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Energy Efficiency and Integration of Renewable Energy Sources in Architectural Design: Techno-Economic Possibilities of Azerbaijan

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Abstract: This article analyzes the technical and economic feasibility of integrating energy-efficient solutions and renewable energy sources (RES) into architectural design in Azerbaijan. The study begins by examining the current state of Azerbaijan's energy sector, which is heavily reliant on natural gas-fired thermal power plants, despite having substantial solar and wind energy potential. The primary aim is to identify optimal strategies for designing energy-efficient buildings in Azerbaijan, considering climatic conditions, available technologies, and economic factors. The methodology involves a multi-faceted approach: a review of passive and active energy efficiency strategies applicable to architectural design (including volumetric planning, natural lighting/ventilation, thermal insulation, shading, efficient HVAC, heat recovery, and Building Management Systems (BMS)); an assessment of Azerbaijan's solar and wind energy potential; and a multi-criteria SWOT analysis. Results indicate a significant, untapped potential for solar (23,000 MW) and wind (3,000 MW onshore, 157 GW offshore) energy in Azerbaijan. The SWOT analysis highlights the strong government support and favorable climate as major strengths, while acknowledging the current low RES penetration and a shortage of skilled professionals as weaknesses. Opportunities include declining global RES technology costs and a growing demand for "green" buildings. Threats include competition from the established fossil fuel sector and potential climate risks. The main conclusion is that integrating RES and energy-efficient design is not only technically feasible but also strategically vital for Azerbaijan's sustainable development, energy security, and environmental protection. Recommendations are formulated to develop an effective strategy for RES integration, focusing on supportive policies, capacity building, financial incentives, and public awareness campaigns. The findings contribute to the field of sustainable architecture by providing a context-specific analysis and practical guidance for architects, engineers, and policymakers in Azerbaijan and similar regions transitioning to a low-carbon energy future. The study's limitations include the reliance on publicly available data and the dynamic nature of energy policy, which requires ongoing monitoring and adaptation of strategies. The practical implications emphasize the need for updated building codes, training programs, and financial mechanisms to promote widespread adoption of energy-efficient and RES-integrated building designs.

Keywords: renewable energy sources, energy efficiency, architectural design, sustainable construction, SWOT analysis, LCOE, bioclimatic architecture, RES integration, Azerbaijan.

Introduction: Global climate change and the depletion of fossil fuel reserves necessitate a transition to a sustainable energy model. A key element of this model is increasing energy efficiency and utilizing renewable energy sources (RES) in the construction industry. Buildings consume a significant portion of the world's energy and produce a substantial volume of greenhouse gas emissions. Therefore, reducing their energy load and decarbonizing the construction sector are priority tasks for achieving sustainable development goals. In this context, architectural design takes on special significance, serving as a tool for creating energy-efficient and environmentally friendly buildings capable of minimizing negative environmental impact. Fundamental decisions that determine a building's future operational characteristics, including its energy consumption, emission levels, microclimate, and user comfort, are made at the design stage. The application of passive and active energy efficiency strategies, as well as the skillful integration of RES into a building's architectural concept, can significantly reduce its environmental footprint and provide long-term economic benefits.

Accordingly, this study is devoted to analyzing the technical and economic indicators of integrating energy-efficient solutions and RES into architectural design. Its goal is to identify optimal building design strategies, taking into account climatic conditions, available technologies, and economic factors. Achieving this goal involves several tasks, including analyzing modern methods for improving building energy efficiency, assessing the potential of using various RES in architecture, developing a methodology for the technical and economic justification of choosing energy-efficient solutions and RES, and identifying barriers and prospects for the development of sustainable construction. The study will consider indicators such as building energy consumption, life cycle cost, payback period of investments in energy-efficient technologies and RES, and environmental indicators reflecting the building's impact on the environment.

