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INSTITUTIONAL AND ECONOMIC FRAMEWORKS FOR ESTABLISHING A GREEN ENERGY ZONE IN AZERBAIJAN: EVIDENCE, CHALLENGES, AND DEVELOPMENT PROSPECTS

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Original Article

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ABSTRACT

This study examines how artificial intelligence, IT infrastructure, and cybersecurity shape digital inequality during labour market transformation in the European Union. Using an integrated analytical framework and panel data analysis, it responds to a research gap in which these dimensions have largely been assessed separately. Findings indicate that artificial intelligence can widen digital inequality when adequate institutional and technological support is lacking. In contrast, advanced IT infrastructure and strong cybersecurity may reduce such disparities by improving access to digital resources, supporting participation in the digital economy, and strengthening trust in digital systems. Further evidence shows that the influence of artificial intelligence on digital inequality varies according to infrastructural capacity and cybersecurity preparedness. This confirms the relevance of broader structural and institutional conditions in determining the outcomes of digital transformation. A key contribution of this study is its integration of technological, infrastructural, and institutional factors within a unified framework. It also emphasizes cybersecurity as a significant component of digital inequality and provides empirical evidence from the European Union context. Policy implications suggest that AI-driven development should be supported by investment in connectivity, digital skills, and cyber resilience. Coordinated policy measures are necessary to foster innovation while advancing digital inclusion and institutional capacity. Limitations arise from the use of aggregated country-level data and proxy indicators for artificial intelligence and cybersecurity. Future research should consider more detailed datasets, sector-specific differences, and the long-term effects of digital transformation on labour markets. Overall, the study demonstrates that the link between artificial intelligence and digital inequality is multidimensional and context-dependent. Inclusive digital transformation requires technological advancement together with robust infrastructure, cybersecurity, and effective public policy.

Keywords: *artificial intelligence, digital inequality, IT infrastructure, cybersecurity, labour market transformation, European Union, digital inclusion*

1. INTRODUCTION

Climate change and increasing anthropogenic pressure on the environment have made energy efficiency and renewable energy development strategic priorities at both global

and national levels. In Azerbaijan, these priorities are reflected in state programs, development strategies, and regulatory frameworks that promote the transition to a green economy. Current initiatives focus on reducing the environmental impacts of the fuel and energy sector through measures such as the remediation of oil-contaminated land, land reclamation, and carbon emission reduction. This study also compares Azerbaijan's approach with international practices and examines the growing contribution of renewable energy, particularly solar and wind power, to the global energy transition. Azerbaijan possesses substantial renewable energy resources and is among the regional leaders in this field. The country's technical offshore wind potential is estimated at approximately 157 GW, providing significant opportunities for large-scale renewable energy development. Solar and wind energy account for the largest share of this potential. In addition, the establishment of a Green Energy Zone in the liberated territories has become a strategic national objective aimed at creating a sustainable and environmentally friendly energy system. This initiative prioritizes the expansion of solar, wind, and hydropower generation, the implementation of energy efficiency measures, the adoption of smart technologies, and the development of electric transport.

2. LITERATURE REVIEW

The transition to green energy and the development of sustainable energy systems have become central themes in energy economics and environmental policy. The literature consistently recognizes renewable energy as a key driver of carbon emission reduction, energy security, and sustainable economic growth. International organizations, including the International Renewable Energy Agency (IRENA), identify renewable energy integration as essential for global decarbonization and the transition to low-carbon energy systems. Recent studies emphasize the economic and environmental benefits of renewable energy deployment. Zhang et al. (2026) argue that renewable energy technologies can simultaneously address growing energy demand, reduce CO_2 emissions, and promote green innovation through effective policy frameworks. In resource-dependent economies, particularly oil-exporting countries, green energy development is also viewed as an opportunity for economic diversification. Gasimli et al. (2024a, 2024b, 2025) demonstrate that strategic investments and institutional reforms could enable Azerbaijan to diversify its economy and strengthen its position as a future exporter of green energy.

