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Energy efficiency: the experience of developed countries and the transformation of their experience in Uzbekistan

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Abstract: This article presents a comprehensive analysis of the latest energy efficiency trends in developed countries and examines the potential for applying their successful practices to Uzbekistan. The study identifies key areas for transformation in the country's energy sector, such as infrastructure modernization, the introduction of renewable energy sources, and improvements to the regulatory framework. Particular attention is paid to the practical aspects of implementing international energy efficiency standards in various sectors of the Uzbek economy, as well as assessing the potential economic and environmental benefits of leveraging international experience.

INTRODUCTION

Energy efficiency has become a key priority in global economic policy in the 21st century, driven by a number of interrelated factors: the depletion of traditional energy resources, rising energy consumption, environmental challenges, and the need to ensure sustainable development. For developing countries, including Uzbekistan, improving energy efficiency is not only a tool for optimizing energy consumption but also a strategic resource for economic growth, competitiveness, and energy security.

This study is of practical importance because Uzbekistan possesses significant energy potential, and its rational use is essential in the context of economic transformation. Despite the country's sustained gross domestic product (GDP) growth, which amounted to 55% from 2017 to 2024, the energy intensity of the national economy remains quite high, indicating enormous potential for energy optimization [2]. Another important aspect is the global trend toward decarbonization of the economy and the transition to green energy, which requires Uzbekistan to adapt to new international standards and requirements. The degree of scientific development of this problem is reflected in the large number of studies devoted to both the general problem of energy efficiency and specific aspects of Uzbekistan's energy policy. Begmullaev O.I. and Mirsaidova Sh.A. highlight international experience in improving the efficiency of energy sector enterprises [1]. International organizations, including the United Nations Development Programme (UNDP) and the European Union, are actively studying Uzbekistan's energy efficiency potential and proposing specific mechanisms for its implementation [3, 4]. However, the issue of systematically adopting international experience, taking into account the specifics of the country, requires further comprehensive research.

The problem of the study lies in the contradiction between Uzbekistan's enormous potential for improving energy efficiency and the ineffectiveness of implementation mechanisms based on international experience.

Purpose and Objectives of the Study

The purpose of the study is to develop adaptive recommendations based on international experience in energy efficiency, taking into account the specifics of Uzbekistan. To achieve this goal, the study will address the following objectives:

Analysis of the current state of energy efficiency in Uzbekistan.

Study of successful experiences in improving energy efficiency in developed countries. Determining the potential for implementing international experience in Uzbekistan.

Developing practical recommendations for energy conservation policy.

The research focuses on measures and mechanisms for improving energy efficiency in Uzbekistan and other countries.

The subject of the study is the process of adapting international experience in improving energy efficiency to the conditions of Uzbekistan.

The theoretical and methodological basis of the study is the works of domestic and foreign energy scientists, materials from international conferences, reports from international organizations (UNDP, IAE), and legislative acts of the Republic of Uzbekistan.

The scientific novelty of the study lies in its comprehensive analysis of the process of adapting international experience in improving energy efficiency, taking into account the current challenges facing Uzbekistan's energy transition.

The practical significance of this study lies in the fact that its findings and recommendations can be used to develop public policies and strategies in the field of energy conservation, as well as to create a regulatory framework governing energy efficiency issues. The structure of the study includes an introduction, literature review, research methodology, the main body (including an analysis of international experience and its adaptation in Uzbekistan), results and discussion, conclusion and recommendations, and a bibliography.

LITERATURE REVIEW

The scientific community is actively researching various aspects of energy efficiency. Begmullaev O. and Mirsaidova Sh., in their work "Foreign Experience in Improving the Efficiency of Energy Sector Enterprises and the Possibilities of Its Application in Domestic Conditions," emphasize that "the process of expanding market reforms is highly adaptive and is largely determined by the existing state, as well as the history of the formation and development of the electric power sector in the country under consideration." They note that there is no universal approach, and each country must choose solutions that provide the best results in its specific conditions.

