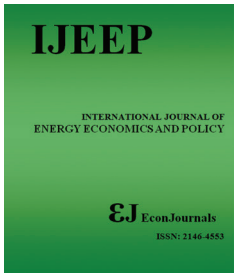

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Renewable Solar Energy Resources Potential and Strategy in Azerbaijan

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ABSTRACT

Solar energy is an inexhaustible and pollution-free energy source that plays a significant role in the sustainable provision of energy services. The main purpose of this study is to examine the potential, current situation, future strategies, and policies of solar energy, which is a renewable resource in Azerbaijan. This study is research in which qualitative methods are used and within the scope of the study, literature review, systematic approach and inductive methods were used. In the study, Azerbaijan's policy towards solar energy has been examined based on the potential sources of solar energy, the current situation and the country's future strategies. Azerbaijan is slightly behind in the production of electricity from renewable energy sources. Along with all this, the most important strategic goals for the use of renewable and alternative energy sources in Azerbaijan have been defined. Thus, by 2030, the share of renewable energy investment in the country's total energy balance to 30% has been determined as the main goal. As a result of the study, it can be said that solar energy policies will have a positive effect on the country's economy in the coming years, since Azerbaijan has a geographical location and an infrastructure system that can be delivered to the countries in need.

Keywords: Renewable Solar Energy; Solar Energy Potential; Solar Energy Strategy; Renewable Energy Policay; Azerbaijan
JEL Classifications: O13, E24, O11, Q28

1. INTRODUCTION

Increasing electricity from renewable sources is critical to decarbonizing the world's energy system. The most important synergy of the global energy transformation comes from the combination of increasing low-cost renewable energy technologies and the wider adoption of electricity for end-use applications in transport and heating. A nearly complete decarbonization of the electricity sector is required by 2050 to implement the energy transition at the required pace and scale. The REmap Case sets a path to achieve an 86% share of renewables in energy production by 2050 (IRENA, 2019a).

Azerbaijan has a well-developed energy infrastructure supported by abundant domestic resources. Especially oil and natural gas played a very important role in the economic development of Azerbaijan, which regained its independence in 1991. As a result of the analysis made based on the data until 1994–2018, the relationship between the economic growth of Azerbaijan, the total amount of exports and energy exports was examined, as a result, no causal relationship was found between growth and energy exports. It is stated that the main reason for this is the country's export of energy products to international markets in the form of raw materials (Huseynli, 2022a).

The "Contract of the Century" agreement signed in 1994 after Azerbaijan gained its independence has a very important role in opening energy resources to international markets. In addition, Azerbaijan, which is also rich in renewable energy resources in terms of sustainability and energy transfer, carries out energy policies that will use this potential. Fossil fuels such as coal and oil have driven economic development and growth over the past 200 years. However, economic growth is not necessarily based on fossil fuel-based energy (Mikayilov et al., 2018).

Renewable energy sources have been proactively explored to replace potential fossil fuels (Bihari et al., 2021). Renewable energy is the cleanest and most permanent technology that will replace fossil fuels in the future, as it does not emit toxic gases to the atmosphere and the people of the region. Examples of renewable energy that can generate electricity include solar, wind, hydro, and biomass, geothermal and tidal.

Renewable energy is essential for the sustainability of the planet. Renewable energy output forecasting has a significant impact on making decisions regarding the operation and management of power systems. Accurate estimation of renewable energy output is vital to ensure grid reliability and continuity and reduce the risk and cost of energy markets and systems (Alkhayat and Mehmood, 2021).

In recent years, renewable energy sources have been used to meet the electricity demand, especially in rural areas disconnected from the electricity grid. According to Bihari et al. (2021) also highlights incentives to reduce costs and examine the possibility of hybrid renewable energy integration into the microgrid system. In a study by Li et al. (2021), appropriate innovative strategies for solar energy investments were examined for both commercial and non-commercial users.

The EU Strategy for the South Caucasus is a long-term strategy to create a secure political, economic, and social environment on the eastern borders of the EU. Azerbaijan is the largest and most populous country in this region and is rich in hydrocarbon resources and plays an important role in the supply of oil and natural gas to the EU (Safarov, 2015). In a study by Gulaliyev (2020), the resource, technical, economic and market potential, ecology, and economic efficiency of solar energy in Azerbaijan were investigated. An article by Rzayeva et al. (2021) discusses these, and other issues related to the application of renewable energy and evaluates Azerbaijan's potentials in adapting this type of energy in the future. As a result of a study examining the relationship between traditional energy production, renewable energy production and unemployment rates in Azerbaijan, a causal relationship was found between unemployment and renewable energy production, renewable energy production and traditional energy production in Azerbaijan according to 2005–2015 data (Huseynli and Huseynli, 2022).