Several studies examine Azerbaijan's policy and institutional framework for renewable energy development. Hajizadeh (2023) highlights the importance of aligning national energy security objectives with sustainability goals, emphasizing investment frameworks and institutional readiness. Similarly, Bayramov (2021) and Guliyev (2024) note that although strategic policies and regulatory instruments have been introduced, implementation challenges and regulatory inconsistencies continue to constrain progress.

Empirical evidence also supports the positive economic effects of renewable energy. Aliyev et al. (2024) identify a long-term positive relationship between renewable energy consumption and economic growth in Azerbaijan, while Gulaliyev et al. (2020) demonstrate the country's substantial solar energy potential and its contribution to emission reduction and regional development. Landoni and Muradzada (2026) further argue that governance quality, regulatory stability, and institutional capacity remain critical determinants of a successful energy transition in hydrocarbon-dependent economies.

Additional research by Shahbazov (2024) and Humbatova (2024) examines the relationship between economic growth, environmental sustainability, and renewable energy development, concluding that policy effectiveness depends on the successful implementation of integrated green energy strategies. Earlier work by Mammadov and Aliyev (2013) provides the theoretical foundation for energy planning and program-target management

in Azerbaijan, complementing national strategic documents such as the *Azerbaijan 2030* development strategy.

Despite the expanding literature, an important research gap remains. Existing studies primarily address macroeconomic impacts, policy frameworks, or individual sectors, whereas limited attention has been given to the integrated institutional and economic conditions required for establishing a coherent Green Energy Zone in Azerbaijan. This study addresses this gap by examining the policy coherence, institutional readiness, and economic feasibility of green energy zone development within a unified analytical framework.

3.DATA AND METHODOLOGY

This study applies a qualitative and comparative research design to examine the development of green energy initiatives in Azerbaijan. It is based on the program-target approach, which enables the assessment of state policies, strategic frameworks, and institutional mechanisms aimed at promoting environmental sustainability and establishing a Green Energy Zone.

The empirical foundation of the research consists of official state programs, strategic development documents, and policy reports adopted in Azerbaijan. These include national energy and environmental programs, socio-economic development strategies, and long-term policy frameworks such as *Azerbaijan 2030: National Priorities for Socio-Economic Development*. These sources provide the basis for evaluating the evolution, priorities, and institutional support of green energy policy.

The methodological framework combines comparative analysis, content analysis, and the program-target method. Comparative analysis is used to examine policy continuity across different periods, while content analysis identifies key priorities, policy tools, and implementation mechanisms in official documents. The program-target method assesses how strategic objectives are transformed into practical measures and programs.

Elements of historical analysis are also included to trace the development of program-based planning, its theoretical foundations, and its application in different national contexts. This approach helps clarify how international experience in program-based management can be adapted to Azerbaijan.

Overall, the selected methods provide a comprehensive basis for assessing the coherence and effectiveness of green energy policies and their contribution to sustainable development.

4.RESULTUS AND DISCUSSIONS

Environmental protection has become a strategic priority in Azerbaijan, with the fuel and energy sector playing a central role in addressing ecological challenges such as the remediation of oil-contaminated land, drainage of polluted water bodies, and land reclamation on the Absheron Peninsula (Aliyev et al., 2024). Globally, annual losses of oil and petroleum products are estimated at approximately 45 million tons, with an additional 8 million tons lost during transportation, highlighting the environmental costs associated with conventional energy production (Mammadov & Aliyev, 2013).

Following its accession to the Kyoto Protocol, Azerbaijan strengthened its environmental policies through state programs and national development strategies that promoted renewable energy and emission reduction. As a result, national carbon dioxide emissions declined from approximately 60 million tons to 37 million tons after 2010. A major contribution was made by the *Comprehensive Action Plan for Improving the Environmental Situation in the Republic of Azerbaijan for 2006–2010*, which focused on addressing ecological problems in Baku and the Absheron Peninsula (CoM, 2006).