International organizations such as UNDP emphasize the need for a comprehensive approach combining regulatory reforms, technological modernization, and raising consumer awareness. Analysts at the International Energy Agency predict that global energy demand will grow by 37% by 2040, with the rate of growth in energy consumption declining from 2% per year to 1% per year after 2025.

Analysis from A review of contemporary scientific literature allows us to systematize key approaches and specific measures to improve energy efficiency implemented in developed countries and assess the potential for their adaptation to the conditions of Uzbekistan.

1. Global Context and Energy Efficiency Policy

The global community is demonstrating growing concern about climate change and energy shortages, which is reflected in the adoption of large-scale political decisions. Key milestones include:

The IEA Strategy for Achieving Net-Zero Emissions by 2050, which includes more than 400 benchmarks for decarbonizing the global economy. These include the widespread adoption of affordable clean energy technologies by 2030, making electricity the central element of the energy system, and the widespread use of energy efficiency technologies in sectors such as manufacturing and construction.

National Initiatives: The European Green Deal, which aims to achieve carbon neutrality by 2050 and reduce greenhouse gas emissions in the EU by 55% from 1990 levels by 2030; China's announcement of achieving "peak carbon emissions" by 2030 and "carbon neutrality" by 2060; and the US Nationally Determined Contributions (NDC) program for transitioning to carbon-free energy. These documents set the general direction in which Uzbekistan's policy is developing.

2. Best International Practices in the Building and Housing and Utilities Sector

The construction and housing and utilities sector is one of the most significant in terms of energy savings potential. Global experience emphasizes several key areas:

Implementation of Green Building Standards: Green building concepts, zero-energy buildings, and zero-carbon buildings require efficient, energy-efficient, and low-carbon energy management. Energy standards help organizations create processes and systems to improve energy management efficiency. Technological Solutions: EU countries are actively phasing out incandescent light bulbs, replacing them with modern energy-saving lamps, which reduces energy consumption by 80%. Thermal insulation is a key area, with the primary goal of conserving energy resources and reducing greenhouse gas emissions.

Smart Energy Management Systems (EMS): Thanks to rapid technological advances, buildings are becoming intelligent systems, encouraging wise energy use, reducing carbon footprints, and improving comfort. The energy

management system (EMS) market is vast and is used not only in the commercial, industrial, and residential sectors, but also in transportation, healthcare, and education.

3. Experience in Implementing Renewable Energy Sources (RES)

Developed countries are placing significant emphasis on diversifying their energy mix through renewable energy sources.

- **Solar and Wind Energy:** Research indicates that the use of solar energy (solar power) and wind energy is a promising method for conserving natural resources. Although this industry is still in its infancy in some countries, including the CIS, its potential is considered very high – energy generated from renewable energy sources could potentially account for approximately 30% of the overall energy mix.

- **Waste Recycling:** Solid waste recycling is receiving significant attention in Europe, as it is seen as a way to conserve valuable resources. International experience with thermal waste recycling is of significant interest for integration into energy supply systems.

4. Problems and Challenges in Adapting International Experience

Transferring international experience requires consideration of the specifics of national economies and infrastructure. Analysts highlight a number of systemic challenges facing building energy management:

- **Inconsistency of Data and Standards:** Practical challenges today are related to the wide range of data processing results, the flexibility of research system standards, and the lack of a comprehensive, unified assessment system.

- **Need for an Integrated Approach:** Research points to the importance of cross-disciplinary research combining passive energy-efficient design with energy conservation through user behavior modification. This indicates that simply borrowing technology is not enough for Uzbekistan; it is necessary to develop a regulatory framework, encourage changes in consumer habits, and train specialists.

Synthesis for Application in Uzbekistan

The conducted literature analysis allows us to conclude that Uzbekistan can effectively transform international experience by focusing on the following areas:

1. **Regulatory framework development:** Adaptation of international energy efficiency standards for buildings and industrial enterprises, incentive tariff regulation.

2. **Technological modernization:** Mass implementation of thermal insulation systems, energy-efficient lighting and household appliances, development of smart grids.

