



Innovative development model in green industry construction in Azerbaijan and assessment of green energy potential

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Abstract

The article examines the formation of an innovative development model and the assessment of green energy potential in ensuring green industrial development in Azerbaijan. The problems of developing and modeling the green industry have been explained. The positive impacts of the green industry on the environment have been analyzed and systematized. Taking into account new challenges, an assessment of the development potential of the green energy industry in Azerbaijan has been conducted. The positive aspects of various types of green energy, including clean and inexhaustible energy sources such as solar, wind, water, biomass, and geothermal, were explained. The possibility of taking effective measures to reduce carbon emissions, prevent environmental pollution, and ensure energy security by expanding the green economy and increasing the production of green energy has been substantiated. The potential of green energy types to significantly reduce carbon emissions and make a significant contribution to maintaining ecological balance has been explored. The development of the green energy industry can ensure the economic revival and improvement of the social well-being of regions. In terms of environmental protection in Azerbaijan, the importance of improving the processes of using and neutralizing waste generated by industrial sectors was emphasized. The volume, use, and disposal of waste generated by industrial enterprises in Azerbaijan in 2024 were analyzed. The role of digitalization and innovation in the development of the green industry was examined. The possibilities of artificial intelligence, blockchain, big data, and other digital technologies were explored. The main benefits of implementing an innovative development model in Azerbaijan are given. The benefits of implementing an innovative development model in industry are schematically presented. The importance of forming an innovative development model in ensuring green industrial construction in Azerbaijan was stated. The implementation processes of a number of major projects related to the development of the green energy industry were analyzed. The volume of electricity generation from green sources has been analyzed. The power of hydro, solar, and wind power plants has been given. The need to develop efficient energy storage systems to ensure a stable green energy supply has been highlighted. In the near future, generalizations were made, recommendations and proposals were prepared on the creation of an innovative development model for green industrial construction in Azerbaijan, and the assessment of green energy potential.

Keywords: green industry, green industrial construction, innovative development model, green energy, assessment of green energy potential, alternative energy sources

1. Introduction

It should be noted that in modern times, the issues of sustainable development and environmental safety are among the most pressing problems on a global scale. To address these problems, countries are formulating various strategies and trying to accelerate the green transformation process in key sectors of the economy. In recent years, building green industries in Azerbaijan has become one of the main priorities of economic development strategies. Taking into account some global problems like efficient management of natural resources, environmental protection, and the fight against climate change, our country is taking persistent steps in this field.

It is well known that the green industry is an industrial activities that minimize its negative impact on the environment during the production process, as well as contributes to sustainable development. These include environmentally friendly activities, which embrace energy efficiency, minimizing waste, and

recycling resources. Moreover, the green industry is characterized by the utilization of green energy and sustainable production methods. Rich natural resources, as well as an advantageous geographical position, provide Azerbaijan with wide prospects for developing the green industry. Some innovations in the field of the energy industry and the use of environmentally friendly technologies help to make the process of developing this sphere even faster. In particular, investments in green energy can be viewed as one of the key pillars of the green industrial paradigm. (Yaşıl Sənaye və Azərbaycanca Yaşıl Sənayenin Önəmi, 2024). Unlike traditional industrial models, the concept of green industry involves reconciling economic efficiency with environmental protection, using fewer resources in production processes, minimizing waste, and expanding the use of green energy sources.

As a result of rapid industrialization and population growth in the modern world, energy demand is continuously increasing. It is known that the widespread use of fossil fuels such as oil, gas, and coal, which are traditional energy sources, creates environmental problems in addition to the problem of resource depletion. Against the backdrop of global problems such as climate change, air pollution, and environmental degradation, humanity is forced to turn to green energy sources. In this context, various types of energy produced from these sources are considered the main energy source of the future.

Green energy mainly includes clean and inexhaustible energy sources such as solar, wind, water, biomass, and geothermal. In modern conditions, the development of technology and the increase in the economic efficiency of renewable energy systems have significantly increased interest in this field. The green energy industry, especially in developing countries, creates new economic opportunities and employment potential (Aliyev, Sh., Gulaliyev, M., Pürhani, S., Mehdiyeva, G., & Mustafayev, E. 2024). Let us add that the production of green energy is of great importance in terms of reducing carbon emissions, preventing environmental pollution, and ensuring energy security. The use of this type of energy helps reduce the impact of climate change and limit global temperature increase. Also, the expansion of the green energy sector leads to the creation of new job opportunities, which is considered a key component of sustainable development. In addition, the development of this sector improves air quality by reducing atmospheric pollution. According to expert forecasts, by 2030, approximately 65% of electricity in the world will be provided by renewable or green sources (Azərbaycanın enerji siyasətinin əsas istiqamətlərindən biri – “Yaşıl enerji”, 2024).

Considering some challenges faced at a global level, such as efficient natural resources management, environmental protection, and combating climate change, our state does not stay away from this process. As is known, green industries refer to those industrial activities that minimize the negative influence of industries on the environment in the course of their activity, as well as contribute to sustainable development. This can be seen in the form of environmentally-friendly industries, which involve energy efficiency, waste minimization, and recycling. Furthermore, green industries include the usage of green energy and sustainable production processes. Being endowed with rich natural resources and a favorable geographical location allows Azerbaijan to have great opportunities in the development of the mentioned area. Innovations in the field of the energy industry and environmentally-friendly technologies allow accelerating the process of development. In particular, investments in green energy can be regarded as one of the main pillars of the mentioned paradigm.