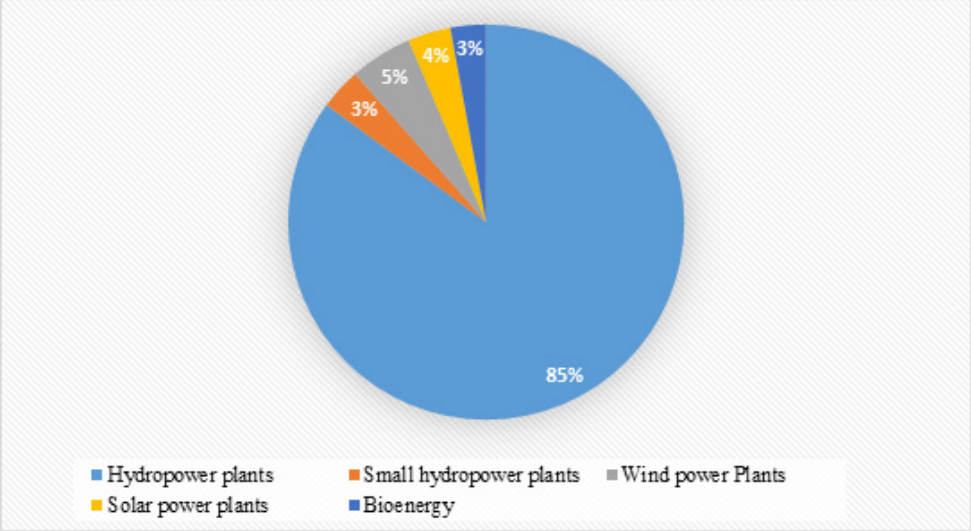
The Absheron Peninsula remains the country's most environmentally vulnerable region, accommodating around 40% of the population and 70% of industrial activity. Consequently, sustainable environmental management and renewable energy development have become national priorities. Since the adoption of the State Program on the Use of Alternative and Renewable Energy Sources in 2004 (SPRES, 2004), Azerbaijan has expanded its commitment to green energy in response to rising energy demand, environmental degradation, and the depletion of fossil fuel resources.

Azerbaijan possesses substantial renewable energy potential, creating favorable conditions for investment and the implementation of large-scale green energy projects. Global trends further reinforce this transition. According to IRENA (2026), renewable energy accounted for 29.9% of global electricity generation in 2023. Between 2012 and 2023, electricity generation from renewable sources grew at an average annual rate of 5.9%, considerably exceeding the 1.3% growth recorded for conventional energy sources. In 2023 alone, renewable electricity generation increased by 5.6%, compared with 1.2% for traditional energy, demonstrating the accelerating role of renewables in the global energy mix (MoE, 2026).

Comparative analysis shows that solar and wind energy have experienced the fastest growth since 2010. In 2023, these technologies generated 13.2% of global electricity and recorded a 15.7% increase compared with the previous year. The structure of renewable energy has also changed substantially over the past two decades, with wind and solar power accounting for 44% of renewable electricity generation in 2023, compared with only 1.1% in 2000.

Despite these global trends, Azerbaijan's renewable electricity generation remains dominated by hydropower, which accounts for approximately 85% of total renewable output. Wind energy contributes 5%, solar energy 4%, while bioenergy and small hydropower each account for 3%. The following section presents the structure of electricity generation from renewable energy sources in Azerbaijan.

Figure 1. Renewable energy plants in Azerbaijan (in %)