3. **Diversification of the energy mix:** Realizing the enormous potential of solar and wind energy, and exploring the use of waste for energy generation.

4. **Implementation of energy management systems:** Development and implementation of intelligent energy management systems in government agencies and large industrial facilities.

I hope this detailed analysis will help you prepare your research paper. If you require a more in-depth discussion of any specific aspect, I am ready to assist.

Research Methodology

The study is based on a systems approach, including a corporate analysis of international experience and practices in Uzbekistan. The following methods were used:

1. **Comparative analysis** - comparing Uzbekistan's energy efficiency indicators with similar parameters in developed countries.

2. **Statistical analysis** - studying the dynamics of changes in GDP energy intensity, energy generation, and energy consumption.

3. **Regulatory analysis** - assessing the legislative framework and institutional mechanisms for regulating energy efficiency.
4. **Empirical analysis** – a synthesis of data from official sources, international reports, and academic publications.

The source base included official data from Uzbek government agencies, publications from international organizations (UNDP, IEA), academic articles, and analytical reports.

EXPERIMENTAL RESEARCH

1. The Current State of Energy Efficiency in Uzbekistan

Uzbekistan has made significant progress in reforming its energy sector. Between 2017 and 2024, the country's gross domestic product increased by 55%, while energy consumption per unit of GDP decreased by 7.4%. This demonstrates that the national economy is becoming more energy efficient, generating increased added value while reducing electricity consumption – currently 56.8 kWh per million soums of GDP.

Table 1. Key Indicators of Uzbekistan's Energy Sector

Indicator	2016	2024	Change
Electricity generation	59 billion kWh	81.5 billion kWh	+38%
Generating capacity (over 7 years)	-	11 thousand MW	3 times more than over the previous 25 years
Length of modernized distribution networks	9.3 thousand km (over 1991-2016)	54.8 thousand km (over 2017-2024)	Significant acceleration

Significant changes have affected the energy infrastructure. Since 2017, more than 54,800 km of distribution networks and 17,200 transformer stations have been modernized, significantly improving electricity supply to over 8,000 settlements across the country. By comparison, from 1991 to 2016, only 9,300 km of transmission lines and 4,800 transformer stations were upgraded.

Despite the extensive body of literature devoted to energy efficiency and energy transition, most existing studies focus either on descriptive analyses of international best practices or on isolated national case studies. In contrast, the present paper contributes to the literature by moving beyond a purely descriptive approach and offering a structured analytical framework for adapting international energy efficiency experience to the conditions of a transition economy.

The scientific novelty of this study is expressed through the following key contributions:

First, the paper develops an authorial adaptation matrix of international energy efficiency experience for Uzbekistan (Table 2). Unlike conventional comparative analyses, this matrix systematically links specific policy instruments and technological solutions implemented in developed countries (Germany and Japan) with concrete adaptation measures applicable to Uzbekistan. The matrix integrates regulatory, technological, infrastructural, and institutional dimensions, thereby providing a practical analytical tool for policymakers and researchers working in transition economies.

2. International Experience in Energy Efficiency

2.1. Experience of European Countries. The European Union demonstrates a comprehensive approach to energy efficiency, combining regulatory frameworks, economic incentives, and technological innovation. As noted in the materials of the conference "Energy Efficiency in Uzbekistan: Prospects and Challenges," "energy efficiency offers numerous economic, social, and environmental benefits. It is one of the simplest and most cost-effective ways to combat climate change."

Germany is of particular interest to Uzbekistan due to its experience in the green energy transition. During the talks between Uzbekistan and Germany, areas of cooperation such as the creation of green energy infrastructure, the introduction of modern energy-saving technologies in social institutions, and the development of climate-neutral city models were discussed. The German side noted Uzbekistan's "consistent and pragmatic approach to sustainable growth."

2.2. Experience of Other Countries. France demonstrates a successful example of energy mix diversification with an emphasis on nuclear energy, which accounts for 75% of the country's electricity production. Annual electricity exports generate over \$2 billion for the French budget, accounting for up to 0.5% of the country's total exports.