This study implicitly investigates several core hypotheses related to the integration of renewable energy sources (RES) and energy-efficient design in the Azerbaijani construction sector. Primarily, it examines the technical feasibility hypothesis, positing that the country's climatic conditions and available technologies permit the effective incorporation of RES (specifically solar and wind) and advanced energy-efficiency strategies into building design, leading to substantial reductions in energy consumption. Concurrently, the economic viability hypothesis is tested, asserting that the long-term financial benefits of such integration, including favorable payback periods and positive returns on investment, outweigh potential higher initial costs, rendering it economically justifiable. Furthermore, the environmental benefit hypothesis is evaluated, proposing that RES-integrated, energy-efficient buildings will demonstrate a significantly reduced environmental footprint, quantified by lower greenhouse gas emissions and resource consumption, compared to conventional building designs. A strategic advantage hypothesis is also considered, suggesting that a multifaceted strategy encompassing policy support, financial incentives, and capacity-building initiatives can effectively mitigate identified barriers and foster widespread adoption. Finally the study tests if passive design strategies will demonstrate a greater return on investment when compared to active design strategies. Therefore, overall, the research operationalizes these hypotheses to assess the technical possibility, economic justification, environmental benefit, and strategic achievability of a paradigm shift towards sustainable building practices in Azerbaijan.

The theoretical significance of the study lies in developing scientific understanding of the relationship between architectural design, energy efficiency, and RES integration. The research results will supplement the theoretical base in the field of sustainable construction and architecture, contributing to the formation of an integrated approach to building design, taking into account energy, environmental, and economic aspects. The methods developed within the study for assessing technical and economic indicators can be used for further scientific research in this area. The study also contributes to the development of architectural design theory, expanding its toolkit by integrating the principles of energy efficiency and sustainable development.

The practical significance is determined by the possibility of applying the results obtained in real design practice. The developed recommendations for optimizing architectural solutions and integrating RES will allow architects and engineers to design energy-efficient and environmentally friendly buildings, reducing their negative impact on the environment. The application of the proposed methods of technical and economic analysis will make it possible to reasonably choose the most effective solutions, taking into account the specifics of the project and climatic conditions. The results of the study can be used in the development of regulatory and technical documentation and educational programs in the field of sustainable construction. In addition, the study contributes to raising public awareness of the importance of energy efficiency and the use of RES in construction.

MATERIALS AND METHODS

This study is based on an integrated approach, combining qualitative and quantitative analysis methods. Various sources of information were used for data collection, including official reports from the Ministry of Energy of the Republic of Azerbaijan, publications from international organizations (IRENA, IEA), scientific articles, industry reviews, and data from open sources. Particular attention was paid to the analysis of statistical information on electricity production and consumption, the structure of installed power plant capacity, the dynamics of RES development, as well as data on climatic conditions and the geographical location of Azerbaijan. Data on global trends in the development of "green" energy, including the dynamics of the levelized cost of electricity (LCOE) for various types of RES, were used to assess the potential of RES and their economic feasibility.

SWOT analysis and multi-criteria assessment methods were used to analyze the technical and economic feasibility of integrating RES into architectural design. The SWOT analysis made it possible to identify strengths, weaknesses, opportunities, and threats associated with the development of RES in Azerbaijan. Multi-criteria assessment was used to determine the significance of various factors influencing the effectiveness of RES integration in buildings, such as resource potential, technological readiness, regulatory framework, investment climate, and social acceptability. An expert assessment of the impact and probability of implementation was carried out for each factor.

In addition, the study used methods of comparative analysis to examine the experience of other countries in the field of RES integration in architecture, as well as forecasting methods to assess the prospects for the development of "green" energy in Azerbaijan. The results of the study are presented in the form of tables and analytical conclusions, which allow for the formulation of specific recommendations for optimizing architectural solutions and increasing the efficiency of RES use in the construction industry. The integrated approach used in the study made it possible to obtain a comprehensive assessment of the feasibility of integrating RES into architectural design in Azerbaijan and to develop practical recommendations for its implementation.

RESULTS

1.Theoretical Foundations of Energy Efficiency in Architectural Design

Energy efficiency in architectural design represents a comprehensive approach aimed at minimizing a building's energy consumption without compromising comfort [1]. This approach is becoming particularly relevant in light of growing challenges in the energy sector that affect the environment, energy security, and economic well-being [1]. Buildings, being a key focus for improving energy efficiency, consume a significant portion of energy — according to data from 2024, buildings in Azerbaijan consume 33.5% of the country's total energy, which exceeds the global average of 30% [2]. If industry and other sectors are included in this figure, the share reaches 50% [2].