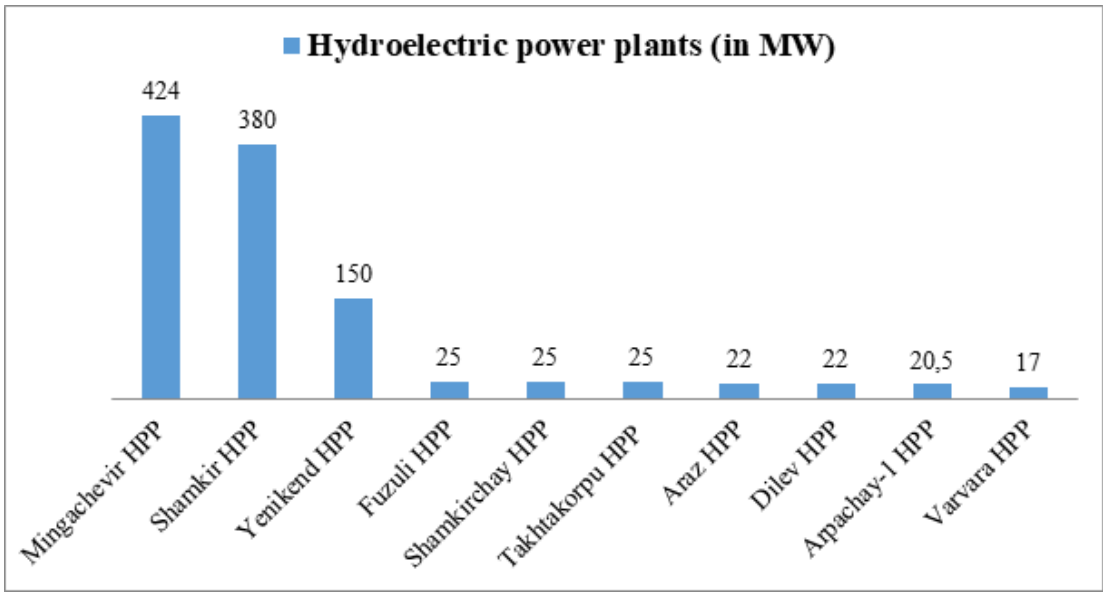


Source: Compiled by the authors based on data from AREA (2026)

Research on Azerbaijan's renewable energy potential indicates that the country has an estimated capacity of 27.5 thousand MW. Solar energy represents the largest share, with 23.0 thousand MW, followed by wind energy at 3.0 thousand MW, mountain rivers at 520 MW, and bioenergy at 380 MW. At present, renewable energy accounts for 17.3% of Azerbaijan's total energy production (MoE, 2026). Progress in this sector is also reflected

in electricity generation from hydropower plants. In 2021, total installed capacity from renewable energy plants reached 1,110.5 MW, mainly generated by major hydropower facilities such as Mingachevir HPP, Shamkir HPP, Yenikend HPP, Fuzuli HPP, Shamkirchay HPP, Takhtakorpu HPP, Araz HPP, Dilev HPP, Arpachay-1 HPP, and Varvara HPP. The dynamics of these indicators are presented in Figure 2.

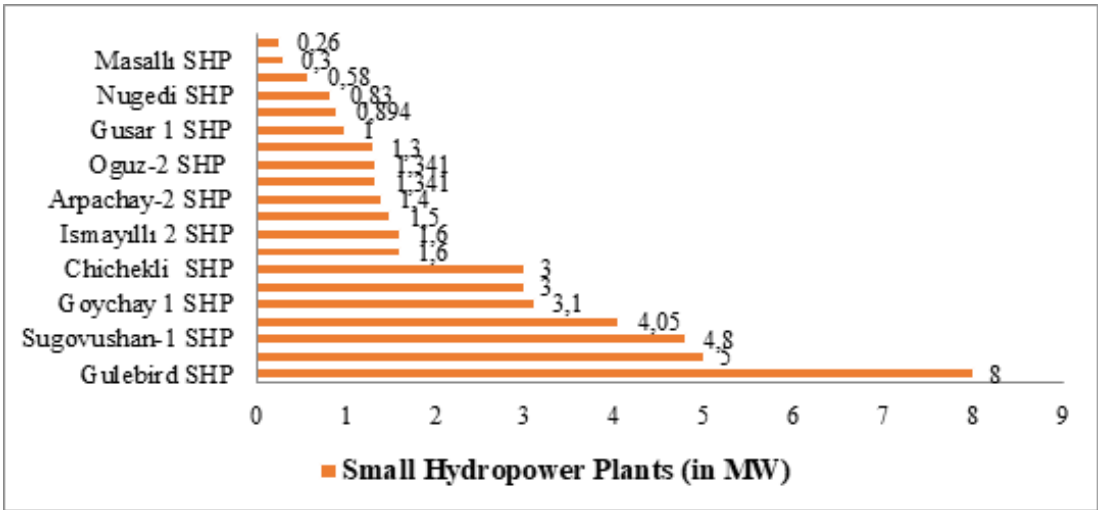
Figure 2. Hydroelectric Power Plants



Source: Compiled by the authors based on data from AREA (2026)