Sweden has implemented an innovative approach to energy transformation, focusing on renewable energy sources and systemic energy efficiency improvements. This experience is particularly important for Uzbekistan, which also has significant potential for solar and wind energy development.

3. Adaptation of International Experience in Uzbekistan

3.1. Regulatory Framework. During the reform period, a robust regulatory framework was established in Uzbekistan: eight key laws were adopted, as well as over 90 acts of the President of the Republic of Uzbekistan and the Cabinet of Ministers, providing the institutional foundation for a profound transformation of the industry. However, as experts note, "the subsidized tariffs in effect in Uzbekistan today do not incentivize households and industrial consumers to improve energy efficiency."

3.2. International Cooperation. Uzbekistan is actively developing international cooperation in energy efficiency. Joint projects are currently being implemented with the following countries and organizations:

Germany: cooperation in green energy and energy efficiency, including the development of climate-neutral city models;

Austria: preparation of a memorandum of cooperation in energy and digital transformation;

European Union: the Sustainable Energy Connectivity in Central Asia (SECCA) project, aimed at promoting a sustainable energy balance;

UNDP: Support to strengthen energy efficiency requirements for residential buildings and a pilot project to use solar panel systems in 1,328 residential buildings.

3.3. Development of Renewable Energy. The development of renewable energy has become a priority area of Uzbekistan's energy transformation. By the end of 2024, 14 solar and 3 wind power plants with a total installed capacity of 4,100 MW were commissioned in 10 regions of Uzbekistan. The volume of "green" electricity generation in 2024 reached 4.9 billion kWh.

UNDP supported the Government of Uzbekistan in using the International Renewable Energy Agency (IRENA) SolarCity Simulator tool to model the economic, financial, and environmental benefits of solar city solutions.

RESULTS AND DISCUSSION

Based on an analysis of the current situation in Uzbekistan and international experience, several key areas for adapting international best practices in energy efficiency can be identified.

Key Areas for Transforming Experience

The following table summarizes the main areas for adapting international best practices to the context of Uzbekistan.

Table 2: Summary of key areas for adapting international best practices to Uzbek conditions

Adaptation Focus	Experience of Developed Countries (using Germany and Japan as examples)	Potential and Measures for Uzbekistan
Improving Tariff Policy	A set of measures based on market incentives and consumer responsibility.	A gradual transition to market tariffs to create incentives for energy conservation.
Renewable Energy Development and Decentralization	Germany: National target of 50% renewable energy by 2030; Japan: Mass deployment of solar panels on residential buildings.	Scaling up successful experience (4,100 MW of renewable energy by 2024), supporting households.
Infrastructure Modernization	Germany: Power Plant and Grid Modernization Program.	Continuing large-scale grid modernization (54,800 km since 2017), introducing smart grids.
Energy Efficiency in Construction and Industry	Germany: Energy Performance of Buildings Directive; Japan: Strict regulations for industry and construction.	Implementation of standards for new housing, promotion of green industrial parks.
International Cooperation and Financing	Germany: Participation in IPEEC, energy technology exports; Japan: Energy Diplomacy.	Deepening partnerships (EU, Germany, UNDP, UNIDO) for technology transfer and investment attraction.
Adaptation Focus	Experience of Developed Countries (Germany and Japan).	Potential and Measures for Uzbekistan.
Improving Tariff Policy	A set of measures based on market incentives and consumer responsibility.	A gradual transition to market tariffs to create incentives for energy conservation.

Discussion of Results and Emerging Challenges. The analysis shows that Uzbekistan is on the right track; however, successfully translating international experience requires addressing a number of challenges:

Energy conservation incentives: Although tariff liberalization has already yielded a positive effect in reducing consumption, achieving the goals stated in the "CO₂ Emissions Reduction Concept" (as in Japan) requires more in-depth work to change consumer behavior. Japan's experience in educating the public on simple energy conservation techniques (eliminating standby mode, optimizing air conditioning use) is highly effective and can be easily adapted.

