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RENEWABLE ENERGY POTENTIAL IN AZERBAIJAN IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Sammary

The main objective of this study is to comprehensively evaluate the current state and development potential of renewable energy sources in Azerbaijan within the framework of sustainable development. The study analyzes the structure of the country's energy consumption and comparatively examines the technical potential of renewable energy resources alongside their actual utilization levels. National and international official statistical data are used as the empirical basis, and descriptive-statistical, comparative, and analytical approaches are applied. The overall findings indicate that although Azerbaijan possesses significant renewable energy potential, the level of its utilization remains limited. In particular, despite the high technical capacity of solar and wind energy, hydropower continues to dominate electricity generation. The analysis further reveals that strengthening institutional mechanisms, improving the investment climate, and expanding the application of innovative technologies are essential for the efficient use of existing resources. At the same time, the study demonstrates that the development of the renewable energy sector has not only environmental but also significant economic and social impacts. In this regard, the findings provide scientifically grounded recommendations for shaping energy policy and implementing sustainable development strategies.

Keywords: Azerbaijan, Energy, Climate Change, Renewable Energy, Sustainable Development

Introduction

The idea of leaving a livable world for future generations has become one of humanity's shared and priority global agendas, particularly since the second half of the twentieth century. In this context, discussions and scientific research focused on sustainability continue to intensify. The institutional foundations of this process were laid with the 1972 Stockholm Conference; subsequently, the United Nations Framework Convention on Climate Change adopted at the 1992 Rio Conference provided a stronger impetus to the concept of sustainable development [7 , p. 17]. A more concrete framework was established at the 2002 Johannesburg World Summit on Sustainable Development, where the principle of “sustainable development for a sustainable world” was accepted as a global objective. Today, sustainable development is regarded as a comprehensive approach that encompasses not only economic growth but also environmental and social dimensions. In this context, a sustainable environment emerges as one of the key components of sustainable development. The protection of natural resources and the maintenance of environmental balance are considered essential responsibilities of the present generation toward future generations. Indeed, this approach is clearly reflected in international meetings, strategies, and projects organized by the United Nations within the framework of sustainable development [4 ,p. 85]. In recent years, Azerbaijan has become one of the regional leaders by closely cooperating with international organizations to ensure sustainable development in the energy sector and to accelerate the “green transformation” of its economy. The country's active participation in the “Environment and Development Partnership (GREEN) Program,” which supports transition economies—particularly in Eastern Europe, the Caucasus, and Central Asia—represents a significant step in this direction. The main objective of this initiative is to promote sustainable economic growth, improve environmental performance, support human capital development, and expand the application of green investments and innovative technologies [7 , p. 15]. The program also strengthens dialogue among public institutions, the private sector, and civil society, while creating opportunities to share best environmental and governance practices across the region. Despite the existing potential in the country, the level of utilization of renewable energy resources remains limited, and certain structural and institutional challenges persist in this field. This situation highlights the necessity of more efficient management of the energy

sector, improvement of the investment climate, and wider adoption of innovative technologies.

The main objective of this study is to analyze the current state and development potential of renewable energy sources in Azerbaijan within the context of sustainable development, to evaluate the level of utilization of existing resources, and to propose scientifically grounded conclusions regarding future development directions. Within the framework of the study, the country's energy structure, the technical potential of renewable energy resources, and their actual utilization are analyzed comparatively.

Methodology

In this study, a comprehensive methodological approach is employed to assess the current state and development potential of renewable energy resources in Azerbaijan. The research is primarily based on descriptive-statistical analysis, comparative analysis, and the interpretation of secondary data. The empirical basis of the study consists of official statistical data. The data are mainly obtained from the Ministry of Energy of the Republic of Azerbaijan, the State Statistical Committee of the Republic of Azerbaijan, as well as open databases of international organizations such as the World Bank and International Renewable Energy Agency [9]. The study utilizes data on energy production, installed capacity, the structure of energy sources, and renewable energy indicators, covering the period from 2015 to 2023.

In addition, a systems approach is applied, allowing the energy sector to be examined comprehensively within the context of sustainable development. This approach enables the consideration of the interactions among economic, environmental, and social factors.

