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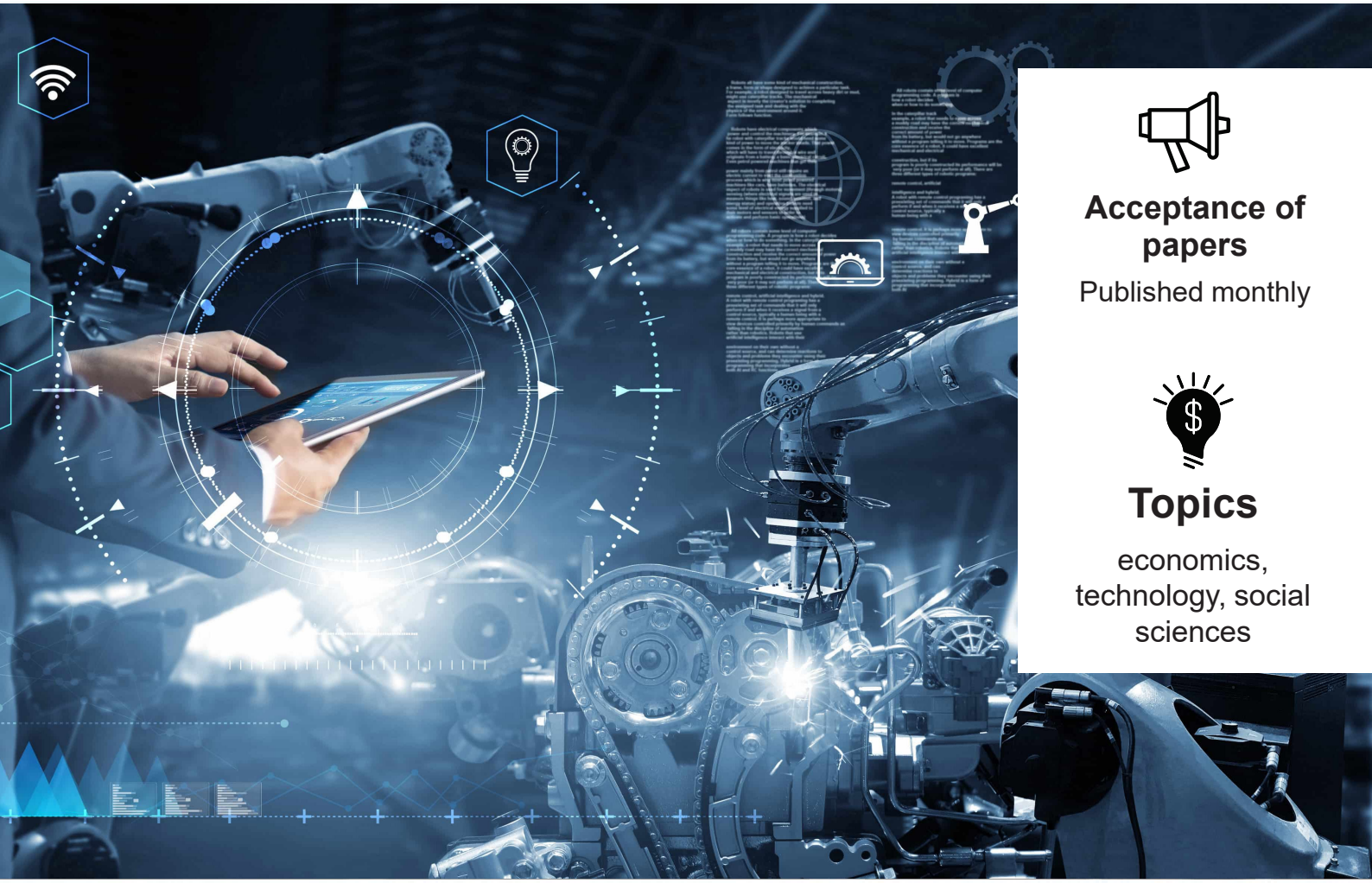