Despite the active development of Azerbaijan's energy infrastructure between 2004 and 2014, including the construction of 17 power plants, over 10,000 km of power transmission lines, and more than 1,500 substations, increasing the total power generation capacity by 2,300 MW [3], building energy consumption remains high. Azerbaijan has been fully self-sufficient in electricity since 2021 [4], but the majority (94%) is produced by thermal power plants (TPPs) operating on natural gas, highlighting the importance of developing renewable energy sources in construction, which, together with hydropower plants, account for only 6%

[5; 6]. In 2019, the installed capacity of power plants in Azerbaijan was 7,642 MW, of which only 101 MW was attributed to wind and solar power plants [7], indicating significant potential for their further development in the architectural sector. The growth in electricity production from 25,229 million kWh in 2018 to 29,004.3 million kWh in 2022 [8; 9], as well as the significant volume of electricity exports (2,997.5 million kWh in 2022) [27], also demonstrate the development of the energy sector, but simultaneously emphasize the need for more efficient energy use in buildings to reduce the overall load on the energy system and decrease the environmental footprint. Therefore, the integration of passive and active energy efficiency strategies at the earliest stages of design is becoming an integral part of the modern architectural process—this not only reduces energy consumption and CO_2 emissions but also contributes to achieving sustainable development goals.

Passive energy efficiency strategies, based on the principles of bioclimatic architecture, represent a set of interrelated design solutions aimed at creating a comfortable and energy-efficient environment [18; 19] (Table 1). These strategies involve the active interaction of the building with the environment, using natural resources—solar radiation, wind, and geothermal energy — as the primary energy sources to maintain an optimal microclimate and minimize negative impacts [18; 19].

When applying passive strategies, optimizing space-planning solutions becomes critically important, as the geometry and orientation of the building significantly influence its energy balance [20]. Taking into account the azimuth and altitude of the sun allows not only for maximizing passive solar gains during the cold season, reducing the need for active heating, but also for minimizing overheating during the summer, reducing the load on cooling systems and, consequently, energy consumption [20]. Choosing compact building shapes with a low surface area-to-volume ratio (S/V) minimizes heat loss through transmission, as confirmed by building energy consumption modeling results using specialized software (e.g., EnergyPlus, TRNSYS) [21; 22]. Moreover, detailed analysis of solar geometry and shadow masks using dynamic modeling tools (e.g., Ecotect, DesignBuilder) allows not only for assessing the amount of solar radiation reaching different building surfaces throughout the year but also for optimizing the building's placement on the site, considering surrounding buildings and landscape, as well as developing effective and aesthetically integrated architectural shading strategies [23; 24].

Another important aspect of passive architecture is the strategic design of window openings and interior spaces to maximize the use of diffuse and reflected daylight [25; 26]. This type of design not only significantly reduces energy consumption for artificial lighting but also creates a more comfortable and productive visual environment for building occupants, positively impacting their psychophysiological state. Calculating the daylight factor (DF) and analyzing daylight autonomy using professional lighting design software (e.g., DIALux, Relux) allows for a quantitative assessment of daylighting effectiveness and optimization of the size, shape, and placement of window openings [25; 26]. Furthermore, the application of advanced lighting solutions, such as light pipes, light wells, atriums, and systems with variable reflective surface geometry, allows not only for efficient distribution of daylight deep into the room but also for the creation of unique architectural and artistic effects [25; 26]. Moreover, integrating natural and artificial lighting systems using light sensors, photocells, and intelligent control systems ensures dynamic adaptation of artificial lighting to changing natural lighting conditions, achieving significant energy savings [25; 26].

Finally, natural ventilation, based on the use of natural forces—wind and thermal convection — represents an efficient and energy-saving alternative to mechanical ventilation systems, contributing to the creation of a healthy and comfortable indoor microclimate [27]. Various natural ventilation strategies, such as cross-ventilation, stack ventilation, night ventilation, and their combinations, can be applied considering specific climatic conditions, architectural features of the building, and the functional purpose of the spaces [27]. To ensure the effective operation of natural ventilation systems, it is necessary to perform detailed airflow calculations considering local climate data and to use modern computational fluid dynamics (CFD) modeling methods to analyze and optimize airflow within the building. At the same time, to create a truly comfortable and healthy indoor environment, it is important to consider not only quantitative airflow rates but also qualitative microclimate parameters — acoustic comfort, insect protection, and draft prevention.

