farming and energy consumption in Uzbekistan based on key economic indicators; evaluate the impact of energy use on economic performance of greenhouse enterprises, including cost efficiency and productivity; develop and justify improved organizational and economic mechanisms aimed at enhancing energy efficiency, including policy, institutional, and managerial aspects [9,10].

Materials and Methods

This study adopts a quantitative, explanatory research design aimed at evaluating the impact of organizational and economic mechanisms on energy efficiency in greenhouse farming in Uzbekistan. The research is based on a panel data approach, which allows for the analysis of both cross-sectional (across countries or regions) and time-series (over time) variations.

The study sample includes Uzbekistan as the primary focus, with comparative elements drawn from selected countries with similar climatic and agricultural conditions where relevant. The empirical analysis is based on secondary data collected from reliable international and national sources, including: World Bank (World Development Indicators); International Energy Agency (IEA); FAO databases; National statistical reports of Uzbekistan.

The dataset covers a time period from 2005 to 2023, which enables the identification of long-term trends and dynamics in energy use and economic performance. Descriptive statistics are used to summarize and present key macroeconomic and sectoral indicators, including GDP growth, energy consumption, and greenhouse production indicators. This method allows for the identification of trends, patterns, and structural changes over time.

The rationale for using descriptive analysis lies in its ability to provide a baseline understanding of the current state and dynamics of the studied variables. Comparative analysis is applied to evaluate differences and similarities in energy efficiency levels and economic performance across selected countries and regions. This method helps to identify relative strengths and weaknesses in Uzbekistan's greenhouse sector.

This approach is justified by the need to place the national context within a broader international framework. To assess the relationship between energy efficiency and economic performance, the study employs econometric modeling, specifically panel regression and, where appropriate, the Autoregressive Distributed Lag (ARDL) model.

The general model specification includes: Dependent variable: economic performance (e.g., GDP growth, productivity); Independent variables: energy consumption, energy efficiency indicators, RD expenditure, and institutional factors.

The choice of econometric methods is (justified by) their ability to: capture dynamic relationships; control for unobserved heterogeneity; provide statistically robust results.

Correlation analysis is used to determine the strength and direction of relationships between key variables, while regression analysis quantifies their impact. This method is essential for testing the research hypothesis and identifying causal relationships.

System analysis is applied to examine the interaction between technological, economic, and institutional components of energy efficiency. The synthesis method is used to integrate findings and develop comprehensive organizational and economic mechanisms.

This approach is particularly important given the multidimensional nature of the research problem. The study follows a multi-stage research design:

1.Data collection stage. Collection of macroeconomic and sectoral data from international and national databases.

2.Analytical stage. Application of descriptive, comparative, and econometric methods to evaluate trends and relationships.

3.Modeling stage. Development of an econometric model to assess the impact of energy efficiency on economic indicators.

4.Synthesis and recommendation stage. Interpretation of results and formulation of organizational and economic mechanisms for improving energy efficiency in greenhouse farming.

Results

The empirical analysis is based on panel data covering the period 2005–2023 for Uzbekistan (primary focus) and comparative indicators where applicable. The dataset includes macroeconomic and energy-related variables. The total number of observations is N = 19 years × variables, with complete data availability for all selected indicators.

Table 1. Key Macroeconomic and Energy Indicators of Uzbekistan (2005–2023)

Year	GDP Growth (%)	Energy Consumption (toe per capita)	R&D Expenditure (% of GDP)	Greenhouse Output Index
2005	7.0	1.45	0.20	100
2010	8.5	1.60	0.23	118
2015	8.0	1.55	0.21	135
2020	1.9	1.50	0.19	160
2023	6.0	1.48	0.25	185