In addition to all these, this study was carried out to fill this gap in the literature, considering that there is no study on solar energy potential, current situation, and future strategies in Azerbaijan. From this point of view, the aim of this study is to examine the potential, current situation, future strategies, and policies of solar energy, which is a renewable resource in Azerbaijan.

2. LITERATURE REVIEW

2.1. Conventional and Solar Energy

Energy is an important tool in ensuring economic development for countries and an important wealth for people for generations. The sun is the most important heater and energy source for the planets around it and therefore the world (Li et al., 2021). Solar energy is the most environmentally friendly and inexhaustible one among the known energy sources (Yüksel et al., 2019). Traditionally produced forms of energy (coal, petroleum products and nuclear power plants) harm natural life through radiation, carbon emissions and chemical waste.

Solar energy is defined as the heating energy obtained from the conversion of hydrogen into helium by the fusion process in the core of the sun. Solar energy can be provided as a natural energy source wherever the sun rises and sets, and it does not require any extra effort to reach it (Li et al., 2021). Solar energy does not harm water resources, forest areas and soil. It is environmentally friendly and does not cause carbon emissions (Qiu et al., 2020).

The sun can be used for heating potential as in Concentrated Solar Energy (CSP) systems, or photon energy in light beams can be used with photovoltaic (PV) systems (Busse and Dinter, 2016). Each system has its own advantages and can be compared with each other using Leveled Cost of Energy (LCOE) (Esram and Chapman, 2007). Photovoltaic generation depends on factors such as photovoltaic material selection and cloud cover.

The sun provides enough energy to the earth in just 90 minutes, which is enough to meet global energy demand for an entire year. Although solar energy is so abundant, it makes up only a small part of the world's current energy mix (Jäger-Waldau, 2020). However, the acquisition of renewable energy sources must be more difficult than using fossil and fuel energy. However, renewable energy sources are of great importance for countries in terms of sustainability. In this sense, solar energy is one of the most natural and easily accessible renewable energy sources (Gielen et al., 2019). However, since solar energy is safer and more sustainable, it does not cause both nature and social problems.

Solar energy in concentrated solar power plants, solar thermal applications (Gonzalo et al., 2019; Wilberforce et al., 2019), solar photovoltaic (PV) plants (Ram et al., 2018; Rezk et al., 2019), photoactive fuel cells (Li et al., 2019), hydrogen fuels (Sharma and Kolhe, 2017) and solar energy. Although solar energy is free everywhere, investments in the establishment of facilities to make solar energy available are initially very costly. These investments, which have expenditure costs, have the potential to transform profits in the long run (Li et al., 2021).

2.2. Review of the Renewable Solar Energy Literature

The world economy is heavily dependent on fossil fuels to meet its persistent energy demands, the primary source of greenhouse gas (GHG) emissions (Koengkan et al., 2018). According to the Green Energy Global Status Report, 26.2% of electricity generation comes from renewable sources; 15.8% of this is hydro energy, 5.5% wind, 2.4% photovoltaic and 2.2% bioelectric, while other energy sources represent 0.4% (Kumar et al., 2020). But this is changing rapidly, thanks to global efforts to improve energy access and security of supply, as well as to tackle climate change (Usman et al., 2020).

There are many studies in the literature on solar energy. Some of these studies evaluate factors such as site selection, technical

competence, customer satisfaction, risk, government policy, cost-benefit analysis, comparison with renewable and traditional sources, skilled workers, respectively.

Between 2010 and 2020 alone, the cost of electricity from industrial-scale solar PV has decreased by 82%, and between 2019 and 2020, the Normalized Cost of Electricity (LCOE) has decreased by 7%. Thus, falling costs have increased the investment value of solar energy in 2010–2019 (Azerbaijan Renewable Energy Agency under the Ministry of Energy of the Republic of Azerbaijan, 2019a,b).

According to the report of the International Renewable Energy Agency (IRENA, 2019a), the total installed capacity of solar power plants in the world in 2020 was 714 GW (24.3%), and the capacity of newly commissioned solar power plants was 127 GW. Thus, in 2020, 49 GW of solar power plants were installed in China, the world's largest market for renewable energy sources, and 15 GW in the United States. The top five countries with solar capacity worldwide include China (255 GW), the United States (75 GW), Japan (68 GW), Germany (53 GW) and India (39 GW).