In Azerbaijan, small hydroelectric power plants produced a total of 44.3 MW per year (SSC, 2026), including the following plants in residential areas: Gulebird SHPP – 8.0 MW; Vaykhir SHPP – 5.0 MW; Suqovushan-1 SHPP – 4.8 MW; Mughan SHPP – 4.05 MW; Goychay-1 SHPP – 3.1 MW; Suqovushan-2 SHPP – 3.0 MW; Chichekli SHPP – 3.0 MW; Ismayilli-1 SHPP – 1.6 MW; Ismayilli-2 SHPP – 1.6 MW; Balakan SHPP – 1.5 MW; Arpachay-2 SHPP – 1.4 MW; Oguz-1 SHPP – 1.341 MW; Oguz-2 SHPP – 1.341 MW; Shaki SHPP – 1.3 MW; Qusar-1 SHPP – 1.0 MW; Oguz-3 SHPP – 0.894 MW; Nugedi SHPP – 0.83 MW; Shaki SHPP – 0.58 MW; Masalli SHPP – 0.3 MW; and Astara K368 SHPP – 0.26 MW.

Figure 3. Small Hydroelectric Power Plants (in MW)

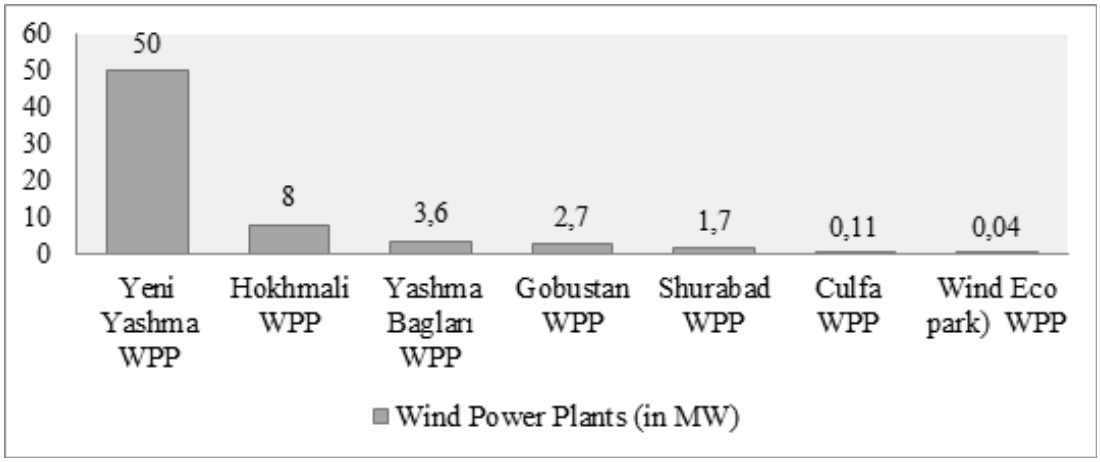


Source: Compiled by the authors based on data from AREA (2026)

Among non-hydropower renewable sources in Azerbaijan, wind energy ranks second in terms of production volume. In 2023, wind energy generation increased by 9.8%, while in 2022 it accounted for 13.9% of renewable energy production.

Total electricity generation from wind power plants reached 66.1 MW. The largest contribution came from the Yeni Yashma Wind Power Plant, followed by Hokhmali, Yashma Bagları, Qobustan, Shurabad, Culfa, and the Wind Eco-Park facilities.