Sustainable Development in the Renewable Energy Sector of Azerbaijan

The Republic of Azerbaijan has stood out with its dynamic economic development model since gaining independence and has become one of the fastest-transforming states in the region. The structural changes observed in recent years, the parallel development of industry, agriculture, and the service sector, the increase in social welfare, and policies aimed at technological modernization are key indicators of this process. The country's economic strategy focuses not only on oil and natural gas revenues but also on the development of human capital, the promotion of knowledge-intensive and innovative production, and the establishment of a competitive and environmentally sustainable economic model. Azerbaijan's energy sector has undergone significant transformation in recent years in line with sustainable development goals. Despite possessing abundant natural energy resources and

being recognized as a global energy exporter, the development of renewable energy sources has become one of the central directions of energy policy. The country's natural and geographical characteristics create highly favorable ecological and climatic conditions for the development of the renewable energy sector. The diversity of relief, high levels of solar radiation, stable wind regimes, and the availability of water resources provide broad opportunities for the efficient utilization of alternative energy sources. This approach not only reduces dependence on oil and natural gas revenues but also contributes to maintaining ecological balance and building a sustainable energy system.

Under the leadership of İlham Aliyev, one of the key priorities of the national energy policy is to increase the share of alternative energy sources and implement practical mechanisms in this field. Comprehensive measures are currently being undertaken to assess and efficiently utilize the country's renewable energy potential. As a result of scientific and technical research, eight regions suitable for renewable energy development have been identified. These regions are considered priority areas in terms of resource availability and infrastructure. At present, work is underway to implement pilot projects in three of these regions. These projects aim to expand the country's experience in green energy production, attract private investment, and test the application of modern technologies [1].

The country is focused on increasing its renewable energy capacity to diversify the economy, reduce carbon emissions, and become a green energy exporter. Key initiatives in this context include increasing the share of solar and wind energy, implementing new laws and incentives to attract foreign investment, and participating in "green energy corridor" projects aimed at exporting electricity to Europe. Azerbaijan has set strategic targets to increase the share of renewable energy in the total energy mix to 30% by 2030 and to reduce greenhouse gas emissions by 40% by 2050. The government is also working on developing a long-term energy strategy covering the period up to 2050. This strategy encompasses key areas such as electricity and natural gas supply, energy efficiency, and the expansion of renewable energy sources.

As reflected in the strategy, the government plans to adopt a "dual-pillar" approach to achieve its long-term objectives. On the one hand, this approach aims to increase electricity generation from renewable energy sources; on the other hand, it seeks to reduce dependence on natural gas in electricity generation. For example, in 2020, the share of electricity generated from renewable energy sources accounted for approximately 6% of total production. Increasing the share of renewable energy in electricity generation will also have a direct impact on reducing greenhouse gas emissions. As stated in the "Azerbaijan 2030: National Priorities for Socio-Economic Development" document, transitioning to a development model based on "green

growth” is one of the country’s key objectives by 2030. As a result of the measures implemented in recent years, Azerbaijan has effectively initiated the process of sustainable development in the energy sector by establishing green energy zones, gradually decarbonizing energy production, and expanding renewable energy projects. At every stage of development, the goal is to sustain economic growth, ensure environmental sustainability, and build an economic system based on energy efficiency.

Renewable Energy Resource Potential in Azerbaijan

The total electricity generation capacity of the Republic of Azerbaijan amounts to 8,320.8 MW, of which 1,687.8 MW (including large hydropower plants) is generated from renewable energy sources (RES). This figure corresponds to approximately 20.3% of the total installed generation capacity. The hydropower sector holds the largest share within the RES structure, with a total capacity of 1,301.8 MW, covering 35 hydropower plants across the country (24 of which are small hydropower plants). The current wind energy capacity is 66.4 MW, with production carried out at 8 power plants (3 of which are hybrid). In the bioenergy sector, 2 plants (one hybrid) are in operation, with a total capacity of 37.7 MW. Solar power plants have a total installed capacity of 281.9 MW, implemented across 13 plants (3 of which are hybrid). Among hybrid facilities, Gobustan, Julfa, and the Gala Ecological Park are particularly noteworthy. These facilities have installed capacities of 2.85 MW in wind energy, 3.8 MW in solar energy, and 0.7 MW in bioenergy. In addition, solar power plants with a total capacity of 39 MW are operating in the Nakhchivan Autonomous Republic. Excluding large hydropower plants, the installed capacity of renewable energy sources in 2023 amounted to 520.3 MW, representing approximately 6.4% of the country’s total electricity generation capacity.