According to the report "Future of Solar Photovoltaic" published by the International Renewable Energy Agency (IRENA, 2019a), the global solar power capacity of 480 GW in 2018 will increase to approximately 8000 GW by 2050. is predicted to increase. The report emphasizes that by 2050, as new markets are formed around the world, a quarter of the global electricity demand will be provided by solar energy. At the same time, the Report predicts that Asia will account for more than 50% of the global installed solar capacity by 2050.

Considering the gradual depletion of traditional energy sources and the large amount of damage caused to the environment during their use, in the developed countries of the world environmentally friendly alternative (renewable) energy sources (solar and wind energy, small HPPs, thermal waters, biomass energy) is widely used. In this field, the USA, Canada, Germany, Finland, Norway, Denmark, Spain, Japan and China occupy a more advanced position. According to statistics, the share of renewable energy sources (including hydropower plants) in developed countries is 13.5 percent of the total energy produced. Today, China is the leading consumer of solar energy, followed by the USA, Japan and Germany (Jäger-Waldau, 2020). However, Australia ranks first in per capita solar energy consumption, followed by Germany, Japan and Spain (Dale, 2019).

Yang et al. (2018), who conducted a cost-benefit analysis for solar energy investment, found that the payback period of such investments takes more than 13 years. In this context, Plank and Doblinger (2018) examined the impact of public funds on firm innovation, considering the renewable energy sector in Germany.

Examining the case of Uzbekistan, Avezova et al. (2019) stated that the training and retraining of highly qualified personnel is necessary for development in the field of renewable energy, especially solar energy. Dinçer and Yüksel (2019), in a study in which they evaluated global investment alternatives in the context of renewable energy, found that customers are one of the most important dimensions of renewable energy investments. As a result of multiple linear regression analysis using data from 2005 to 2015, there was no relationship between renewable energy and economic growth for Azerbaijan, but a significant result was obtained between traditional energy production and economic growth (Huseynli, 2022b). Solar energy is a viable option as it is a clean, renewable, and widely available energy source (Hereher and El Kenawy, 2020; Magazzino et al., 2021).

3. RESEARCH METHODOLOGY

3.1. Purpose of the Study

The main purpose of this study is to examine the potential, current situation, future strategies, and policies of solar energy from renewable resources in Azerbaijan.

3.2. Analysis Method

Solar energy is an inexhaustible and pollution-free energy source that plays a significant role in the sustainable provision of energy services. Studies in this context have been carried out within the scope of physics, economy, politics, pollution, and their combination. Transforming resource potential into strategy is very important. Because these strategic decisions can only be taken by considering land use, topography, distance to consumer locations and similar factors (Leibowicz et al., 2019).

This study is research using qualitative methods. That is, within the scope of the study, literature review, systematic approach and inductive methods were used. The work is organized as follows:

1. First step: The literature on solar energy in the world and in Azerbaijan was reviewed
2. Second step: Azerbaijan's solar energy potential was examined
3. Third step: The current situation of Azerbaijan regarding energy and solar energy was analyzed
4. Fourth step: Azerbaijan's renewable solar energy policies for the future were examined
5. Fifth step: Based on all of this, a critical analysis of Azerbaijan's potential, current and future strategic solar energy policies was made.