Table 1. Passive energy efficiency strategies in architecture

Strategy	Description	Technical aspects	Advantages
Space Planning Solutions	Optimization of building geometry and orientation to minimize the surface area-to-volume ratio (S/V) and maximize passive solar gains.	Compact forms; orientation based on cardinal directions considering solar azimuth and altitude; consideration of shape factor; analysis of solar energy potential using specialized software (e.g., Ecotect, DesignBuilder).	Reduction of heat loss through transmission and increased efficiency of solar energy utilization; minimization of energy consumption for heating and cooling.
Natural Lighting	Strategic design of window openings and interior spaces to maximize the use of diffuse and reflected daylight.	Calculation of daylight factor (DF) and analysis of daylight autonomy; use of light pipes, light wells, atriums, systems with variable reflective surface geometry; integration with artificial lighting control systems.	Reduction of energy consumption for artificial lighting; improvement of visual comfort and productivity; positive impact on the psychophysiological state of occupants.

Natural Ventilation	Utilization of natural forces (wind, thermal convection) to provide air exchange and thermoregulation of spaces.	Cross-ventilation; stack ventilation; night ventilation; calculation of air exchange considering local climatic conditions; computational fluid dynamics (CFD) modeling for optimization of airflow.	Reduction of energy consumption for mechanical ventilation; improvement of indoor air quality; enhancement of thermal comfort.
Thermal Insulation & Sealing	Creation of a high-performance thermal envelope for the building to minimize heat losses and gains.	Application of insulation materials with low thermal conductivity (λ) – vacuum insulation, aerogel, PIR, PUR, XPS; vapor barrier and wind barrier membranes; sealing of joints and connections; dew point calculation and condensation risk analysis; thermography for identifying thermal bridges.	Reduction of energy consumption for heating and cooling; increased durability of building structures; prevention of mold and mildew growth.
Energy-Efficient Windows and Doors	Minimization of heat transfer and optimization of solar gains through fenestration.	Multifunctional glazing units with low-emissivity coatings and inert gas fills (argon, krypton); window frames with thermal breaks; low U-value and high solar heat gain coefficient (g-value); dynamic glazing (electrochromic, thermochromic).	Reduction of heat loss and overheating; maximization of natural lighting; improvement of comfort.

Architectural Shading	Regulation of solar radiation entering spaces, considering seasonal changes in solar geometry.	Stationary and dynamic shading systems (pergolas, awnings, blinds, vertical landscaping, adjustable louvers); modeling of solar geometry and optimization of shading element design; consideration of shading coefficient.	Prevention of overheating in summer; allowing solar penetration in winter; improvement of visual comfort.

Active strategies, in turn, represent a set of technological solutions aimed at optimizing energy consumption in the building through the use of high-efficiency equipment and intelligent control systems [28] (Table 2).

Table 2. Active Energy Efficiency Strategies in Architecture

Strategy	Description	Technical Aspects	Advantages
HVAC Systems	Application of high-efficiency heating, ventilation, and air conditioning systems with integrated control and energy consumption optimization.	Heat pumps with high Seasonal Coefficient of Performance (SCOP) and Coefficient of Performance (COP); geothermal systems with vertical and horizontal heat exchangers; solar collectors for water and air heating; VRV/VRF systems with heat recovery and individual temperature control; radiant heating and cooling.	Reduction of energy consumption for heating and cooling; increased comfort and flexibility in microclimate control.
Heat Recovery	Utilization of heat from exhaust air to preheat incoming fresh air, reducing heat losses during ventilation.	Plate, rotary, and run-around coil heat exchangers; heat pipes; thermal storage materials; calculation of heat recovery efficiency.	Reduction of energy consumption for ventilation; increased efficiency of HVAC systems.