2. Research Results

Having regard to certain problems which exist at the international level, such as effective management of natural resources, environmental protection, and overcoming the effects of climate change, our country is not excluded from this process.

As we all know, green industries represent those industrial activities that reduce the harmful impact of industries on the environment as well as make contributions to sustainable development. This can be demonstrated through environmentally-friendly industries which are characterized by energy efficiency, waste reduction, and recycling. In addition, green industries include green energy and sustainable



production. Rich natural resources and favorable geographical conditions create good premises for the development of this area in our country. Advances in the energy industry and environmentally-friendly technologies make it possible to accelerate this process. One of the important components of the discussed paradigm may be the investments in green energy. This is of strategic importance not only in terms of economic profitability, but also in terms of environmental sustainability. The second important direction is the modernization of industrial enterprises and their adaptation to environmental standards. Technological innovations are being implemented, and recycling and waste management systems are being established, in order to reduce the environmental impact of existing industrial facilities. For example, as a result of the application of new technologies in the petrochemical, metallurgical, and construction materials industries in our country, productivity is increasing and harmful effects on the environment are decreasing. In addition, a number of projects are being implemented in the field of waste sorting, neutralization, and recycling.

In Azerbaijan, processes of utilization and neutralization of waste generated by industrial sectors are being implemented in terms of environmental protection. In some years, the volume of waste generated by industrial enterprises is less than that used and neutralized, which is an important step in their greening (see Figure 1).

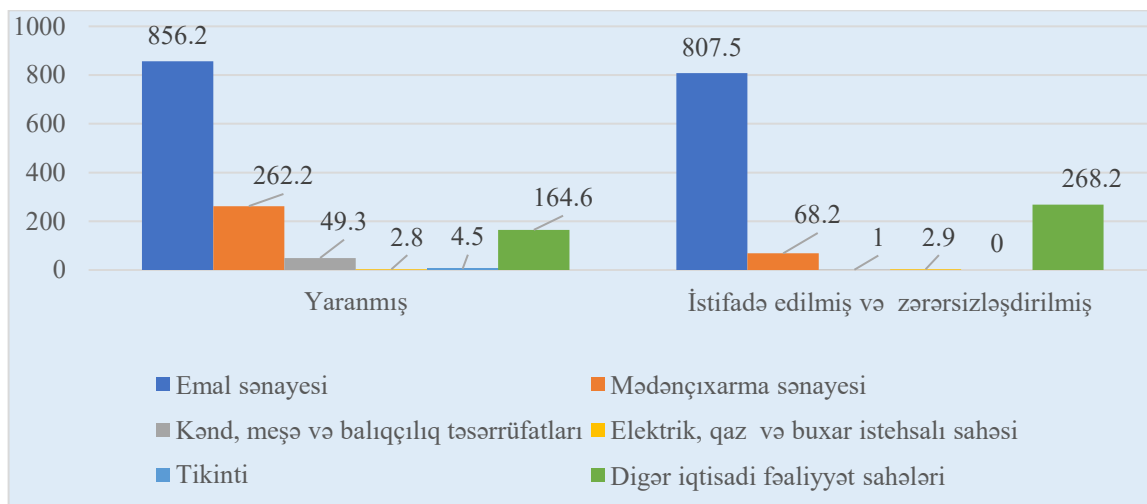


Figure 1 shows that in 2024, the largest amount of waste was generated in the processing industry - a total of 856.2 thousand tons. 807.5 thousand tons of this waste were either used or neutralized, meaning that the vast majority of what was generated - approximately 94.3% - was managed properly. This means that only a small portion of industrial waste (approximately 48.7 thousand tons) has neither been used nor disposed of. This may pose a certain risk to the environment, as uncontrolled waste can cause pollution.

Protecting resources and ensuring environmental sustainability during the establishment of green industries in Azerbaijan leads to important economic, environmental, and social consequences. The application of advanced technologies and green approaches that ensure the efficient use of resources creates conditions for cost optimization, reducing environmental impact, and increasing social responsibility. Together, these factors not only increase the competitiveness of green industries in the market but also have a positive impact on their overall innovative development (Zeynalova, 2023). The role of digitalization and innovation in the development of the green industry is also undeniable. Thanks to the capabilities of artificial intelligence, blockchain, big data, and other digital technologies, production processes are planned and managed more accurately. This creates conditions for minimizing energy consumption and waste. In Azerbaijan, various incentive mechanisms are being implemented to strengthen the innovation ecosystem in this area, startup projects are being supported, and business incubators and technoparks are being created for the development of environmentally friendly technologies.

In addition, green industry encompasses not only technological and economic changes, but also social aspects (Reilly, J.M., 2012). The demand for green skills in the labor market is increasing, which necessitates appropriate reforms in the education system. Vocational and higher education institutions in Azerbaijan are implementing new curricula, establishing international collaborations, and conducting advanced training courses to strengthen personnel training in this area. The development of human capital and increasing the ability to adapt to green technologies are among the key factors ensuring the long-term sustainability of the industry. It can be said that the development of green industries creates the basis for the emergence of new technologies, skills, and practices, which in turn allows for the formation of a more flexible and professional workforce (Jones & Kettlewell, 2021). Green jobs that emphasize sustainability have a positive impact on economic and social stability by reducing dependence on depleting resources. As a result of tightening environmental protection requirements, industries will increasingly need workers who can implement sustainable approaches and have relevant green skills. Investments directed towards the creation of such business areas create conditions for the country to rise to a leading position in the field of innovation and sustainable development, which significantly increases its international reputation and competitiveness (Humbatova, S.R., 2024). The green industry maintains its importance as an important tool in achieving sustainable development goals. This sector makes significant contributions to society not only from an economic and social perspective, but also from an ecologically safe perspective by producing products. Larger-scale research and practical applications in this direction in the future will accelerate the integration of green industrial models into various fields, create opportunities for the formation of innovative approaches and their more efficient implementation (Babayeva, 2025).