Among renewable energy types, wind energy is considered one of the most efficient sectors due to its relatively low cost, ecological cleanliness, and inexhaustible nature. According to estimates, Azerbaijan’s annual wind energy potential is approximately 800 MW, corresponding to an electricity generation potential of about 2.4 billion kWh per year [2]. Based on scientific and technical assessments, the total technical potential of renewable energy resources in Azerbaijan is estimated at approximately 130,000 MW/year (see Table 1). This indicator is of great importance for diversifying the country’s energy security strategy and transitioning to a green economy model.

Table 1. Technical Potential of Renewable Energy Resources in Azerbaijan

Renewable Energy Sources (RES)	Capacity (MW/year)
Solar Energy	>115,200
Wind Energy	>15,000
Bioenergy	>900
Geothermal Energy	>200
Small Hydropower	>650
Total	>130,000

Source: <https://www.adb.org/sites/default/files/publication/522891/adbi-wp992.pdf>

The table presents the total technical potential of renewable energy sources in Azerbaijan. According to the data, the largest potential belongs to solar energy (over 115,200 MW), which is closely associated with the country's high level of solar radiation. Wind energy ranks second, demonstrating a potential of more than 15,000 MW. Other energy types—bioenergy, geothermal energy, and small hydropower—have relatively smaller shares. Overall, with a total potential exceeding 130,000 MW, Azerbaijan has substantial opportunities to diversify its energy sector and transition toward a green economy.

Table 2. The capacity indicators of renewable energy power plants in Azerbaijan are presented

Type of Power Plant	Capacity (MW/year)
Hydropower Plants	1,106.4
Wind Power Plants	15.7
Waste-to-Energy Plants (Municipal Waste)	42.0
Biogas Power Plants	1.0
Solar Power Plants	28.4

The table reflects the actual installed capacity of renewable energy-based power plants operating in Azerbaijan. The indicators clearly show that hydropower currently holds a dominant position. On the other hand, the shares of wind and solar energy remain relatively limited. This situation indicates that the country's renewable energy potential has not yet been fully

realized and that additional investment and technological support are required for the development of alternative energy sources.

The forecast indicators formulated for renewable energy sources (RES) in Azerbaijan constitute one of the key directions of the country's long-term energy strategy. Based on these projections, Azerbaijan's strategic objective is to steadily increase the share of renewable sources in total energy production in the coming years, while diversifying the energy portfolio and strengthening energy security. The implementation of this policy will not only ensure environmental sustainability but also enhance export potential. In this way, meeting part of domestic demand through renewable energy will help conserve natural gas resources and create additional opportunities for their export to European markets [8 p. 22].

Based on the current situation and future targets, Azerbaijan's "**Renewable Energy Strategic Roadmap**" has been developed. This document envisages a gradual increase in the share of renewable energy sources in the overall energy balance by 2030 and sets specific capacity targets for solar, wind, hydropower, and bioenergy. The current status of these renewable energy sources and the planned capacity indicators up to 2030 are presented in detail in **Table 3**. This table reflects the projected growth potential and institutional targets envisaged for the implementation of **Table** .

Table 3. Azerbaijan's energy transition strategy.

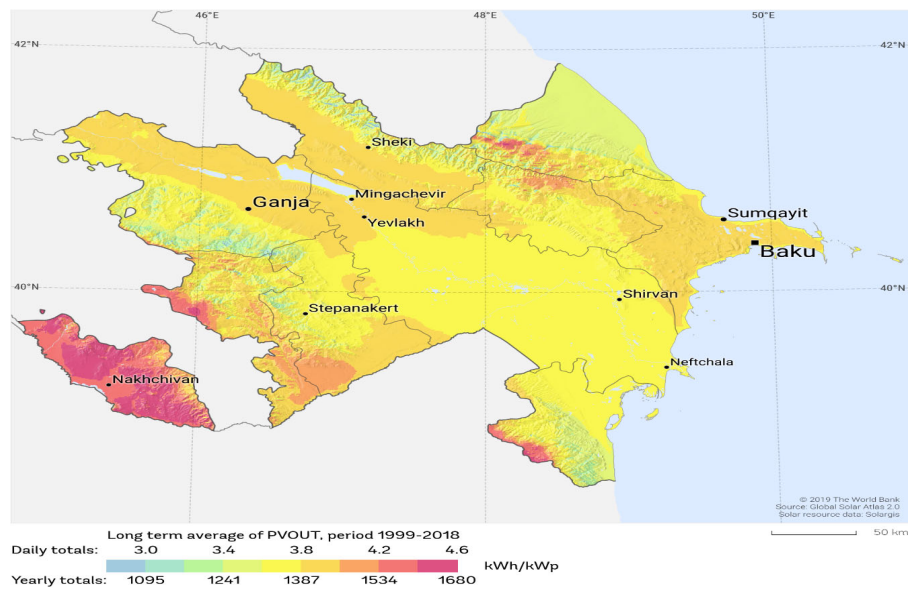
Renewable Energy Sources (RES)	2018	2020	2025	2030
Wind Power Plants	311 MW	350 MW	440 MW	465 MW
Solar Power Plants	35 MW	50 MW	150 MW	190 MW
Hydropower Plants	—	10 MW	220 MW	220 MW
Bioenergy Power Plants	37 MW	20 MW	30 MW	50 MW
Total (MW)	383 MW	430 MW	840 MW	925 MW
Total (%)	8.1%	20%	25–30%	35–40%