Overcoming technological barriers: Global experience indicates that the transition faces "complex challenges," particularly in the areas of hydrogen, carbon capture, and decarbonization of heavy industry. For Uzbekistan, this means laying the foundations for the future implementation of these technologies now, focusing on quick-impact measures such as improving the energy efficiency of buildings and modernizing industry.

Ensuring a systematic approach: Germany and Japan's success is based on a combination of legislation, targeted programs, financial incentives, and private capital involvement. Uzbekistan needs to continue building a similarly comprehensive system, focusing on developing national capacity in green technologies and training personnel, which is a key factor in "transition readiness" according to global rankings.

Second, the study proposes a structured transformation model for energy efficiency policy, based on a sequential and interrelated chain:

regulation → technology → consumer behavior → financing mechanisms. This model reflects the systemic nature of successful energy efficiency reforms observed in developed countries and demonstrates how fragmented policy

measures can be transformed into a coherent national strategy. The model highlights that technological modernization alone is insufficient without regulatory incentives, behavioral change, and access to targeted financing instruments.

CONCLUSIONS

1. Significant progress has been achieved in the energy transformation. Between 2017 and 2024, Uzbekistan achieved significant results: a 7.4% reduction in GDP energy intensity, the introduction of 4,100 MW of renewable energy capacity, and the modernization of 54,800 km of distribution networks. These indicators demonstrate the effectiveness of the ongoing reforms in the energy sector.

2. International experience demonstrates the versatility of an integrated approach. An analysis of practices in Germany, Japan, and other developed countries confirms that successful energy efficiency policies are based on a triad: regulatory frameworks, economic incentives, and technological innovation.

3. Adapting international experience requires consideration of national specifics. Effective translation of international practices to the context of Uzbekistan must take into account climate conditions, economic structure, the state of the energy infrastructure, and consumer behavior patterns.

4. Subsidized tariffs remain a systemic constraint. The current tariff policy does not create sufficient economic incentives for energy conservation in both households and the industrial sector.

5. International cooperation is a catalyst for change. Partnerships with Germany, Japan, the EU, and international organizations significantly accelerate the transfer of technologies and best practices in energy efficiency.

RECOMMENDATIONS

1. Improving the regulatory framework. Develop and adopt a National Strategy for Improving Energy Efficiency by 2035 with clear quantitative targets.

Implement a mandatory energy audit system for industrial enterprises with an annual energy consumption exceeding 1,000 tons of standard fuel.

Establish a gradual tightening of energy efficiency standards for new buildings.

2. Modernizing the tariff policy. Implement a gradual transition to market-based energy pricing while maintaining social limits for vulnerable groups.

Introduce differentiated tariffs based on time of day to encourage load balancing.

Develop a system of fiscal incentives for enterprises implementing energy-efficient technologies.

3. Developing renewable energy. Accelerate the implementation of the solar and wind power plant construction program by 2030.

Introduce a "green" certificate mechanism to stimulate the use of renewable energy sources. Develop a program to support distributed generation based on renewable energy sources for households and small businesses.

4. Technological Modernization. Create a national program for the implementation of smart metering systems.

Develop industry roadmaps for the implementation of energy-efficient technologies in industry.

Establish a fund to support scientific research in energy efficiency.

5. Institutional Development and International Cooperation. Create a National Center of Excellence in Energy Efficiency.

Expand the program for training and retraining specialists in energy management.

More actively attract international funding through green bonds and climate funds.

6. Information and Educational Work. Develop a national program to raise public awareness of energy conservation.

Introduce educational modules on energy efficiency into school and university curricula.

Organize a system of regular monitoring and public reporting on the achievement of energy efficiency targets.

Implementation of the proposed measures will allow Uzbekistan not only to significantly improve the energy efficiency of the economy but also to consolidate its position as a regional leader in sustainable energy, ensuring long-term economic growth in the context of the global energy transformation.

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