It should be noted that in recent years, ensuring ecological sustainability, effective resource management, and developing an industry based on the principle of minimal environmental damage have been among the priorities in Azerbaijan. In this context, the innovative development model is of particular importance, because it is systems built on innovation that can ensure economic efficiency and environmental sustainability in parallel. The application of an innovative development model is considered necessary to increase the competitiveness of all industrial sectors and expand access to world markets. For this purpose, the maximum amount of direct budget funds directed at stimulating innovation activity is determined not only by the state's financial resources, but also by the extent to which that funding is effectively implemented through innovative and anti-crisis measures. When formulating national priorities for technological development, joint activities of government agencies, banking and industrial capital, scientific research institutes, and industrial enterprises are considered more appropriate. Through this approach, coordination between the main directions of scientific-technical and financial policy can be ensured, as well as opportunities to increase innovation activity can be comprehensively assessed (Rasulov, K.A., 2015).

We believe that the innovative development model is a dynamic model that responds to the economic, technological and social challenges of the modern era. Unlike traditional economic development mechanisms, this model is built on creating a sustainable competitive advantage, rapidly commercializing new ideas, and unleashing creative potential in all segments of society. The innovative development model is formed through the synergistic effect of science, technology, and education, and emphasizes the development of sectors that create high added value in the economy. Innovative development has the potential to act as a key factor in ensuring economic prosperity in the future. At the same time, innovations play an important role in shaping the level of national development and the competitive advantage of the state. In a broader sense, the innovation potential of countries is considered a decisive criterion in assessing competitiveness at the global level (Fataliyeva, 2020). Since innovation is centered on the creation of new products, services, and processes, this model leads to serious changes in the structure of the economy.

One of the main conditions for an innovative development model is the existence of a strong scientific and research base. Strong cooperation between universities, research institutes, and the private sector plays an important role in this area. Creating a favorable legal and economic environment for the



commercialization of science and technology ensures the transformation of innovations into real market products, and the role of the state in shaping this environment is indispensable. The state should actively participate not only in terms of improving the regulatory framework, but also in terms of financing and promoting innovative projects. One of the most important benefits of implementing an innovative development model is increasing the sustainability and competitiveness of the economy. The traditional approach of growth is such that there is heavy dependence on external markets as well as the sources of raw materials. But in the case of an innovation-led growth model, the economy becomes more diversified and self-sufficient. The other advantage of adopting the innovation-led model of growth is the development of human resources. An innovative economy creates a demand for highly qualified personnel, which leads to qualitative changes in the education system. Stimulating personal initiative, creativity, and technological literacy raises the overall intellectual level of society, thanks to which sustainable development is observed not only in the economic but also in the social sphere.

An innovative development model in a global context allows countries to strengthen their positions in the international arena. Countries that lead in technological innovation gain economic and political influence. Developing countries based on such a model are more successful in attracting foreign investment and are able to promote their products in international markets, which creates the basis for the formation of a national brand and the improvement of the overall image of the country.

We have reflected the benefits of implementing an innovative development model in the industry in Figure 2.

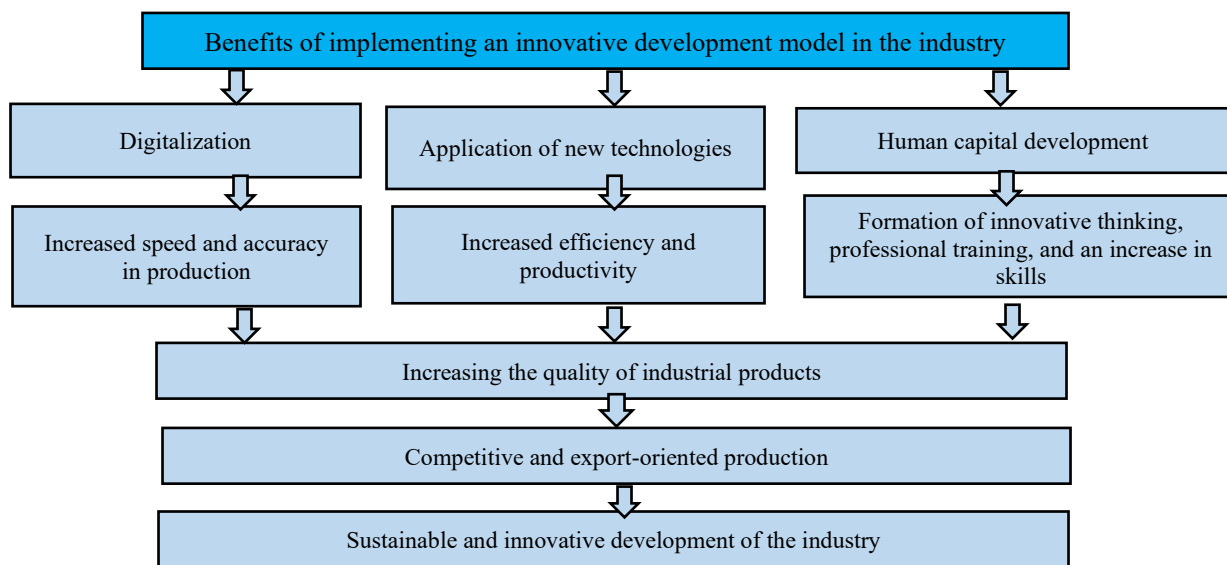


Figure 2. Benefits of implementing an innovative development model in industry (compiled by the author)

The implementation of an innovative development model also offers environmental benefits. New technologies cause less damage to the environment, save energy, and reduce waste. This is especially important in the context of global climate change. Promoting green technologies and green energy sources is an environmentally and economically beneficial strategy. Therefore, investigating the issues of increasing the role of the innovative development model in ensuring green industrial construction in Azerbaijan is of great practical importance.