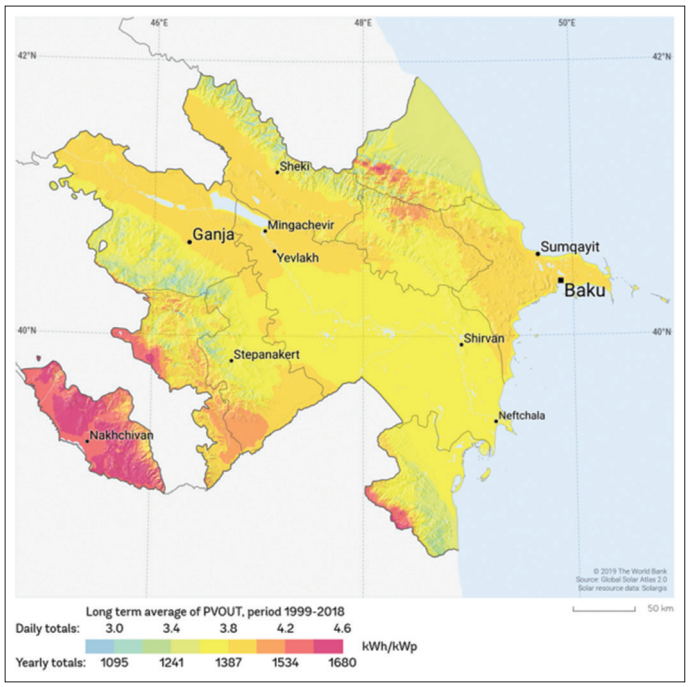
4. ANALYSIS AND RESULTS

4.1. Determination Of The Potential For The Use Of Solar Energy Sources In Azerbaijan

The natural climatic conditions of Azerbaijan open wide opportunities to increase the production of electricity and heat energy by using solar energy. The development of the use of solar energy can partially solve the energy problem in many regions of Azerbaijan. Recently, the Photovoltaic Program (FVP) has been widely implemented in several advanced countries of the world. The involvement of Azerbaijan in this Program can play an important role in the implementation of such type of energy systems in the region. The design reflecting the number of sunny hours throughout the year in Azerbaijan is shown in Figure 1.

It should be noted that the efficiency of solar plants depends on the natural climate and geographical location of the country. As

Figure 1: Number of sunny hours in Azerbaijan during the year (in hours).



Source: Source: Global Solar Atlas 2.0, Solar resource data: Solargis.com

it can be seen, the amount of sunlight falling on the territory of Azerbaijan is superior compared to other countries, which can be considered as one of the efficiency criteria for attracting investments in the use of solar energy.

According to the results of the research, the criteria to be considered in the selection of the place were determined as solar radiation, average temperature and average hours of sunshine (Aktas and Kabak, 2019). Azerbaijan is one of the countries with high potential for renewable energy sources. Thus, the potential of economically viable and technically usable renewable energy sources of our country is estimated at 27,000 MW, including 3,000 MW of wind energy, 23,000 MW of solar energy, 380 MW of bioenergy potential, and 520 MW of mountain river potential.

The potential of renewable energy sources in Azerbaijan was also assessed by IRENA (2019b). Thus, Azerbaijan has a technical potential of 23,040 MW of solar energy, 520 MW of energy from small HPPs, 3,000 MW of wind energy, and 380 MW of bio-waste energy.

Azerbaijan has a lot of solar energy resource potential and using modern technical equipment it is possible to replace traditional carbon energy types with solar energy (Gulaliyev et al., 2020). A study by Mustafayev et al. (2022) analyzed the potential of renewable energy in Azerbaijan with a focus on solar and wind energy, discussed the shortcomings hindering the development of the renewable energy industry, and developed recommendations for actionable actions to improve the situation in the country.

4.2. Analysis Of The Current Situation On The Use Of Solar Energy Sources In Azerbaijan

According to the Ministry of Energy of the Republic of Azerbaijan, according to operational data on electricity for 2021, the production of electricity in Azerbaijan in December was 2591.2 mln. kWh, export 289.6 mln. kWh, import 10.5 mln. was kW·st. Compared to the corresponding period of 2020, the production of electricity in Azerbaijan in December was 201.4 mln. kWh, export 127.9 mln. kWh increased and import by 0.2 mln. kWh decreased (marja.az).

According to the Ministry of Energy of the Republic of Azerbaijan (2022a), the total electricity production capacity of Azerbaijan is 7542.2 MW, the capacity of renewable energy power plants, including large hydropower plants, is 1304.5 MW, which is 17.3% of the total capacity.

In the months of January-December 2021, compared to 12 months of 2020, the production of electricity in thermal power plants is 1840.5 million. kWh increased to 26238.8 mln. kWh, 207.9 million in HPPs. kWh increased to 1277.3 mln. kWh, and 3.6 mln for other sources (KES, GES and BMTYZ). kWh decreased to 339.9 mln. was kW·st. 91.5 million in wind power plants. 55.2 million kWh in solar power plants. kWh, and 193.2 million at the Solid Household Waste Incineration Plant (BMTYZ). kWh of electricity was produced. During 2021, the production of electric energy by "Azerenerji" OJSC is 25038.0 mln. kWh (23905.0 million kWh in HPPs, 1133.0 million kWh in HPPs), 451.0 million by the State Energy Service of Nakhchivan. kWh (269.5 million kWh in HPPs, 130.3 million kWh in HPPs, 51.2 million kWh in GES), 66 in wind power plants of "Azerishiq" OJSC 1 mln. 2,300.9 mln. per kWh, independent power plants. kWh (marja.az).