The table reflects Azerbaijan's long-term strategic targets in the field of renewable energy. According to the indicators, a significant increase in installed capacity for wind and solar energy is planned by 2030. It is envisaged that the total renewable energy capacity will reach 925 MW and its share in the energy balance will increase to 35–40%. This dynamic clearly demonstrates that the "green transition" strategy is a key priority in the country's energy policy.

Azerbaijan's solar and wind energy potential constitutes one of the fundamental directions of its renewable energy policy, while the country's natural and geographical conditions create broad opportunities in this field. In terms of solar energy, the annual sunshine duration averages around 2,500 hours in the Absheron Peninsula and the Caspian coastal regions, while it reaches approximately 2,900 hours in the Nakhchivan Autonomous Republic. Based on these indicators, the annual solar energy potential per square meter in the country ranges between 1,300 and 1,750 kWh/m². According to estimates, Azerbaijan's total solar energy potential is about 115,200 MW/year.

Currently, five solar power plants (SPPs) with a total capacity of 2.8 MW are operating in the districts of Samukh, Sumgait, Pirallahi, Surakhani, and Garadagh. In addition, a sixth solar power plant with a capacity of 20 MW has been commissioned in the Nakhchivan Autonomous Republic. These facilities make a significant contribution to the regional development of the renewable energy sector and the diversification of energy supply.

Figure1. Azerbaijan's photovoltaic power potential.

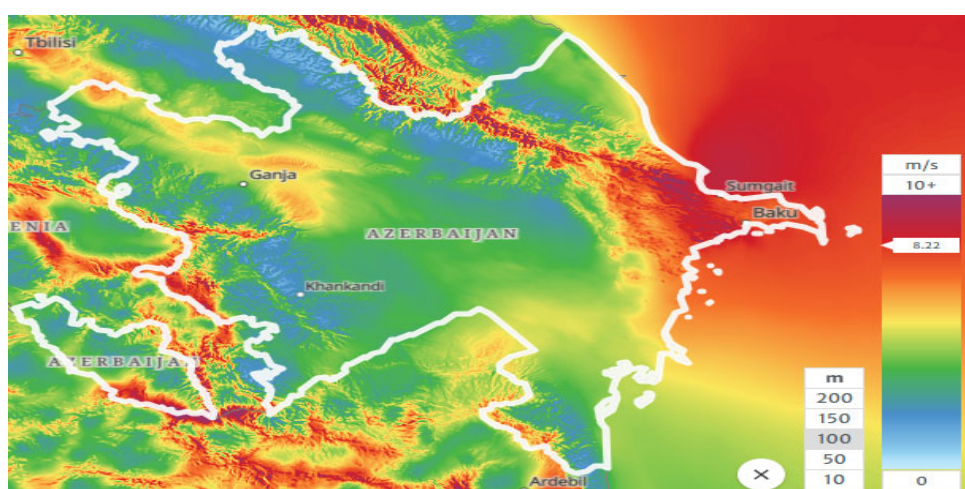


Source: The World Bank Group Global Solar Atlas. Global Solar Atlas. Available online: <http://www.globalsolaratlas.info/>