The formation of a green industry in Azerbaijan is primarily related to the establishment of a more diversified and technology-based economic model, moving away from the dominant position of the oil and gas sector. In recent years, important steps have been taken towards the development of the non-oil sector, the establishment of "green energy zones", the implementation of the "green economy" concept, and the expansion of green energy sources (Gasimli, V.A. et al., 2014). In particular, the development of Karabakh

and East Zangezur as green energy zones marks the beginning of a new phase in the country's energy policy. Innovative technologies such as solar and wind energy production, smart energy grids, digital control, and automated management systems implemented within the framework of these initiatives act as effective tools to minimize the carbon emissions of the industry.

The decree signed by President I. Aliyev's on ensuring coordination in the field of innovative development in Azerbaijan is considered one of the important initiatives towards the realization of green industrial construction in the country. The decree places the responsibility on state authorities to ensure coordination in terms of the creation and implementation of products, services, processes, and solutions based on scientific knowledge, technological innovations, and digital development. This stimulates the development of innovations in industrialization that focus on energy-saving, resource-saving, waste-reduction and environmentally friendly technologies (Azərbaycan Respublikasında innovativ inkişaf sahəsində koordinasiyanın təmin edilməsi haqqında Azərbaycan Respublikası Prezidentinin Sərəncamı, 2019).

The innovative development model is not limited to technology alone; it is also characterized by the renewal of management systems, the development of human capital, the promotion of scientific and research activities, and the openness of business to innovation. A number of initiatives are being implemented in Azerbaijan in this direction. Connecting science and education with industry, supporting startup projects, operating innovation centers, and creating technoparks stimulates the application of environmentally friendly and resource-saving technologies. This approach allows industrial enterprises to operate more efficiently in the areas of energy efficiency, waste reduction, and water conservation.

Specific targets for the development of the green economy have been set within the framework of the socio-economic development strategy of the Republic of Azerbaijan until 2030. This includes environmental protection, mitigating the impacts of climate change, and shaping a competitive industrial model. This includes environmental protection, mitigating the impacts of climate change, and shaping a competitive industrial model (Azərbaycan 2030: sosial-iqtisadi inkişafa dair Mili Prioritetlər, 2021). In addition, the introduction of modern technologies to the country through international partnerships and foreign investments, the promotion of clean production processes, and the establishment of certification systems in line with international standards contribute to the green transformation of the industry.

Against the background of all these measures, developing infrastructure and improving legislation for the wider application of innovation is one of the important issues. In order to encourage green technology initiatives, the use of instruments such as tax incentives, grants, and green certification systems should be included in policymaking. Moreover, environmental risk assessment and sustainable investments may create opportunities for the advancement of green industry models. Specialization of technoparks and innovation centers in green technologies acts as one of the main tools that creates conditions for the synthesis of the country's ecological and economic development (Хмельницкий, 2011). The reforms carried out in the field of technological development in Azerbaijan in recent years, and the innovation infrastructure created, have formed a favorable basis for the transformation of the industry. However, the process of specializing existing technological platforms in green technologies is still at an early stage, and the need to take strategically oriented steps in this area is evident. The application of these technologies in the industrial sector not only provides environmental benefits, but is also of strategic importance in terms of creating new economic opportunities - the creation of export-oriented products, the creation of new jobs, and the formation of a high-tech manufacturing sector.

The process of specializing technoparks in green technologies begins, first of all, with the adaptation of the research and production activities of enterprises operating in these spaces to environmental standards. For this purpose, the application and development of energy efficiency technologies, green energy sources, waste processing, and reuse systems should be encouraged in technoparks. Pilot projects and technology transfer platforms should be established in these centers to achieve innovation-based green transformation



of traditional industrial structures. This will serve to ensure close integration between science, education, and industry. In general, the specialization of technoparks and innovation centers on green technologies will play a key role in accelerating the construction of Azerbaijan's green industry and strengthening its innovative development model. In this direction, coordinated state policy, scientific and industrial cooperation, investor support, and public education should be implemented with a comprehensive approach.

Tax incentives should be considered in a comprehensive manner for the effective implementation of an innovative development model to ensure green industrial development in Azerbaijan. These concessions should primarily aim to stimulate scientific research in areas of priority and strategic importance. Also, incentive mechanisms should be applied to promote innovative programs and projects and support their implementation. In this process, the formation of innovative and scientific potential and its provision with institutional and technological infrastructure are of particular importance, and these processes should be accompanied by tax incentives (Ağayev, 2023). Also, supporting innovation-oriented scientific and marketing research and promoting these activities should be one of the main directions of the concession policy. Finally, it is important to implement an effective tax incentive system to financially and institutionally support and stimulate innovative projects implemented by research institutes and higher education institutions.

Education and awareness also play an important role in successfully implementing innovative development. It is of great importance for society, and especially industrial entities, to have an understanding of environmental responsibility, to understand the advantages of green technologies, and to expand training and professional development opportunities in this direction. Joint cooperation between the public and private sectors is necessary to fill the existing gaps in this area in Azerbaijan.