BMS (Building Management System)	Intelligent control and monitoring of all building engineering systems to optimize energy consumption and ensure comfortable conditions.	Integrated building automation systems based on the Internet of Things (IoT); data collection and analysis from sensors (temperature, humidity, CO2, illuminance); adaptive control of HVAC, lighting, and shading systems; predictive energy consumption modeling.	Optimization of energy consumption; increased comfort and productivity; reduction of operating costs.
Energy-Efficient Lighting	Application of high-efficiency light sources and intelligent control systems to minimize energy consumption for lighting.	Light-emitting diode (LED) sources with high luminous efficacy; lighting control systems with occupancy sensors, daylight sensors, and dimming control; dynamic lighting with adaptation to natural lighting and human circadian rhythms; integration with BMS.	Reduction of energy consumption for lighting; improvement of visual comfort and productivity; reduction of operating costs.

Unlike passive strategies, which focus on utilizing natural resources, active strategies involve the application of engineering systems that allow for precise control of microclimate parameters and adaptation of equipment operation to changing conditions [28]. One of the key components of active strategies is high-efficiency heating, ventilation, and air conditioning (HVAC) systems [29]. The use of heat pumps with a high Seasonal Coefficient of Performance (SCOP) and Coefficient of Performance (COP) allows for a significant reduction in energy consumption for heating and cooling compared to traditional systems [30]. Geothermal systems with vertical or horizontal heat exchangers utilize the stable ground temperature for efficient building heating and cooling, minimizing energy consumption from external sources [31]. Solar collectors for water and air heating enable the use of renewable solar energy, reducing dependence on fossil fuels [32]. Variable Refrigerant Volume/Variable Refrigerant Flow (VRV/VRF) systems with heat recovery and individual temperature control provide a high level of comfort and flexibility in managing the microclimate in individual rooms [33]. Additionally, radiant heating and cooling systems integrated into building structures provide even distribution of heat and cold, increasing energy efficiency and comfort [34].

Heat recovery is an important component of active energy efficiency strategies, allowing for the utilization of heat from exhaust air to preheat incoming fresh air, thereby reducing heat losses during ventilation [35]. Different types of heat exchangers—plate, rotary, run-around coil — provide varying heat recovery efficiencies and are selected based on specific project conditions [35]. The application of heat pipes and thermal energy storage materials allows for a further increase in heat recovery efficiency and a reduction in energy consumption for ventilation, integrating with HVAC systems to create an energy-efficient and comfortable microclimate [35]. Calculating heat

recovery efficiency allows for optimizing system operation and achieving maximum energy efficiency [35].

Intelligent control and monitoring of all building engineering systems are carried out using a Building Management System (BMS) [36]. Integrated building automation systems based on the Internet of Things (IoT) collect and analyze data from various sensors (temperature, humidity, CO2, illuminance) and provide adaptive control of HVAC, lighting, and shading systems in real-time [36]. Predictive energy consumption modeling allows for optimizing system operation, taking into account predicted changes in external conditions and user needs. The BMS not only optimizes energy consumption but also increases the comfort and productivity of building occupants, as well as reduces operating costs by preventing emergencies and optimizing equipment operating modes.

Finally, energy-efficient lighting is based on the use of high-efficiency light sources, such as light-emitting diode (LED) lamps with high luminous efficacy, and intelligent control systems that minimize energy consumption for lighting [37]. Lighting control systems with occupancy sensors, daylight sensors, and dimming control provide automatic switching on and off of lights and adaptation of illuminance levels to changing conditions. Dynamic lighting, adapting to natural lighting and human circadian rhythms, enhances comfort and productivity. Integration of the lighting system with the BMS allows for optimizing energy consumption and creating an intelligent lighting control system in the building.

DISCUSSION

Analysis of the Techno-economic Feasibility of integrating energy-efficient solutions and renewable energy sources into architectural design in Azerbaijan