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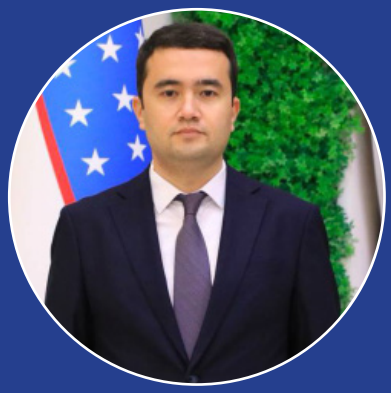

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ECONOMIC EFFICIENCY OF RENEWABLE ENERGY DEPLOYMENT IN UZBEKISTAN

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Abstract. This article evaluates the economic efficiency of solar and wind energy in Uzbekistan through a comparative cost–benefit analysis with natural gas. The findings indicate that renewable energy sources are more cost-effective and sustainable in the long term compared to conventional fuels. Accordingly, expanding renewable energy capacity by 2030 is both economically viable and environmentally sound.

The study also emphasizes the importance of gradually reducing fossil fuel subsidies, fostering private sector investment, and strengthening regional energy cooperation.

Keywords: renewable energy, green economy, cost–benefit analysis, levelized cost of energy (LCOE), solar energy, wind energy, Uzbekistan, energy policy.

Annotatsiya. Ushbu maqolada O‘zbekistonda quyosh va shamol energetikasining iqtisodiy samaradorligi tabiiy gaz bilan qiyosiy xarajat–foyda tahlili asosida baholanadi. Tadqiqot natijalari qayta tiklanuvchi energiya manbalari uzoq muddatda an’anaviy yoqilg‘ilarga nisbatan iqtisodiy jihatdan samaraliroq va barqarorroq ekanligini ko‘rsatadi. Shu bois, 2030-yilgacha qayta tiklanuvchi energiya quvvatlarini kengaytirish iqtisodiy jihatdan maqsadga muvofiq hamda ekologik jihatdan asoslangan hisoblanadi.

Maqolada, shuningdek, qazib olinadigan yoqilg‘ilarga beriladigan subsidiyalarni bosqichma-bosqich qisqartirish, xususiy sektor investitsiyalarini rag‘batlantirish hamda mintaqaviy energetik hamkorlikni rivojlantirish zarurligi ta’kidlanadi.

Kalit so‘zlar: qayta tiklanuvchi energiya, yashil iqtisodiyot, xarajat–foyda tahlili, energiyaning darajalashtirilgan qiymati (LCOE), quyosh energiyasi, shamol energiyasi, O‘zbekiston, energetika siyosati.

Аннотация. В данной статье оценивается экономическая эффективность солнечной и ветровой энергетики в Узбекистане на основе сравнительного анализа затрат и выгод с природным газом. Результаты исследования показывают, что возобновляемые источники энергии являются более экономически эффективными и устойчивыми в долгосрочной перспективе по сравнению с традиционными видами топлива. В связи с этим расширение мощностей возобновляемой энергетики к 2030 году является экономически целесообразным и экологически обоснованным.

В статье также подчеркивается необходимость поэтапного сокращения субсидий на ископаемое топливо, стимулирования частных инвестиций и углубления регионального энергетического сотрудничества.

Ключевые слова: возобновляемая энергия, зелёная экономика, анализ затрат и выгод, приведённая стоимость энергии (LCOE), солнечная энергия, ветровая энергия, Узбекистан, энергетическая политика.

INTRODUCTION

As the global economy gradually reduces its dependence on fossil fuels, renewable energy sources are fundamentally reshaping the world's energy landscape. The convergence of climate change priorities, energy security concerns, and the sharp decline in technology costs has accelerated this transition. According to the International Renewable Energy Agency (IRENA), solar photovoltaic systems accounted for 77.8% of all newly installed electricity capacity worldwide in 2024, bringing global renewable capacity to 4,443 GW.