The following should be mentioned regarding public-private partnership: this approach is not only used as a means of distributing costs, but it is also used to speed up the implementation of innovation, provide for managerial flexibility, and optimize resource utilization. Utilizing this cooperation approach within the context of green industries produces synergy by utilizing the regulation and promotion capacity of the government and the technological knowledge and financial power of private enterprises. Innovative solutions can be implemented through this synergy when it comes to implementing environmental-friendly technologies, managing wastes, saving energy, and using alternative energy resources within industries.

In creating a green industry in Azerbaijan, cooperation between the government and private sector companies as an innovative model of development should not only serve as a facilitation method, but also as a tool for strategic planning and realization. To implement such a model successfully, one needs to enhance institutional structure, introduce efficient partnership models, and build an atmosphere of mutual trust between the parties involved. It will only then that Azerbaijan can ensure its development based on the principles of competitiveness, environmental sustainability, and innovation in the sphere of green industry. In other words, the importance of using public-private cooperation as an innovative development model in green industrial development should be increased, since this work will greatly contribute to the country's sustainable development objectives.

The international obligations of the country are another stimulus for developing the green energy industry. Since the country committed itself to reducing the levels of greenhouse gases in the atmosphere by 35% in 2030 according to the Paris Climate Agreement, the country needs to develop its capability to produce renewable energy to meet the requirements. Moreover, holding the COP29 conference in Baku in 2024 can be considered another chance for the country. The conference can provide a platform for demonstrating the achievements made by the country in the sphere of green energy development and establishing new relationships. In case of the country that has considerable amounts of natural resources such as oil and gas, the green energy industry appears to be a viable sphere. (Hacizade, 2023). It should be noted that geographic position and climate in Azerbaijan make it easy to exploit renewable sources of energy. One of such promising directions may be the wind energy in the regions near the coast of the Caspian sea. Based on some calculations, it is possible to generate about 3,000 Megawatts of wind energy

per year in Azerbaijan (Aliyev, Sh.T., 2025). This is particularly true in regard to Absheron peninsula and the neighboring areas. It should also be mentioned that the installation of wind power stations is of great importance in view of satisfying the demand of the country and further development of export activities. In addition, solar energy may become another promising area for Azerbaijan. According to the data, the number of sunshine hours in Azerbaijan makes from 2,400 till 3,200 hours.

In this regard, one must also mention some achievements made by our country in the sphere of hydro power. Considering the capacity of small rivers existing in mountainous and hilly parts of the republic, building small hydroelectric power stations is carried out. This direction is of great significance as an alternative energy source, especially for those territories where there is agricultural activity, but no industrial enterprises. It is worth mentioning some alternative energy sources like bio-energy and geothermal energy; however, any significant development in these spheres has not yet occurred. As can be seen from the results gained, the overall capacity of renewable energy sources in Azerbaijan makes up about 27 thousand MW, of which 3 thousand are wind, 23 thousand – solar, 380 - small hydro-power, and the rest – bio-energy and geothermal.

Azerbaijan, with a deep understanding of global trends, is taking a proactive approach to international challenges and is taking significant steps towards a transition to a green energy strategy (Eliyeva, 2025). The Azerbaijani government has created a legal and institutional framework for the development of green energy. The law adopted in 2021, which provides for the use of renewable energy sources in electricity production, and the document covering the period until 2030 and reflecting national priorities, define strategic goals in the field of green energy. These legal documents focus on diversifying the energy sector and increasing green energy production. Within the framework of these documents, areas such as improving the investment climate, expanding public and private sector cooperation, attracting foreign investors, and technology transfer have been identified as priorities. The main goal is to increase the share of renewable energy sources in the country's energy production, strengthen energy security, and minimize negative impacts on the environment. Both documents assess the development of the green energy industry as a strategically important area in terms of fulfilling international obligations within the framework of combating climate change and creating new economic opportunities (Elektrik enerjisi istehsalında bərpa olunan enerji mənbələrindən istifadə haqqında Azərbaycan Respublikasının Qanunu, 2021).

Recently, a number of major projects related to the development of the green energy industry have been implemented in Azerbaijan. It is planned to build approximately 6 gigawatts of solar, wind and hydropower facilities in our country by 2030. However, this is only a part of the envisaged projects, as contracts and memorandums of understanding for 10 gigawatts of renewable energy projects have already been signed. Azerbaijan's technical potential in the field of renewable energy is 135 gigawatts on land and 157 gigawatts offshore. In 2023, the 230-megawatt Garadagh Solar Power Plant, implemented by the United Arab Emirates' Masdar company, was put into operation. The construction of the 240-megawatt Khizi-Absheron wind power plant was completed by the Saudi Arabian ACWA Power company.