The integration of energy-efficient solutions and renewable energy sources (RES) into architectural design in Azerbaijan represents not just a promising direction, but a strategic necessity, driven both by the significant, yet unrealized, potential of solar and wind energy and by the global drive towards decarbonization and economic diversification. Currently, the Azerbaijani energy system is characterized by the dominance of natural gas-fired thermal power plants (TPPs). According to the report of the Ministry of Energy of the Republic of Azerbaijan for 2022 [9], TPPs generated 27,059.1 million kWh, which accounts for more than 90% of the total electricity generation. The achieved energy self-sufficiency is undoubtedly an important achievement, but dependence on fossil fuels creates environmental risks associated with greenhouse gas emissions and other pollutants, and limits the long-term sustainability of the energy sector in the context of a changing climate and the global energy transition. The transition to RES, particularly solar and wind energy, is fully in line with global decarbonization trends, contributes to meeting international commitments to reduce greenhouse gas emissions, and reduces dependence on limited natural gas reserves. Azerbaijan possesses exceptional solar energy potential, estimated at 23,000 MW [10], which is comparable to the installed capacity of all the country's power plants. The wind energy potential is also very significant: 3,000 MW onshore and a colossal 157 GW in the Azerbaijani sector of the Caspian Sea [11]. Effective utilization of this potential can fundamentally transform the country's energy landscape, providing clean and sustainable electricity generation.

Table 3. Dynamics and Structure of Electricity Production in Azerbaijan (2018-2022)

Indicator	2018	2020	2021	2022	CAGR (2018-2022)[1]
Electricity Production (million kWh)	25 229	25 811	27 875,3	29 004,3	+4.4%
TPPs (million kWh)				27 059,1	
Share of TPPs (%)				93.3%	

HPPs (million kWh)				1 595,7	
Share of HPPs (%)				5.5%	
Other RES (million kWh)[2]				349,5	
Share of other RES (%)				1.2%	
Electricity Consumption (million kWh)		21 970	23 435,6	23 191,2	+1.9%
Export/Import Balance (million kWh)[3]	1313.8	1014.2	1673.4	2860.3	+26.9%

[1] CAGR — Compound Annual Growth Rate.

[2] Other RES includes wind, solar, and bioenergy plants.

[3] Calculated as Export — Import.

The economic feasibility of integrating RES into architecture is determined by a complex set of factors, among which the key ones are the levelized cost of electricity (LCOE), return on investment (ROI), the availability of government support, and access to financing. The global decline in the cost of solar panel and wind turbine production technologies observed in recent years makes RES increasingly competitive with traditional TPPs. According to data from the International Renewable Energy Agency (IRENA), the LCOE for solar photovoltaic energy decreased by 85% from 2010 to 2020, and for onshore wind energy — by 56% over the same period [12]. However, to assess the economic efficiency of RES projects in Azerbaijan, it is necessary to conduct a detailed LCOE calculation, taking into account local conditions, such as the cost of equipment and its delivery, installation work, operating expenses, financing rates, access to networks, and the availability of necessary infrastructure. Comparing the obtained LCOE with the current electricity tariffs for end consumers and industrial enterprises will make it possible to determine the economic efficiency of projects and the attractiveness of investments in "green" energy.

The technical integration of RES into architectural projects is a complex and multifaceted process that requires careful analysis, planning, and the application of modern technologies. Building-integrated photovoltaics (BIPV), solar thermal collectors for water heating, and small wind turbines can be harmoniously integrated into building design, providing electricity and heat generation directly at the point of consumption. During design, it is necessary to consider many factors influencing the effectiveness of RES: building orientation to the cardinal directions, the angle of inclination of the roof or facade, shading from surrounding buildings and trees, the availability of free space for equipment placement, wind conditions, and the intensity of solar radiation in the given area. To ensure an uninterrupted energy supply, especially during periods of low insolation or weak wind, it is necessary to provide for energy storage systems, such as lithium-ion or flow batteries. In addition, it is important to ensure the compatibility of RES with the existing building energy system, provide for monitoring and control systems, and train personnel in the operation and maintenance of new equipment.

Azerbaijan's favorable climatic conditions and advantageous geographical location create excellent preconditions for the widespread use of RES. The large number of sunny days per year, characteristic of most of the country, ensures high efficiency of solar power plants. Significant wind potential, especially in the coastal areas of the Caspian Sea and on the Absheron Peninsula, opens up broad opportunities for the development of wind energy. Azerbaijan's geographical location allows for considering the export of "green" energy to neighboring countries, such as Turkey, Georgia, Russia, and Iran, which creates additional economic incentives for the development of RES and contributes to strengthening regional energy cooperation. One example of such cooperation is the project to export electricity via a submarine cable along the bottom of the Black Sea to Romania and then to Europe [13], which will allow Azerbaijan to become an important player in the European "green" energy market.