In the field of wind energy, the Absheron Peninsula and the Caspian Sea coastal areas are considered regions where strong winds occur for more than 270 days per year. Wind currents mainly enter through a narrow strip along the Caspian coast and natural corridors between the Greater and

Lesser Caucasus Mountains, which contributes to the continuous intensification of wind density in the region. According to measurements, the annual average wind speed at a height of 80 meters above ground varies between 7.0 and 8.5 m/s, which is characteristic of areas with high energy potential. By a decision of the Tariff Council of the Republic of Azerbaijan since 2007, the electricity sales tariff for wind energy has been set at 4.5 AZN. This tariff policy has encouraged the implementation of several wind energy projects, including Yeni Yashma (1.7 MW), Shurabad (48 MW), Sitalchay (3.6 MW), Hokmali (8 MW), the offshore “Kulek Island” project (200 MW), and the Yeni Yashma Wind Power Plant (50 MW) (State Agency for Alternative and Renewable Energy Sources, 2019) [3].

Figure 2. Average wind speed at 100 m height.



Source: The World Bank Group Global Solar Atlas. Global Solar Atlas. Available online: <http://www.globalwindatlas.info/>

Azerbaijan’s renewable energy resources are not limited to solar and wind energy; the country also possesses significant potential in bioenergy, geothermal energy, thermal waters, and hydropower. In 2022, the amount of production and consumption waste generated in the country in terms of bioenergy reached 3,985.1 thousand tons, of which 20% (802 thousand tons) was utilized or neutralized (*Environment in Azerbaijan, 2023*, p. 139). The energy production potential of municipal waste exceeds the capacity of the existing waste incineration plant. In addition, waste is generated during the processing of fruits, vegetables, grains, vegetable oils, tea, and tobacco (113.5 thousand tons), sugar processing (20.1 thousand tons), and cotton ginning (83.5 thousand tons). These wastes can be effectively utilized as biomass [6. p.

63]. Azerbaijan also has considerable potential in geothermal energy resources. Existing thermal resources are mainly concentrated in the Greater and Lesser Caucasus mountain systems, the Absheron Peninsula, the Talysh Mountains, the Kura-Araz lowland, the Nakhchivan Autonomous Republic, and the northwestern part of the Caspian Sea. However, the high costs associated with drilling and operating geothermal wells limit the implementation of large-scale electricity generation in this sector. Moreover, since the temperature of many thermal water sources in the country is below 80°C, recently developed low-enthalpy geothermal technologies have made it possible to utilize these resources more efficiently.

The estimated operational reserves of thermal waters in Azerbaijan are approximately 2,000 m³/day (t = 30–50°C) on the southern slope of the Greater Caucasus, 21,000 m³/day (t = 40–85°C) in the Guba-Khachmaz region, and 20,000 m³/day (t = 40–90°C) on the Absheron Peninsula (Namazova, A.M., 2017, p. 26). These include 17 wells in Guba with a total discharge of 30,000 m³/day, 10 wells in Khachmaz with 30,000 m³/day, 10 sources in Gakh with 3,100,000 m³/day, 10 thermal wells in Shabran with 27,500 m³/day, 8 thermal wells in Shamakhi with 505,000 m³/day, and 7 thermal wells in Ismayilli with 440,000 m³/day. The temperatures of these wells range from 4°C to 97°C, with an overall operational reserve of approximately 245 thousand m³/day.

Hydropower is considered the most widely used and developed form of renewable energy in Azerbaijan. The presence of more than 1,100 rivers in the country indicates substantial technical opportunities in this field. According to historical records, the first hydropower plant was built in 1883 in the village of Galakend in the Gadabay region to supply energy to a copper smelting facility. However, in modern times, the full potential of hydropower has not yet been completely utilized, and efforts are ongoing to expand small and medium-sized hydropower plants across the country.

From a sustainable development perspective, the realization of renewable energy potential provides not only economic but also environmental advantages. In particular, in the context of combating climate change, reducing carbon emissions and applying environmentally friendly technologies in energy production are of critical importance. In this regard, the expansion of renewable energy sources enables the country to act in accordance with its international climate commitments.