During 2021, 55.2 mln. kWh (55200 MW) of electricity was produced (Ministry of Energy of the Republic of Azerbaijan, 2022a). Currently, the share of natural gas use in electricity production in Azerbaijan is 93% (Cəfərov, 2020). Today, 0.3 cubic meters of gas is used in the production of one kV/h of electricity.

According to the information of the Ministry of Energy of the Republic of Azerbaijan (2022), according to the data on electricity in 2021, the production of electricity in the republic in December was 2591.2 mln. kWh, export 289.6 mln. kWh, import 10.5 mln. was kW/h.

Energy subsidies as before, an important system of energy subsidies operates in Azerbaijan. The amount of energy subsidy was approximately 3.4% of GDP in 2016, with average energy subsidies estimated at US$130 per capita. The total amount of subsidies doubled from 2014 to 2016, from 751 million US dollars to 1,269 million US dollars. In 2015 and 2016, more than half of the subsidies were given to the electricity sector due to the support of oil and gas energy sources, while subsidies to renewable energy sources were negligible (IRENA, 2019).

4.3. Directions Of Strategic Development Of Solar Energy Sources In Azerbaijan

In order to develop the field of renewable energy in Azerbaijan, to improve the legislative and institutional environment in this field, relevant laws and normative legal acts have been adopted. In recent years, the works carried out in the field have been continued, and in 2021, the Law of the Republic of Azerbaijan "On the use of

renewable energy sources in the production of electricity", which makes a special contribution to the development of renewable energy, was approved.

The strategy for renewable energy sources in Azerbaijan is also reflected in the strategic plans for the future. Thus, in paragraph 5 of the document "Azerbaijan 2030: National Priorities for Socio-Economic Development" ("Clean Environment" and "Green Growth Country"), in the direction of climate change and its fight, as well as renewable energy based on the principles of green energy space in our country issues of application from energy to all areas of the economy were included. Thus, in accordance with the country's socio-economic development priorities, in the current and future period, more attention is being paid to the use of renewable energy sources and the expansion of the application of "green" technologies. Within the framework of the works carried out in this field, camera studies were continued across the country in the direction of identifying and prioritizing areas with the potential of renewable energy sources. National Priorities are of particular importance in the direction of the implementation of the obligations arising from the UN "Transformation of our world: Agenda for sustainable development until 2030" (Decree of the President of the Republic of Azerbaijan, 2021).

In addition, several works are being carried out on the assessment of the possible potential to produce electricity from renewable energy sources in Azerbaijan and the steps to be taken and measures to be taken to use this potential. 8 areas have been selected in the direction of identification and prioritization of areas with the potential of renewable energy sources. Appropriate measures are already being taken regarding the implementation of pilot projects in the 3 selected areas. Compared to wind energy, it is planned to implement projects in the regions in the next years to use the potential of solar energy available in the entire territory of the country, to use land unsuitable for agriculture, and to distribute electricity generation capacities on renewable energy sources. Work is being continued in the direction of investing in selected and prioritized renewable energy sources in areas with high potential through an auction. Currently, the project "Support for holding renewable energy auctions in Azerbaijan" is being implemented with the European Bank for Reconstruction and Development (EBRD). Within the framework of the project, the preparation of the auction rules, the set of conditions for auctions, as well as the electricity purchase agreement, the qualification requirements for participation in the auction (RFQ) and the form of the offer for auction (RFP) will be provided (Ministry of Energy of the Republic of Azerbaijan, 2022a).

Within the framework of cooperation with the German Energy Agency (DENA), the project "Cooperation between the Ministry of Energy of the Republic of Azerbaijan and DENA within the framework of promoting decentralized energy supply with the application of renewable energy technologies in selected areas of Azerbaijan" is being implemented (Ministry of Energy of the Republic of Azerbaijan, 2022b). The main goal of the project is to support the Ministry of Energy in fulfilling the framework conditions for renewable energy for the development of the renewable energy market in Azerbaijan, to prepare recommendations to support the development of decentralized renewable energy in Azerbaijan, and to jointly define the areas of application. Within the framework of the project, various pilot project proposals have been put forward for the application of solar energy systems for subartesian wells, small powerful mobile solar and battery energy systems, combined solar and heat pump energy systems for greenhouses, energy systems for thermal use of biomass energy in buildings. Technical and economic analysis of the mentioned pilot project proposals, implementation strategy and stakeholders were identified, and general recommendations were developed to support the development of decentralized renewable energy.