It should be noted that on June 1, 2023, a Memorandum of Understanding was signed between the Ministry of Energy and the Chinese company "China Gezhouba Group Overseas Investment" on the implementation of 2 GW of renewable energy projects in Azerbaijan. This document covers the investigation of investment opportunities in green hydrogen production projects, as well as the introduction of industrial-scale solar energy, onshore and offshore wind energy, energy storage technologies, and smart energy systems in the country. The memorandum also includes the integration of projects into the energy grid, assessment of possible environmental impacts, and conducting geological and topographic surveys (Azərbaycanda bərpa olunan enerji mənbələrindən istifadə, 2025). In addition, as part of the COP29 event, the foundation stone for the 240-megawatt "Shafag" Solar Power Plant was laid in the Jabrayil region in cooperation with the United Kingdom's BP company. Within the framework of that event, Azerbaijan's SOCAR Green LLC, the UAE's Masdar company, as well as the European Bank for Reconstruction and Development, the Asian Development Bank, and the Asian Infrastructure and Investment Bank signed



agreements on financing two solar energy projects to be implemented in the Bilasuvar and Neftchala regions of our country. The total cost of the projects is 670 million US dollars and is planned to be completed and put into operation in 2027. The implementation of these projects is expected to generate more than 1.7 billion kilowatt hours of clean energy annually, thus preventing the use of 380 million cubic meters of natural gas per year. In addition, important contracts for projects with a total capacity of 1,000 MW were signed with the United Arab Emirates' Masdar company during the 2024 Baku Energy Week. These projects include the construction of 445 MW solar power plants in Bilasuvar and 315 MW in Neftchala, as well as a 240 MW wind power plant in Absheron-Garadagh (Bərpa olunan enerji mənbələri, 2024). Implementation of such projects provides for diversification of energy production in the Republic of Azerbaijan, in particular due to the expansion of renewable energy sources usage. Thus, there is a chance to use the resources of the natural gas of the country for export and minimize carbon emission. The introduction of such energy sources is very important and significant for the state being a part of Paris Climate Agreement. Such types of projects might lead to active economic activities in particular areas as well as generate new workplaces. Hundreds of professionals and workers participate in the construction and exploitation of such plants. This might contribute to the enhancement of employment and increase of technological knowledge. In case Azerbaijan will manage to develop this sphere successfully, it will guarantee sustainable development of economy of the country in oil-free future and also help to decrease carbon emission contributing to positive outcomes from this point of view all over the world. One should note that Azerbaijan aims to cut greenhouse gas emissions by 40% by 2050.(Huseyn, 2022).

In our opinion, Azerbaijan has great potential in the field of green energy, and with the right strategies, legal reforms, and technological modernization, this sector can become one of the main pillars of the national economy. Since electricity production in the green energy industry in Azerbaijan is mainly produced in hydro, solar, and wind power plants, let us analyze the current status of their production volume in those areas (Figure 3).

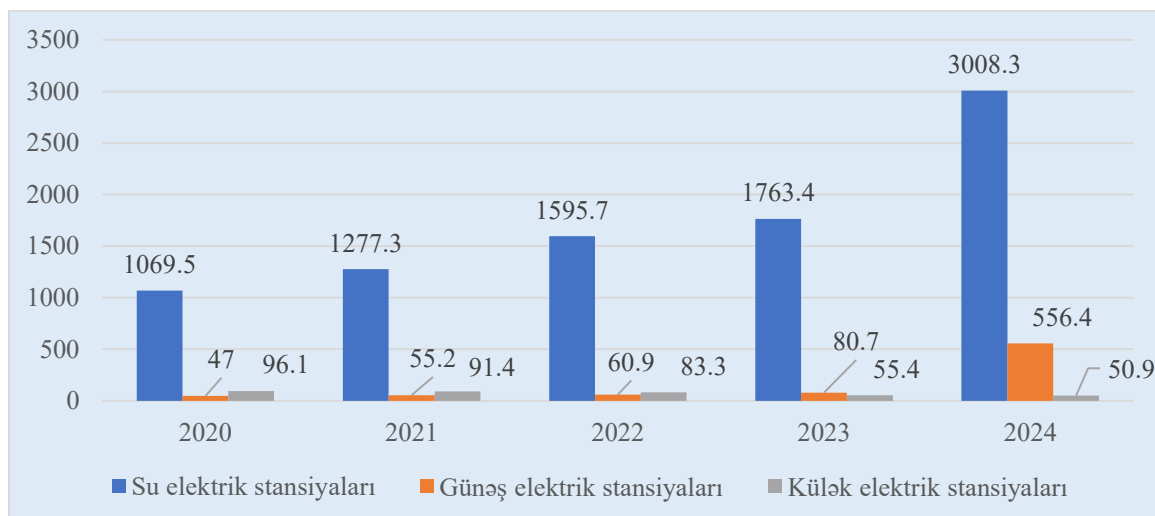


Figure 3. Volume of electricity generation from green sources, million kWh (Source: Prepared based on the State Statistical Committee of the Republic of Azerbaijan, https://www.stat.gov.az/source/balance_fuel/)

Significant changes were observed in electricity production in Azerbaijan in 2024. A total of 28,412.6 million kilowatt-hours of electricity were produced during the year, and the share of renewable energy sources in this production increased significantly. In particular, the combined production of hydroelectric power plants, solar power plants, and wind power plants reached 3615.7 million kilowatt-hours, accounting for 12.8% of the total production. Hydropower plants had the largest share – 3008.4 million kilowatt-hours, which accounts for 10.6% of total production. It should be noted that production at hydroelectric power plants increased by 70.6% compared to 2023, which may be due to increased rainfall, restoration of water resources, or increased operational efficiency of the plants. There has also been a significant increase in

solar power plants, with 6.9 times more energy being produced here than in 2023, reaching 556.4 million kilowatt-hours. This means that the potential of solar energy in the country is increasingly being utilized effectively and clearly confirms that the government's policy regarding renewable energy sources is producing tangible results. In turn, wind power stations faced decline with power production falling by 8.8% from 2023 to 50.9 million kilowatt-hours. The decline could be caused by various factors including purely technical ones or simply because the stations were not working at full capacity. Taking into account the development trends in renewable energy sources in Azerbaijan for 2024, we can conclude that the process can be positively assessed. The growth of hydroelectric power stations and solar power stations, in particular, proves that energy sector development is moving quite quickly, and the transition to renewable energy sources is becoming very effective. It is possible that in the future years, the percentage of green energy sources will continue to grow. Let us summarize the generation capacity of the power plants we examined in Figure 4.

