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Sustainable Solution for Increasing the Share of Solar Photovoltaic Usages on Residential Houses in Azerbaijan

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The Republic of Azerbaijan, as the largest nation state in the South Caucasus Region, has the potential for developing and using renewable sources of energy in order to support the environmental challenge resolution associated with climate change, improving the environmental situation in the country. Solar photovoltaic (PV) comprises one of the direct usages of solar energy. In this paper, a sustainable PV usage scenario in residential houses was introduced to reduce negative environmental effects in land use, water consumption, air pollution, etc. It was recommended by the author that PV systems can be part of function and design of residential building components, such as roofs, walls and windows.
Keywords: *renewable energy, photovoltaic engineering, sustainable energy usage scenario, environmentally friendly, energy efficiency*.

1 Introduction

Energy security and climate change comprise some of the most important concerns facing humankind today and probably in the future if they are not addressed appropriately. The 2010 annual report by the United Nations Environment Programme (UNEP) pointed out that the energy system ought to offer an energy service that meets 3 criteria, which must be environmentally sound, economically viable and socially acceptable (UNEP, 2010). In order to stabilise the global climate, there is the need for the world to lessen its use of fossil energy, which requires enhancement of current energy efficiency as well as development of novel energy sources, such as energy obtained from renewable sources. There is no doubt that the steady transition towards a solar-based economy is likely to result in the development of completely new sectors, behaviours and jobs that are pro-environmental (Aliyev & Khalilova, 2010).

Azerbaijan has a programme targeted at reducing carbon dioxide emissions and increasing the percentage of renewable energy in the general energy consumption by 2020 (Aliyev, 2010). At present, the economy of Azerbaijan depends significantly on the production of gas and oil. This reliance on fossil fuels only worsens the local environmental situation. During the next 3 decades, oil production is projected to exceed the total oil production in the country for the last 30 years (Ciarreta & Nasirov, 2012). From an environmental perspective, this increase in oil production bears a heavy cost (Ciarreta and Nasirov, 2012). The exploration, transportation, and refinement of oil in the Azerbaijan Caspian Sea pose a significant danger to the natural environment. This is being further aggravated by the fact that the country lacks an effective monitoring system and that there is no organised initiative between the states in the Caspian Basin and the Republic of Azerbaijan. In Azerbaijan, the most crucial issues concern the health of the population residing near the onshore oil fields, management of waste linked to oil production and restoration of oil polluted territories. The Apsheron Peninsula is considered the heart of onshore oil production in Azerbaijan. Presently, about 200 oil waste lakes are found in the area; however, 4% of the area is polluted (Orujova, 2014). In order to address these environmental challenges, Azerbaijan has envisioned a strategy that involves “thinking globally and acting locally." This means exploitation of the country's geographical potential for the development of renewable sources of energy. In 2000, Azerbaijan agreed to the Kyoto Protocol as a non-Annex I Party, which implies that the country is allowed to take part in the Clean Development Mechanism of the Kyoto Protocol (Aliyev & Khalilova, 2010). In order to support the initiatives aimed at mitigating the effects of climate change, and due to the agreement with the Kyoto Protocol, Azerbaijan made a commitment to reduce the amount of greenhouse gas (GHG) emission by 5% until 2020, while only 1.8% was achieved until the mid of 2015, which is delay. Several regional and international programmes focusing on increasing climate change awareness have been implemented in the country. Also, it has focused on building its capacity to implement GHG reduction projects (Aliyev, 2010).