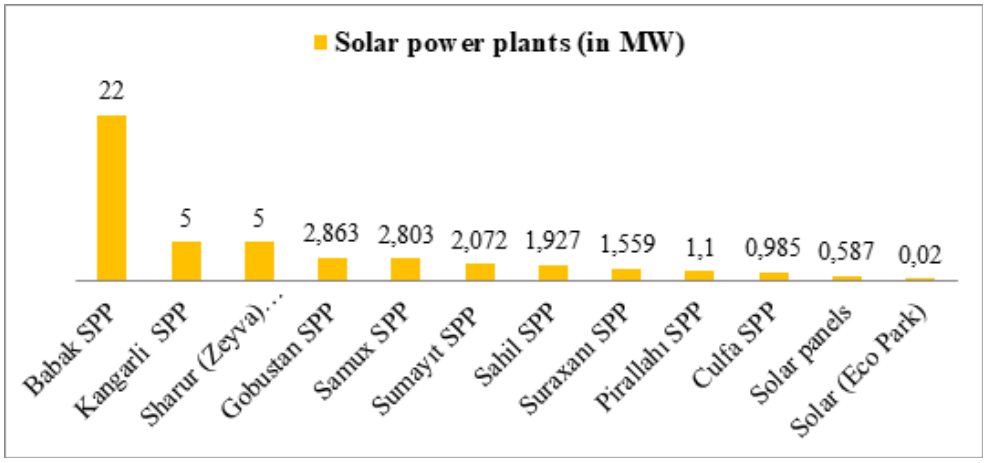
Figure 4. Wind Power Plants (MW)



Source: Compiled by the authors based on data from AREA (2026)

In recent years, the fastest-growing sector of the renewable energy industry in Azerbaijan has been solar energy production. Compared to the previous year, energy production in this sector increased by 25.2%, marking the highest level of energy output observed since 2018.

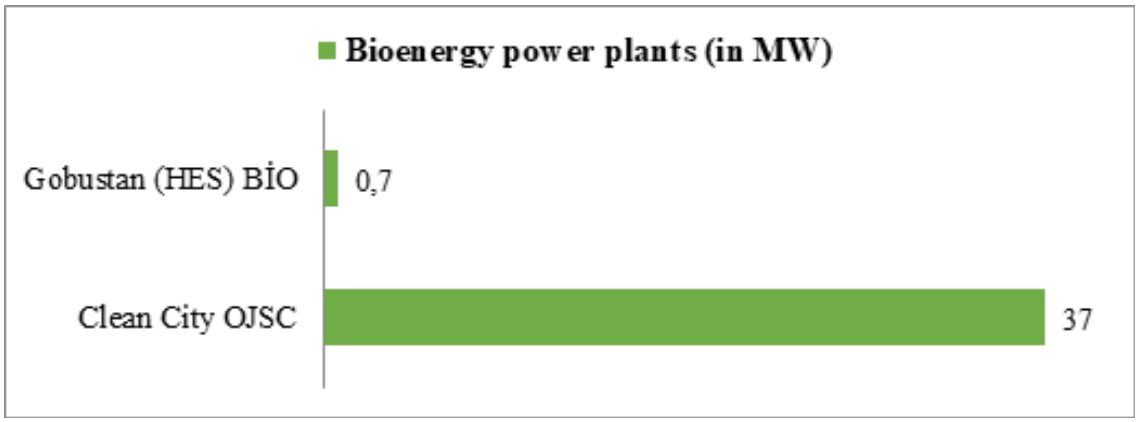
Figure 5. Solar power plants (MW)



Source: Compiled by the authors based on data from AREA (2026)

Figure 5 shows that the total capacity of solar power plants in Azerbaijan is 45.9 MW. The largest contributions come from the Babek, Kengerli, and Sharur Solar Power Plants, followed by smaller facilities in Gobustan, Samukh, Sumgait, Sahil, Surakhani, Pirallahi, Culfa, and Eco-Park. Bioenergy production in Azerbaijan remains more limited, with a total capacity of 37.7 MW. Most of this capacity is generated by “Clean City” JSC, while the Gobustan bioenergy facility accounts for a smaller share.

Figure 6. Bioenergy (in MW)



Source: Compiled by the authors based on data from AREA (2026)

In addition to hydropower, wind, solar, and bioenergy, Azerbaijan has an estimated geothermal energy potential of 98 MW and approximately 1 MW of marine energy capacity. Expanding the share of renewable energy in the national energy mix requires continued attraction of both domestic and foreign investment, alongside the adoption of international best practices.