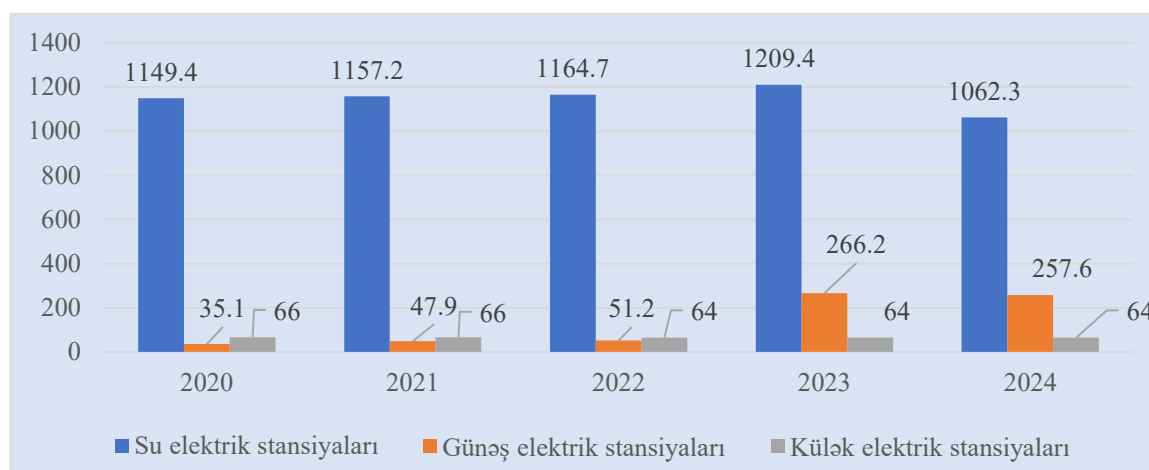


Figure 4. Capacity of hydro, solar, and wind power plants, megawatt (Source: Prepared based on the State Statistical Committee of the Republic of Azerbaijan, https://www.stat.gov.az/source/balance_fuel/)

The total capacity of power plants in the country in 2024 was 7,115.1 megawatts. From the above figures, 1,383.9 megawatts, which amounts to 19.4%, is attributed to hydroelectric, solar and wind power plants which fall under the category of renewable energy sources. The above figures indicate that even though renewable energy sources play a relatively insignificant role in energy production, they form an important part of the total energy structure. All in all, the reductions and stagnations experienced in renewable energy industry during 2024 call for more efforts to promote these energy sources in terms of their involvement in energy production. Climate change, technological advancement and funding problems are some of the issues at hand.

It is worth emphasizing that insufficiency in the development of infrastructure, aging of energy transmission and distribution networks, lack of local qualified specialists in renewable energy technology, and technological dependency may be named among the primary causes that hinder sustainable development in this industry. Additionally, the need to enhance legislation and create incentives for green energy remains topical. Conducting a detailed and comprehensive analysis of this problem shows that the challenges that this sector faces are rather diverse. In the first place, one may name the obsolescence of energy infrastructures and their inadequacy to modern technological demands as a factor that lowers efficiency of energy systems. In particular, it primarily results in the energy losses and decrease in the effectiveness of the system operation. In particular, the fact that energy transmission and distribution systems were constructed decades ago and have no modern technologies does not contribute to efficient exploitation of renewable energy sources (Шипилов, И.А., 2024). In such networks, managing energy flow and overload problems is a complicated issues that result in technical faults and energy supply disruptions.



First of all, the creation of an effective energy storage system is necessary for providing steady access to green energy. Even though such systems may still evolve, their price remains one of the critical problems hindering the process. Investment in R&D will allow for developing energy storage that would be both inexpensive and effective. At the same time, the influence of climate conditions on the effectiveness of using alternative energy sources should not be underestimated. Solar panels are ineffective during cloudy days and winter due to short daylight. The same applies to wind energy; therefore, it is crucial to create a strategy for the use of various types of green energy depending on certain conditions.

The possibility of a stable green energy supply is also a necessary condition, for which the development of effective energy storage systems is of great importance (Hacızade, 2023). Although energy storage technologies continue to develop, their high cost is one of the main factors hindering their widespread implementation. Investments in this area can enable the creation of more cost-effective and highly efficient storage solutions. Also, climatic conditions seriously affect the performance of renewable energy sources. For example, solar panels are less efficient in cloudy weather or during the winter months due to short daylight hours. The operation of wind turbines depends on stable wind flows. Therefore, it is necessary to develop complex strategies that ensure the effective integration of different types of renewable energy sources, taking into account their different characteristics (Попов et al, 2025).

The nature of renewable energy sources is that they are typically produced in smaller and geographically dispersed facilities, which requires their effective integration into the central energy system. However, outdated infrastructure lacks the ability to manage energy flows flexibly and in real time. In such a case, the introduction of energy from solar, wind, and other renewable energy sources into the system is either technically impossible or accompanied by high losses, which makes investments in this area risky and unprofitable. To solve the problem, it is important to gradually upgrade the energy transmission and distribution networks (Hacızade, 2022). This includes replacing old transformers, cable systems, and other physical components with modern technologies, as well as implementing smart grid technologies. These technologies make it possible to monitor energy flows in real time and direct them according to supply and demand, which ensures the seamless integration of renewable energy sources into the system.