Uzbekistan is also part of these global energy transformations. As Central Asia's largest economy, the country, with a population of about 35 million, faces growing electricity demand. In 2023, total electricity generation reached 78,005 GWh; of this amount, 89% or 69,605 GWh came from non-renewable sources, primarily natural gas. Hydropower contributed 10%, while solar energy accounted for only 1%. This structure demonstrates the need to further diversify the national energy mix and strengthen the role of renewable energy sources in supporting long-term economic growth.

The issue is also closely linked to the government's continued support for natural gas, electricity, and petroleum products. According to International Energy Agency (IEA) estimates, these subsidies amounted to USD 3.8 billion in 2020, equivalent to 6.6% of GDP. While such support mechanisms have played an important role in ensuring energy affordability, a gradual transition toward more market-based pricing can improve investment signals and encourage private sector participation in renewable energy development.

The government has set a target of installing 12 GW of renewable capacity by 2030, including 7 GW of solar and 5 GW of wind power. However, the economic rationale for these plans, particularly a rigorous cost–benefit comparison with conventional energy sources, requires further academic examination. Therefore, this article aims to assess the economic efficiency of renewable energy deployment in Uzbekistan and evaluate its long-term benefits compared with traditional fossil fuel-based energy generation.

LITERATURE REVIEW

Recent scholarship in energy technology economics consistently highlights a clear trend: renewable energy is increasingly recognized not only as an environmentally preferable option but also as a competitive and efficient economic choice. According to the International Renewable Energy Agency (IRENA, 2024), 91% of newly installed renewable capacity in 2024 generated electricity at a lower cost than the most affordable fossil fuel alternatives. In the same period, solar energy was on average 41% less expensive than fossil fuels, while onshore wind energy costs were approximately 53% lower.

Studies focusing on developing economies provide particularly valuable insights. Acharya and Sadath (2021) [1], based on a cost–benefit analysis of solar energy projects in India, found that the net present value (NPV) was positive, while the internal rate of return (IRR) ranged between 12% and 18%. Similarly, Dong and Zhang (2019) [2], analyzing China's experience, identified the long-term decline in the levelized cost of energy (LCOE) as a key factor shaping national energy policy directions.

Research dedicated to Central Asia and Uzbekistan is gradually expanding. Vokulchuk and Overland (2021) emphasized that Central Asia represents a strategically important region within the global green energy transition. The International Energy Agency (IEA, 2022), in its comprehensive review of Uzbekistan's energy sector, examined the role of natural gas subsidies and suggested their gradual optimization to enhance market efficiency and investment attractiveness. In addition, a policy brief by UNECE (2024) [3] projects that electricity demand in Uzbekistan may nearly double by 2030, reaching approximately 120 TWh.

Overall, the existing body of literature indicates strong potential for renewable energy development; however, there remains a need for more detailed country-specific analyses. In particular, comprehensive cost–benefit assessments based on Uzbekistan's economic conditions, including the role of existing support mechanisms, can further enrich academic and practical understanding. This study aims to contribute to this direction by providing an in-depth evaluation of the economic efficiency of renewable energy deployment in Uzbekistan.

RESEARCH METHODOLOGY

The levelized cost of energy (LCOE), which represents the average cost of electricity generation over a project's lifetime, is calculated using the following formula:

$$LCOE = \frac{\sum_t \frac{Capex_t + Opex_t}{(1+r)^t}}{\sum_t \frac{E_t}{(1+r)^t}}$$

where:
$Capex_t$ – capital expenditure in year t;
$Opex_t$ – operating expenditure in year t;
E_t – electricity generated in year t (kWh);
r – discount rate (10%);
t – project lifetime (solar: 25 years; gas-fired power plant: 30 years).
For the cost–benefit analysis (CBA), two primary scenarios were defined.
Scenario 1: construction of an additional 1 GW natural gas–fired power plant during the period 2023–2030.
Scenario 2: installation of an additional 1 GW of solar and wind energy capacity over the same period.