Conclusion

Based on existing statistical data, the share of renewable energy sources in Azerbaijan's total electricity generation capacity has shown an increasing trend in recent years. Although this growth is mainly driven by the extensive

use of hydropower resources, significant progress has also been observed in the fields of solar and wind energy. In this context, the direction of state policy and the implementation of international cooperation mechanisms play a crucial role. Azerbaijan's renewable energy potential offers broad development prospects, both in terms of its rich natural resources and its strategic policy framework. However, for the full realization of this potential, it is necessary to continue institutional reforms, improve the investment climate, and expand the application of innovative technologies. Steps taken in this direction will accelerate the country's transition to a sustainable development model and contribute to long-term economic stability. In particular, the diversification of energy production and the transition to a "green energy" model will play a key role in ensuring long-term economic resilience.

In conclusion, the effective realization of Azerbaijan's renewable energy potential requires the implementation of a comprehensive and coordinated policy approach. Measures undertaken in this direction will accelerate the country's transition toward sustainable development and further strengthen its position in the regional energy market.

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**Потенциал возобновляемых источников энергии в
Азербайджане в контексте устойчивого развития**
Аннотация

Основной целью данного исследования является комплексная оценка текущего состояния и потенциала развития возобновляемых источников энергии в Азербайджане в рамках концепции устойчивого развития. В рамках исследования проанализирована структура энергопотребления страны, а также проведено сравнительное изучение технического потенциала возобновляемых энергетических ресурсов и уровня их фактического использования. В качестве эмпирической базы использованы национальные и международные официальные статистические данные, а также применены дескриптивно-статистический, сравнительный и аналитический методы. Полученные результаты показывают, что, несмотря на значительный потенциал возобновляемой энергии, уровень его использования в Азербайджане остается ограниченным. В частности, несмотря на высокий технический потенциал солнечной и ветровой энергии, гидроэнергетика по-прежнему занимает доминирующее положение в производстве электроэнергии. Проведенный анализ свидетельствует о необходимости усиления институциональных механизмов, улучшения инвестиционного климата и расширения применения инновационных технологий для более эффективного использования имеющихся ресурсов. В то же время исследование показывает, что развитие сектора возобновляемой энергетики имеет не только экологическое, но и значительное экономическое и социальное значение. В этом контексте полученные результаты предоставляют научно обоснованные рекомендации для формирования энергетической политики и реализации стратегий устойчивого развития.

Ключевые слова: Азербайджан, энергетика, изменение климата, возобновляемые источники энергии, устойчивое развитие

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**Azərbaycanda Davamlı İnkişaf Kontekstində Bərpa Olunan
Enerji Potensialı
Xülasə**

Bu tədqiqatın əsas məqsədi Azərbaycanda bərpa olunan enerji mənbələrinin mövcud vəziyyətini və inkişaf potensialını davamlı inkişaf çərçivəsində kompleks şəkildə qiymətləndirməkdir. Tədqiqat çərçivəsində ölkənin enerji istehlakı strukturu təhlil edilmiş, bərpa olunan enerji resurslarının texniki potensialı ilə onların faktiki istifadə səviyyəsi müqayisəli şəkildə araşdırılmışdır. Empirik baza kimi milli və beynəlxalq rəsmi statistik məlumatlardan istifadə olunmuş, deskriptiv-statistik, müqayisəli və analitik yanaşmalar tətbiq edilmişdir. Ümumi nəticələr göstərir ki, Azərbaycan əhəmiyyətli bərpa olunan enerji potensialına malik olsa da, bu potensialdan istifadə səviyyəsi hələ də məhduddur. Xüsusilə günəş və külək enerjisi üzrə yüksək texniki imkanlara baxmayaraq, elektrik enerjisi istehsalında hidroenerji üstün mövqedə qalmaqdadır. Aparılan təhlil göstərir ki, mövcud resurslardan səmərəli istifadə üçün institusional mexanizmlərin gücləndirilməsi, investisiya mühitinin yaxşılaşdırılması və innovativ texnologiyaların tətbiqinin genişləndirilməsi zəruridir. Eyni zamanda, tədqiqat bərpa olunan enerji sektorunun inkişafının yalnız ekoloji deyil, həm də mühüm iqtisadi və sosial təsirlərə malik olduğunu ortaya qoyur. Bu baxımdan əldə edilən nəticələr enerji siyasətinin formalaşdırılması və davamlı inkişaf strategiyalarının həyata keçirilməsi üçün elmi əsaslı tövsiyələr təqdim edir.

Açar sözlər: Azərbaycan, Enerji, İqlim Dəyişikliyi, Bərpa Olunan Enerji, Davamlı İnkişaf

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