Insufficient development of local chains of production and supply leads to the occurrence of significant strategic and economic challenges, mainly in the sphere of renewable energy. Purchasing a majority of technological equipment, like solar panels, windmills, inverters, and battery packs from abroad entails not only financial expenses but also leads to a long process of project implementation. Such a practice threatens the energy security of the country in the sense that disruption or any conflict between countries may cause the delay or even stopping of energy projects on the national level. Moreover, technological dependency makes it impossible for the state to have strategic freedom in the energy sector. Namely, having foreign firms providing key technologies means that it is the conditions and prices established by foreign parties that determine the specifics of technologies that prevent forming an independent energy strategy, innovation, and technology transfer.

The following measures can be taken in order to solve the given problem, and one of the main aspects that needs to be done is developing long-term strategies that aim at fostering the development of local manufacturing. The involvement of the state should be essential in this respect. Another strategy is the encouragement of establishing joint ventures with foreign firms that specialize in the production of technologies, since that would lead to the technology transfer as well as the training of local human capital. The next measure to take is the fostering of cooperation between universities and research institutes on the one hand and industry on the other hand, as well as upgrading educational programs in engineering and other technical specializations. It is impossible to provide for technological development without skilled human capital. The lack of skilled local specialists contributes to higher dependence, especially in terms of high-tech system construction and operations. Moreover, it is necessary to improve the infrastructure related to logistics and supply chains in order to ensure timely delivery of produced elements at the places of their application. On a longer-term basis, such actions will allow not only reducing technological dependency, but also creation of employment, developing export capabilities and promoting further development of the

local industry. Therefore, increasing local manufacturing capacities along with creating a sustainable supply chain should be seen as an essential strategy for ensuring sustainable development of the renewable energy sector.

However, at the same time, another important condition is also necessary, namely, a legal and regulatory framework should meet the current needs. In case the incentive schemes for green energy implemented within the scope of the legislation are badly formed in terms of tax breaks, subsidy programs, long-term contracts, and tariff regulations, such factors create an adverse atmosphere for investments. In case the incentive schemes are not effectively used by the country, then this process will be rather complicated, especially when implementing innovations. Moreover, there are shortcomings in terms of the protection of the rights of local populations, in terms of environmental and social risk assessment in the context of implementation of renewable energy technologies. Sometimes, the lack of public participation in this regard can even become one of the reasons for mistrust between all participants of the process. At last, because of scientific innovation being weak, the creation of relevant technologies becomes complicated. University-industry cooperation, support for startup initiatives, and the development of technology incubation centers can play an important role in this area. Another important issue is that awareness of green energy is still low at the societal level. There is a need to expand educational activities in the field of energy conservation, efficient use of energy, and the application of renewable energy sources. The ability of the population, especially those living in rural areas, to transition to green energy should be stimulated through subsidies and technical support programs.

3. Conclusion

Considering the findings of our research, one can say that the innovation development model acts as an inevitable mechanism for creating a green industry in Azerbaijan. Implementation of the model will be beneficial not only for the environment but also for the economy and society of the country. Introduction of new innovations, development of green energy resources, use of digital technology, and adaptability in management constitute crucial elements for the creation of a green industry. Considering the situation today, the actions of Azerbaijan regarding this issue can be regarded as positive, but additional actions should be taken to ensure faster and more systematic implementation of the process. Such actions can include:

- preparation of a national road map for the implementation of green innovations;
- Introduction of tax incentives for industrial enterprises that encourage the transition to green technologies;
- specialization of techno parks and innovation centers in green technologies;
- strengthening tripartite cooperation between science, education, and industry;
- expanding climate financing and cooperation with international donors;
- Organizing information and awareness campaigns on the green industry, etc.

The implementation of the aforementioned recommendations will allow the restructuring of Azerbaijan's industrial sector on a green and innovative basis, increase the country's sustainability in the domestic market, and create conditions for its recognition as a competitive and environmentally responsible economic entity in the international market.

Research has shown that Azerbaijan has great renewable energy potential in the fields of solar, wind, hydro, and bioenergy. In order to use these potentials purposefully and efficiently, strategic documents on the development of the green energy sector have been adopted at the state level, and specific projects are being implemented. Foreign investors' interest in Azerbaijan's green energy industry is growing, and several international cooperation agreements have already been signed in this direction. The Karabakh and East Zangezur regions have been declared priority green energy zones, and real work is being done in this direction. However, there are technological, personnel, and infrastructure problems, as well as



shortcomings in the legal and educational fields. Therefore, I consider it appropriate to take measures in the following areas to develop the green energy industry in Azerbaijan:

- Development of special laws, incentives, and incentive mechanisms that promote the development of renewable energy sources;
- Minimizing dependence on foreign technology by promoting local production, technology transfer, and establishing innovation centers;
- Creation of green energy curricula in higher and secondary specialized educational institutions, study of foreign experiences;
- Increasing the level of public knowledge about green energy, stimulating the population's transition to green energy;
- Upgrading existing energy transmission and distribution systems and adapting them to green energy projects;
- Prioritizing green energy projects in the regions, especially in the liberated territories, and using these projects as a key element of socio-economic revival.
- Deepening cooperation with international financial institutions and technology companies by taking advantage of globally significant events such as COP29, etc.

Thanks to the implementation of these or other measures mentioned, it is possible to expect an increase in green energy production, diversification of energy exports, and ensuring environmental sustainability in the future, which could become the main pillars of Azerbaijan's energy policy. Through sustained and planned investments, institutional reforms, and international cooperation, Azerbaijan has the potential to become a regional green energy hub.

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