Azerbaijan's renewable energy policy has evolved through a series of state programs and strategic initiatives. The *State Program on the Use of Alternative and Renewable Energy Sources* (SPRES, 2004) established the institutional foundation for the sector by promoting the use of renewable resources, improving the efficiency of hydrocarbon consumption, and encouraging environmentally sustainable energy production. Subsequent policy documents, including the *State Strategy on the Use of Renewable Energy Sources for 2012–2020*, strengthened this framework through legislative reforms, tariff and subsidy mechanisms, technological innovation, and support for private investment. Public-private partnership mechanisms, reinforced by regulations adopted in 2024, have further enhanced investment opportunities in the renewable energy sector.

The development of a Green Energy Zone in Azerbaijan's liberated territories represents one of the country's principal strategic priorities. Following the 2020 Patriotic War, the government adopted a dedicated decree to promote renewable energy development in these areas and commissioned the preparation of a comprehensive concept with the support of the Japanese consulting company TEPSCO. The initiative aims to utilize the region's considerable renewable energy resources, introduce energy-efficient and low-carbon technologies, and establish a sustainable energy system supported by demand forecasting and modern planning approaches.

Implementation measures include the expansion of renewable electricity generation, improvements in energy efficiency, deployment of electric vehicles, installation of rooftop solar systems, use of solar-powered public lighting, application of smart energy management technologies, and energy recovery from waste. At the UN Climate Change Conference (COP26) in 2021, Azerbaijan announced its commitment to reduce greenhouse gas emissions by 40% by 2050 and to establish a net-zero emissions zone in the liberated territories.

Preliminary assessments indicate that the districts of Qubadli, Zangilan, Jabrayil, and Fuzuli possess more than 7,200 MW of technical solar energy potential, while Lachin and Kalbajar have approximately 2,000 MW of wind energy potential. The Tartar and Hakari rivers also provide significant opportunities for hydropower development. To support these objectives, several hydropower plants have already been restored and commissioned in Lachin, Kalbajar, and Sugovushan, while construction continues on the Khudaferin and Giz Galasi hydropower projects on the Araz River. Additional investments include a planned 100 MW wind farm in the Lachin–Kalbajar region and a 240 MW solar

power project in the Zangilan–Jabrayil area implemented through cooperation between the Ministry of Energy and BP.

5. CONCLUSION

This study examined the institutional and economic foundations for establishing a Green Energy Zone in Azerbaijan by analyzing the country's renewable energy potential, policy framework, and implementation mechanisms. The findings indicate that Azerbaijan has established a comprehensive strategic and institutional basis for renewable energy development through state programs, national strategies, and regulatory reforms. Although notable progress has been achieved in expanding renewable energy capacity, particularly in hydropower, wind, solar, and bioenergy, the energy system remains dominated by hydropower, while the potential of other renewable sources is not yet fully utilized. The analysis further shows that institutional challenges, including limited interagency coordination, regulatory inconsistencies, and delays in project implementation, continue to constrain the pace of the energy transition. Strengthening governance structures, improving regulatory effectiveness, and expanding public–private partnerships will be essential for accelerating renewable energy development. From an economic perspective, Azerbaijan possesses considerable untapped renewable energy resources that can support energy diversification, attract investment, and promote sustainable economic growth. The Green Energy Zone initiative in the liberated territories represents a strategic opportunity to modernize regional energy infrastructure and align national energy policy with global sustainability objectives. This study contributes to the literature by integrating institutional, economic, and spatial dimensions within a unified analytical framework. Unlike previous studies that primarily examined individual sectors or policy measures, it provides a comprehensive assessment of the factors shaping green energy zone development in Azerbaijan. Overall, the findings suggest that Azerbaijan has established a solid foundation for the transition to a green energy system. Nevertheless, fully realizing the country's renewable energy potential will require continued institutional reforms, greater investment, wider adoption of advanced technologies, and effective policy implementation. Future research should focus on quantitative evaluations of investment efficiency, cost–benefit analyses of renewable energy projects, and comparative studies of energy transition in other resource-rich economies.

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