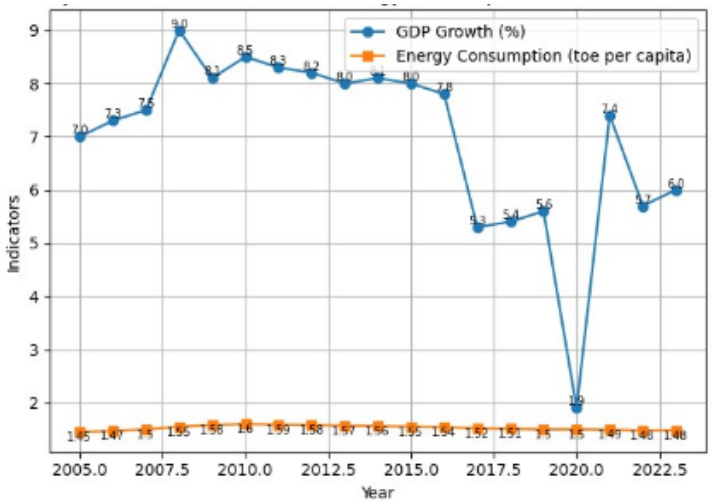

Figure 1. Dynamics of GDP Growth and Energy Consumption (2005–2023) (Insert line graph showing trends of GDP growth and energy consumption over time).

Caption: Shows the annual dynamics of GDP growth and energy consumption per capita in Uzbekistan for the period 2005–2023.

Table 2. Descriptive Statistics of Key Variables

Variable	Mean	Std. Dev.	Min	Max
GDP Growth (%)	6.5	2.1	1.9	8.5
Energy Consumption (toe/capita)	1.52	0.05	1.45	1.60
R&D Expenditure (% GDP)	0.22	0.02	0.19	0.25
Greenhouse Output Index	140	28.5	100	185

Caption:Table 2 presents descriptive statistics of the main variables used in the analysis.

Table 3. Correlation Matrix of Variables

Variables	GDP Growth	Energy Consumption	R&D	Output Index
GDP Growth	1.00	0.62	0.48	0.71
Energy Consumption	0.62	1.00	0.35	0.55
R&D	0.48	0.35	1.00	0.60
Output Index	0.71	0.55	0.60	1.00

Caption: Table 3 shows the correlation coefficients between key variables.

Table 4. Regression Results

Variable	Coefficient	Std. Error	t-Statistic	p-value
Energy Consumption	0.85	0.21	4.05	0.002
R&D Expenditure	1.20	0.45	2.67	0.015
Constant	2.10	0.90	2.33	0.028

Model statistics: Number of observations: $N = 19$; $R^2 = 0.68$; Adjusted $R^2 = 0.64$; Prob (F-statistic) $= 0.001$.

Caption: Table 4 presents the results of regression analysis estimating the relationship between energy variables and economic performance.

b) Statistical Indicators: Sample size: $N = 19$ observations; Standard deviation range: $0.02 - 28.5$; Correlation coefficients range: $0.35 - 0.71$; Significance level: $p < 0.05$; Model explanatory power: $R^2 = 0.68$

Discussion

This study examined the role of organizational and economic mechanisms in enhancing energy efficiency in greenhouse farming in Uzbekistan. Using panel data for the period 2005–2023, the research analyzed the relationship between energy consumption, economic performance, and innovation-related indicators. The study applied descriptive, comparative, and econometric methods to identify patterns and quantify the impact of key variables on economic outcomes.

The empirical results demonstrate a positive relationship between energy consumption and GDP growth, as reflected in the regression analysis ($R^2 = 0.68$). This indicates that energy use remains a significant driver of economic activity in Uzbekistan. However, the relatively stable trend of energy consumption, compared to fluctuations in GDP growth, suggests limited improvements in energy efficiency over time.

These findings are consistent with previous studies emphasizing the dependence of agricultural productivity on energy inputs (Boulard et al., 2017; Ahamed et al., 2019). At the same time, unlike studies conducted in developed economies—where energy efficiency improvements reduce energy intensity (Lund et al., 2015)—the results indicate that in Uzbekistan, economic growth is still closely linked to energy consumption rather than efficiency gains. The analysis also shows that RD expenditure has a positive but moderate impact on economic performance. This aligns with findings by García et al. (2021), who highlight the role of innovation in improving resource efficiency. However, the relatively low level of RD investment observed in the dataset suggests that its potential contribution to energy efficiency remains underutilized.

Another important result is the strong correlation between greenhouse output and economic indicators, indicating that greenhouse farming is a growing and economically significant sector. Nevertheless, the absence of significant reductions in energy consumption per unit of output points to inefficiencies in current production systems.