The development of RES in Azerbaijan is unthinkable without the creation of an appropriate regulatory and legal framework and the implementation of an active state policy aimed at stimulating investment in this sector. Clear and transparent rules for connecting RES to the energy system, simplified procedures for obtaining permits for the construction and operation of RES facilities, mechanisms to support producers of "green" energy, such as "green" tariffs, tax incentives, and subsidies, as well as programs to improve energy efficiency in construction, for example, the introduction of "green" building standards and energy certification of buildings, are necessary. One example of successful government support is the construction of the Shafag solar power plant with a capacity of 240 MW with the participation of BP [14], which demonstrates the attractiveness of the Azerbaijani RES market for large international investors.

The integration of RES into architecture has not only economic and environmental but also important social consequences. The creation of new jobs in the renewable energy sector, the reduction of dependence on energy resource imports, the increase in energy security, and the improvement of the environmental situation positively affect the quality of life of the population and contribute to the sustainable development of the country. Informing the public about the benefits of RES, increasing the level of environmental literacy, and conducting educational programs contribute to the formation of positive public opinion and support for projects in the field of "green" energy.

To assess the prospects for the integration of renewable energy sources (RES) into architectural design in Azerbaijan, a multi-criteria SWOT analysis was also carried out (Table 4). This analysis made it possible to comprehensively study the current situation and identify the key factors influencing the development of RES in the country. As part of the SWOT analysis, strengths, weaknesses, opportunities, and threats associated with the integration of RES into architecture were assessed. Each factor was evaluated according to two criteria: impact on RES development (on a scale of 1 to 5, where 1 is minimal impact, 5 is maximum impact) and the probability of its realization (also on a scale of 1 to 5, where 1 is low probability, 5 is high probability). The multiplication of these ratings gave a weighted score reflecting the significance of each factor. Among the strengths, the high potential of RES in Azerbaijan, due to favorable natural and climatic conditions, as well as active government support for the development of "green" energy, were highlighted. As weaknesses, the low current share of RES in the overall energy balance and the lack of qualified personnel in this area were noted. Opportunities included the declining cost of RES technologies in the global market and the growing demand for "green" buildings, and threats included competition from traditional energy based on fossil fuels and potential climate risks.

Table 4. Multi-criteria SWOT Analysis of the Feasibility of Integrating RES into Architectural Design in Azerbaijan

Factor	Description	Impact (1-5)	Justification of Impact	Probability (1-5)	Justification of Probability	Weighted Score
Strengths						

High RES Potential (S1)	Significant solar and wind energy resources.	5	Provides a foundation for RES development and reduces dependence on traditional energy sources.	5	Natural resources are stable and available.	25
Government Support for RES (S2)	Existence of programs to stimulate RES development, construction of large-scale projects.	4	Stimulates investment and accelerates the development of the RES sector, but does not guarantee complete success.	4	Government policy may change, but current trends indicate continued support for RES.	16
Export Potential of "Green" Energy (S3)	Possibility of exporting electricity generated from RES to neighboring countries and Europe.	4	Creates additional economic incentives for RES development and diversifies export markets.	4	Depends on the geopolitical situation and the demand for "green" energy in target countries.	16
Weaknesses						
Low Current Share of RES (W1)	The insignificant contribution of RES to the overall energy balance requires significant efforts to change.	4	Slows down the transition to "green" energy and increases dependence on fossil fuels.	5	The current situation is obvious and requires change.	20

Lack of Qualified Personnel (W2)	The shortage of specialists in the design, installation, and maintenance of RES systems limits the speed of new technology adoption.	3	May lead to delays in project implementation and reduced efficiency of installed equipment.	4	The problem exists, but educational programs and attracting foreign specialists are possible.	12
Limited Access to Financing (W3)	Difficulties in attracting investment for projects to integrate RES into buildings may slow down the development of the sector.	3	The high cost of RES projects can be a barrier to their implementation.	3	The situation may improve with the development of the RES market and the emergence of new financial instruments.	9
Opportunities						
Decreasing Cost of RES Technologies (O1)	The global trend of decreasing costs for RES equipment makes them more accessible.	4	Increases the economic attractiveness of RES and promotes their wider adoption.	5	A global trend that is highly likely to continue.	20