All costs are expressed in 2024 USD. A social discount rate of 8% was applied. The benefit analysis incorporates several key components, including direct cost savings, the social value of CO_2 emission reductions (estimated at USD 50 per tonne), gains associated with reduced reliance on fossil fuel consumption, and employment generation effects.

At the same time, certain methodological considerations should be noted. First, due to limited availability of project-level LCOE data specific to Uzbekistan, global benchmark values adjusted with a regional correction coefficient were applied. Second, energy demand projections may vary depending on changes in economic growth trends and demographic dynamics. Third, grid integration and system flexibility aspects can be further explored in future analyses to enhance the comprehensiveness of the assessment.

ANALYSIS AND RESULTS

The data presented in Table 1 indicate that natural gas remains the primary source of electricity generation in Uzbekistan, while the share of renewable energy sources is still at an early stage of development. This reflects the country's current energy structure and, at the same time, highlights the potential for further expansion and diversification of renewable energy within the national energy mix (Table 1).

Table 1
Structure of Electricity Generation in Uzbekistan, 2023

Energy Source	Generation (GWh)	Share (%)	Sources
Natural Gas	69,605	89.2	IRENA, 2024
Hydropower	7,770	10.0	IRENA, 2024
Solar Energy	622	0.8	IRENA, 2024
Wind Energy	7	0.01	IRENA, 2024
Other	1	0.01	IRENA, 2024
TOTAL	78,005	100	

Source: IRENA Statistical Profile Uzbekistan (2024)

These figures indicate that in 2023, the combined share of non-hydropower renewable energy in Uzbekistan's total electricity generation accounted for approximately 0.8%. At the same time, electricity demand is increasing at an annual rate of 6–7% and is projected to nearly double by 2030, reaching around 120 TWh. This dynamic underscores the importance of expanding generation capacity and identifying energy technologies that provide the most efficient and sustainable economic outcomes.

Table 2 presents a comparison of levelized cost of energy (LCOE) indicators across different energy technologies based on IRENA data, illustrating how global cost trends can be meaningfully adapted to Uzbekistan's energy context (Table 2).

Table 2
Comparative LCOE Indicators by Energy Technology (2023-2024)

Technology	LCOE 2023 ($/kWh)	LCOE 2024 ($/kWh)	Change since 2010	Source
Solar PV (utility-scale)	0.044	0.043	-90%	IRENA, 2024
Onshore Wind	0.033	0.034	-69%	IRENA, 2024
Hydropower	0.057	0.056	-	IRENA, 2024
Fossil Fuels (average)	0.100	0.100	+11%	IRENA, 2024

Natural Gas (Uzbekistan)*	~0.100	~0.065	subsidized	Climatescope, 2025

Source: IRENA Renewable Power Generation Costs in 2023 & 2024; Global Climatescope (2025)

* Solar PV installation cost: USD 691/kW (IRENA 2024 global average); wind: USD 1,041/kW; blended project average: USD 870/kW.

The table indicates that in 2023, solar energy was globally about 56% less expensive than fossil fuel–based generation, while onshore wind energy was approximately 67% more cost-efficient. This advantage is largely driven by the significant decline in solar module prices—around 93% since 2010—as well as continuous improvements in wind turbine efficiency.

It is also important to note that Uzbekistan's current electricity tariffs (approximately USD 65/MWh in 2024) are influenced by existing support mechanisms and therefore may not fully reflect the underlying production costs. When a more comprehensive economic cost perspective is applied, the relative competitiveness of renewable energy sources becomes even more evident (Table 3).