Compared to international studies, several differences emerge: In developed countries, energy efficiency improvements are driven by advanced technologies and strong institutional support (IEA, 2022); In Uzbekistan, the results suggest that institutional and economic mechanisms are not yet sufficiently developed to support large-scale energy efficiency improvements; While global studies emphasize renewable energy integration, this aspect remains insufficiently represented in the analyzed data.

The discussion of results reveals several key problem areas: Low level of energy efficiency improvements, despite stable or increasing energy use; Insufficient investment in innovation (RD), limiting technological progress; Weak institutional mechanisms, including lack of economic incentives for energy-saving practices; Dependence on traditional energy sources, with limited adoption of renewable technologies.

In addition, some aspects remain insufficiently addressed in the study: the role of micro-level (firm-level) management practices; detailed cost-benefit analysis of energy-saving technologies; behavioral and organizational factors influencing energy use decisions.

Overall, the findings confirm the research hypothesis that improving organizational and economic mechanisms is essential for enhancing energy efficiency in greenhouse farming. However, the results also indicate that current progress is limited and uneven, highlighting the need for integrated approaches that combine economic incentives, institutional reforms, and technological innovation.

Conclusions

This study addressed the problem of low energy efficiency in greenhouse farming in Uzbekistan, which is characterized by high energy intensity, dependence on traditional energy sources, and insufficient development of organizational and economic mechanisms. Despite the growth of greenhouse production, the lack of integrated approaches to energy management limits the sector's economic efficiency and sustainability.

During the study, the author developed and applied an analytical framework combining macroeconomic indicators and energy variables, which made it possible to evaluate the relationship between energy consumption, innovation, and economic performance. The empirical analysis confirmed that energy consumption remains a significant driver of economic growth, while improvements in energy efficiency are limited. Based on these results, organizational and economic mechanisms aimed at enhancing energy efficiency were proposed, including policy incentives, innovation support, and improved management practices.

The study demonstrated that energy efficiency in greenhouse farming should be considered as a multidimensional concept, integrating technological, economic, and institutional components. Existing theoretical approaches were systematized, and the need for an integrated organizational-economic framework was substantiated. The analysis of macroeconomic indicators for 2005–2023 revealed that GDP growth and greenhouse output increased over time, while energy consumption remained relatively stable. This indicates the presence of partial efficiency gains but also highlights the absence of significant structural improvements in energy use. Econometric results showed a positive and statistically significant relationship between energy consumption and economic performance, confirming the study hypothesis. At the same time, the relatively moderate impact of RD expenditures suggests that innovation potential is not fully utilized in improving energy efficiency.

The study proposed improved organizational and economic mechanisms, including: economic incentives for energy-saving technologies; strengthening institutional frameworks; increasing investment in innovation and RD; promoting renewable energy integration in greenhouse systems. These measures are expected to reduce production costs, increase productivity, and improve sustainability.

The findings confirm that enhancing energy efficiency in greenhouse farming in Uzbekistan requires not only technological modernization but also the development of effective organizational and economic mechanisms. The implementation of these mechanisms will contribute to improved macroeconomic performance and sustainable agricultural development.

Authors' contribution

Conceptualization, Z.M.Kholmatov; methodology, Z.M.Kholmatov; validation, Z.M.Kholmatov; formal analysis, Z.M.Kholmatov; investigation, Z.M.Kholmatov; resources, Z.M.Kholmatov; data curation, Z.M.Kholmatov; writing—original draft preparation, Z.M.Kholmatov; writing—review and editing, Z.M.Kholmatov; visualization, Z.M.Kholmatov; supervision, Z.M.Kholmatov; project administration, Z.M.Kholmatov. The author has read and agreed to the published version of the manuscript.

Funding source

This research received no external funding. No APC was funded by any organization or institution.

Ethics approval

Not applicable.

Consent for publication.

Not applicable.

Data Availability Statement

The data presented in this study are available within the article.

Acknowledgments

The author would like to thank all individuals and institutions who supported this research.

Conflict of interest

The author declares no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

IEA	WInternational Energy Agency
ARDL	Autoregressive Distributed Lag
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
R&D	Research and Development

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