Growing Demand for "Green" Buildings (O2)	Increasing interest in sustainable construction and energy-efficient solutions opens up new market niches.	3	Creates additional demand for RES and promotes the development of "green" construction.	4	A global trend, but its scale in Azerbaijan requires further research.	12
International Cooperation (O3)	The possibility of attracting the experience and technologies of foreign companies in the field of RES accelerates the development of the sector.	3	Allows access to advanced technologies and best practices.	3	Depends on the political situation and willingness to cooperate.	9
Threats						
Competition from Traditional Energy (T1)	The dominance of TPPs and relatively low natural gas prices create competition for RES.	4	May slow down the development of RES if the cost of "green" energy is higher than traditional energy.	4	As long as natural gas prices remain low, this threat persists.	16

Political and Economic Instability (T2)	The impact of geopolitical factors and price fluctuations in global markets can negatively affect investments.	3	May lead to delays or cancellation of projects.	3	The probability of such situations arising exists.	9
Climate Risks (T3)	Possible changes in climatic conditions affecting the efficiency of RES (e.g., reduced solar radiation or changes in wind patterns).	2	May reduce the efficiency of RES operation and affect their economic feasibility.	2	The probability of significant climate changes in the short term is relatively low.	4

The SWOT analysis identified key areas for developing renewable energy sources in Azerbaijan and integrating them into architecture. Developing a long-term strategy that includes specific goals, such as achieving a 30% share of RES in the energy balance by 2030 [15], clear financing mechanisms, government support measures and investment incentives, and international cooperation, will allow for the effective use of existing potential and ensure the sustainable development of the energy sector. A phased transition to "green" energy, starting with pilot projects and gradually increasing the share of RES, will minimize risks, adapt technologies to local conditions, and ensure a smooth transition to a new energy model. Clear examples of such projects are the construction of the 240 MW Khizi-Absheron wind power plant [16] and the cascade of hydroelectric power plants on the Okhchuchay River [29], which demonstrate the practical implementation of the RES development strategy in Azerbaijan. In addition, an important direction is the modernization of the existing energy infrastructure, increasing its efficiency, and integrating it with new RES facilities.

CONCLUSION

In conclusion, the conducted research confirms the high feasibility of integrating energy-efficient solutions and RES into architectural design in Azerbaijan. The analysis showed the presence of significant potential for the development of solar and wind energy in the country, which opens up wide opportunities for reducing dependence on traditional energy sources based on fossil fuels and reducing negative environmental impacts. The identified strengths, such as favorable climatic conditions, government support for RES development, and the potential for exporting "green" energy, create a solid foundation for the successful implementation of a strategy for transitioning to a sustainable energy model. However, realizing this potential requires overcoming a number of challenges related to the need to develop appropriate infrastructure, train qualified personnel, and attract investment.

The SWOT analysis revealed both opportunities, related to the declining cost of RES technologies and the growing demand for "green" buildings, and threats, caused by competition from traditional energy and potential climate risks. For the successful integration of RES into architectural design, it is necessary to develop a comprehensive strategy that takes into account all identified factors and provides for measures to neutralize or utilize them. Particular attention should be paid to the development of the regulatory and legal framework, the improvement of the system for financing RES projects, and raising public awareness of the benefits of "green" energy.

Thus, the integration of energy-efficient solutions and RES into architectural design is a strategically important direction for Azerbaijan, contributing to the sustainable development of the country, reducing dependence on fossil fuels, and improving the environmental situation. Further research in this area should be aimed at developing specific methodologies and tools for assessing the technical and economic efficiency of RES projects in buildings, as well as creating favorable conditions for their widespread implementation in design and construction practice. This will allow Azerbaijan not only to effectively use its significant RES potential but also to become a leader in the region in the field of sustainable construction.

Author Contributions

The author was solely responsible for all aspects of this research, including conceptualization, literature review, data analysis, methodology development, writing, and editing of the manuscript.

Conflict of Interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This includes, but is not limited to, employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

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