Table 3
25-Year Cost-Benefit Analysis for 1 GW of Installed Capacity (USD million)

Indicator	Natural Gas CCGT (Scenario 1)	Solar + Wind (Scenario 2)	Difference
Capital Expenditure (Capex), USD mln	900-1,100	700-900*	-200
Annual O&M Cost, USD mln	40-60	15-25	-30
Fuel Cost (25 years, USD mln)	1,800-2,400	0	-2,100
CO_2 Savings Value (@$50/t), USD mln	0	+750-900	+825
Net Present Value (NPV), USD mln	-1,200 (negative)	+850 (positive)	+2,050
Internal Rate of Return (IRR)	7-9%	12-16%	+5-7 p.p.
Payback Period (years)	18-22 years	10-14 years	-8 years

Source: Author's calculations based on IRENA (2024), IEA (2022), and UNECE (2024) data.

CONCLUSION AND RECOMMENDATIONS

The results of the cost–benefit analysis (CBA) clearly indicate the strong economic viability of the renewable energy scenario. In the case of natural gas–based electricity generation, one of the main considerations is the significant fuel cost over a 25-year period (estimated at USD 1.8–2.4 billion), along with the associated environmental costs of CO_2 emissions. In contrast, renewable energy projects benefit from zero fuel costs, operating expenses that are approximately 40–60% lower, and a payback period that is about 8 years shorter. The internal rate of return (IRR), estimated at 12–16%, aligns well with international climate finance benchmarks.

Uzbekistan's current electricity tariffs do not fully reflect underlying production costs. In 2020, support mechanisms for fossil fuels amounted to USD 3.8 billion, equivalent to 6.6% of GDP. As pricing structures gradually evolve toward market-based approaches, the relative cost structure of natural gas–based electricity becomes more transparent. According to International Energy Agency (IEA, 2022) estimates, under more comprehensive cost conditions, the levelized cost of electricity (LCOE) for gas-fired power plants may approach USD 0.100/kWh, compared to approximately USD 0.043–0.044/kWh for solar energy.

Trends in electricity tariffs further illustrate ongoing structural adjustments. Average tariffs increased from USD 38/MWh in 2021 to USD 66/MWh in 2022, stabilizing at around USD 65/MWh in 2024. This pattern reflects a gradual transition toward more economically aligned pricing mechanisms. As this trajectory continues, renewable energy sources are expected to strengthen their cost competitiveness within the national energy system.

Investment activity in Uzbekistan's clean energy sector has also demonstrated positive momentum. According to Global Climatescope data, investment increased from USD 2.03 billion in 2023 to USD 2.90 billion in 2024, representing a 43% growth. In July 2024, construction commenced on a 500 MW solar power plant in the Beshariq district, supported by USD 350 million in investment and expected to generate 1.6 billion kWh annually. In addition, in November 2023, Voltalia reached an agreement to develop the 500 MW Artimisya hybrid complex in the Bukhara region, integrating solar, wind, and battery storage technologies.

The findings of this study support two key conclusions. First, the expansion of renewable energy in Uzbekistan represents a highly efficient and forward-looking investment direction. The CBA results show that the renewable

scenario (Scenario 2) generates a positive net present value (NPV) of approximately +USD 850 million and an IRR of 12–16%, exceeding commonly accepted international thresholds. This confirms that solar and wind energy are not only environmentally beneficial but also economically advantageous.

Second, existing support mechanisms for fossil fuels play an important role in shaping current market dynamics. As these mechanisms are gradually optimized, market signals are expected to more accurately reflect the true cost structure of different energy sources, thereby supporting a more balanced and competitive energy mix.

Financing renewable energy projects has become a strategic priority for Uzbekistan. In 2024, clean energy investment reached USD 2.9 billion, reflecting substantial growth. Key considerations for further development include managing currency-related factors (as project costs are often denominated in foreign currency while revenues are in local currency), ensuring policy consistency, and strengthening domestic technical capacity. Enhancing power purchase agreement (PPA) frameworks and deepening cooperation with international financial institutions such as the European Bank for Reconstruction and Development (EBRD), the Asian Development Bank (ADB), and the International Finance Corporation (IFC) can play a significant role in supporting sustainable sector development.

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