Within the framework of the "Knowledge exchange and technical assistance support for the development of the floating solar panel system" pilot project implemented with the support of the Asian Development Bank, the installation of a 100 kW photovoltaic system in Lake Buyukshor, as well as the formation of business models for the purpose of promoting the participation of the private sector in the installation of solar installations, training tools it is intended to strengthen the national potential. The implementation of the project is planned to be completed by March (berpaolunanenerji 2023).

Within the framework of renewable energy projects, contracts were signed with the companies "ACWA Power" of Saudi Arabia and "Masdar" of the United Arab Emirates. According to the agreements, the construction projects of 240-megawatt wind power plants with "ACWA Power" company and 220-megawatt solar power plant projects with "Masdar" company will be implemented. Foreign investment of 400 million dollars will be invested in both projects (Rzayev, 2022).

Azerbaijan is slightly behind in the production of electricity from renewable energy sources. Along with all this, the most important strategic goals for the use of renewable and alternative energy sources in Azerbaijan have been defined. Thus, the main goal is to increase the share of renewable energy investment in the total energy balance of the country to 30% by 2030 (Ministry of Energy of the Republic of Azerbaijan, 2022a).

5. DISCUSSION AND CONCLUSION

Perhaps the most important factor in solar energy investments is location selection. Although sunlight can be found everywhere, parameters such as solar radiation, daily sundial, access to electricity grids and distance to local centers are of great importance in site selection (Apostolopoulos and Liargovas, 2016). In this context, Aktas and Kabak (2019), investigating the appropriate location for solar energy investments, applied the analytical hierarchy process (AHP) and order preference technique like the ideal solution methods based on fuzzy logic. The potential of Azerbaijan's sunny areas and the current use of some of these potentials play a role in shedding light for future projects.

Today, the interdependence experienced on a global scale has gained even more importance with the increasing demand for energy resources. Due to the differences in strategy between

countries regarding access to energy resources, the situation of interdependence may cause various conflicts (Tutar et al., 2022). Photovoltaic solar energy, a renewable energy source, is seen as an alternative to meet the challenges of energy scarcity from traditional sources (Sampaio, 2017). Azerbaijan's solar energy potential offers great opportunities for such investments.

There are studies investigating the socio-economic effects of the adoption of solar photovoltaic (PV) technology (Khan, 2020). Yadav et al. (2019) found income status, education level, solar usage time and user satisfaction among the factors affecting solar energy acquisition. One of the important criteria in solar energy investments is the cost-benefit analysis of the investment to be made. Since the capital to be spent at the beginning is quite costly, the return of the investment and the profit to be obtained are the determining factors in the investment (Strantzali and Aravossis, 2016). With the right strategies, this vital problem should be transformed into a situation that does not prevent uninterrupted energy use. Making Azerbaijan's energy products ready for export will be the beginning of self-development and great achievements (Huseynli, 2022a). Solar energy issues are a complex process involving many economic, social, and environmental criteria. Therefore, it is difficult to identify a single specific strategy for solar investments (Li et al., 2021).

According to Anake and Wang (2015), battery storage technology is a more mature technology and can therefore be considered reliable and more accessible. In addition, countries can thus become producers of their own energies instead of being dependent on external resources (Zhou et al., 2020). Thus, solar energy investments make a great contribution to the reduction of the country's current account deficit (Li et al., 2021).

Azerbaijan's solar energy potential will further strengthen the country's energy exports in the future because of the right investments. As it is known, Azerbaijan is a country rich in oil and natural gas resources and exports these resources. The role of Azerbaijan in the energy security of Europe is known all over the world. In addition, determining the potential of renewable energy sources as a strategic target within the scope of sustainability conditions will further strengthen the role of energy policies in economic growth. In particular, the determination of Azerbaijan's main target to have a 30% share of renewable energy in the country's total energy balance by 2030 has a very important place in terms of the country's economic and energy policies. Based on all these, it can be said that solar energy policies will have a positive impact on the country's economy in the coming years, due to Azerbaijan's geographical location and having an infrastructure system that can be delivered to countries in need.

This policy, which Azerbaijan has determined within the scope of renewable energy resources, is also in line with the 2030 Sustainable Development Goals accepted by the United Nations. That is, the 2030 Agenda for Sustainable Development (United Nations, 2015), adopted by the United Nations in September 2015, represents the main framework for achieving sustainable development. The core of the agenda is the 17 Sustainable Development Goals (SDGs) to be met by 2030. Implementing the 2030 Agenda and achieving the Sustainable Development Goals (SDGs) require profound transformations in the global energy industry (Xia et al., 2019; Asl et al., 2021).

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