The issue of renewable energy has received substantial attention in Azerbaijan during the recent past, specifically since 2009 (Aliyev, 2010; Aliyev & Khalilova, 2010). This can be attributed to a number of observations. For instance, on June 10, 2009, Azerbaijan signed an agreement with the International Renewable Energy Agency (IRENA), which was followed by setting up the State Agency on Alternative and Renewable Energy Sources. Despite these steps, there are relatively few real world implementations of clean technology in the country (Ciarreta & Nasirov, 2012). As mentioned earlier, the energy sector of Azerbaijan depends strongly on the production of oil and natural gas. With the predictable increase in the production of oil, the amount of hydrocarbon emissions stemming from oil and gas will be about 80–85% of the total hydrocarbons emitted from Azerbaijan in 2025, which will also be about 1.8 times more when compared with the current emission levels (Guliyev, 2015). Given the gradual increase in GHG emissions from Azerbaijan, addressing the problem requires improved energy effectiveness, which can be achieved by a gradual shift towards renewable energy sources to lessen carbon dioxide emissions and by promoting the diversification of energy sources in the country. Therefore, the shift from the conventional sources of energy towards renewable sources is a potential solution, especially the promotion and development of solar energy sources. Renewable energy refers to energy obtained from natural processes and has the ability of being restocked constantly (Ciarreta & Nasirov, 2012). Some of the various renewable sources include energy directly harnessed from the Sun, geothermal sources, biofuels, biomass, hydropower, ocean and wind. Presently, renewable energy is perceived as an insignificant player with respect to energy provision. Moreover, renewable energy sources are considered less important when compared with fossil energy. Nevertheless, the damage to the environment stemming from the use of fossil energy is too enormous to be ignored. According to Aliyev (2010), the future is not in the concept of "global cities", but rather in "solar cities" and "sustainable cities", which can strengthen the economy of the country by enabling cities to meet their long-term energy needs through the use of renewable energy sources. Thus, the following concepts, as sustainable development, socio-economic state enhancement, and natural environment protection should not be looked at in isolation. In Azerbaijan, there is a great potential for the development of renewable energy sources, especially wind and solar energy, which can subsequently reduce the amount of GHG emissions. This can be attributed to the fact that the country has a high amount of solar insolation, which ranges 3−4.7 kWh/m^2/day (Aliyev & Khalilova, 2010). Despite this potential, Azerbaijan does not have any officially solar photovoltaic (PV) plants.

Whereas the existing worldwide environmental challenge associated with climate change has been acknowledged as evident through the country's commitments on climate change, emphasis has not been placed on renewable energy sources, especially solar energy. Azerbaijan has been reported to have a significant potential for solar energy – it has about 2,400−3,200 sunshine hours annually, which translates into a great potential for solar PV electricity as well as heat generation (Aliyev, 2010). It has been estimated that the solar PV has the potential for generating 16 billion kilowatt-hours (kWh) annually in Azerbaijan, which would save up to 0.7 million tons of fossil fuel, help to prevent the depletion of ozone and reduce the amount of carbon dioxide emissions to the atmosphere. In this regard, it is imperative to note that in most parts of the country, the potential for solar energy ranges between 1,600 kWh/m^2/year and 2000 kWh/m2/year (Guliyev, 2015). Renewable energy consumption constitutes only 2.7% of the total consumption of energy as of 2013 (Ciarreta & Nasirov, 2012). This means that renewable energy in Azerbaijan will require additional significant investments to become competitive with the enormous fossil energy sources. Reduction of the energy consumed for cooling and heating is another significant challenge that is likely to be addressed partially by using efficient technologies. Cooling and heating comprise at least 50% of the total energy consumption (Aliyev & Khalilova, 2010). In line with the need to develop renewable energy sources in the country, the Ministry of Industry has made plans to invest about $8.9 billion with the aim of increasing the renewable energy generation to 20% as of 2020 (Aliyev & Khalilova, 2010). To this end, the goal of this paper is to propose a scenario for increasing the solar PV usages on residential houses in Azerbaijan.

2 Materials and methods

Theoretical, methodological and legal bases of the renewable energy usage in the Republic of Azerbaijan were presented in the present case. The "Azerbaijan 2020" programme was used as a legal base for this research. It was defined that the main 2 targets of this programme had a big delay according to economic (high level dependence on the fossil fuel usage) and legislative (lack of a monitoring system) factors. These targets are: 1) to reduce GHG emission by 5% until 2020, and 2) to increase renewable energy usage by 20% in the energy consumption until 2020 of this programme. The literature describing the solar power energy usage in Azerbaijan was searched and scenario formation was used for PV usage on residential houses. This literature covers the books of local and international authors, like Aliyev, Khalilova, Ciaretta, etc. According to the Kyoto Protocol, the commitment of reducing GHG in Azerbaijan until 2020 was used as one of the core base of the research paper. The scenario suggests using of building-integrated photovoltaic modules in residential houses in Azerbaijan to produce electricity for energy demand consumption. These modules could be used in the house architecture and design as a window part, rooftop, etc. The scenario was performed taking into consideration the environmental aspects, such as land use, greenhouse gas emission, climate change and air and water pollution. The environmental impacts of land use and water pollution by Building Integrated Photovoltaics (BIPV) were calculated and presented in Tables 1 and 2 until 2030 and 2050.

Solar Pro software was used for the presented data analysis and calculation for land requirement and water consumption by various solar energy technologies. The calculation was done through applied mathematics formulas and probability theory, which are the core elements of the presented software.

The data collection is done for the scenario formation. This data is about the land requirement and water consumption by various solar energy technologies as well as BIPV. The used data is from the Azerbaijan Statistic Committee Report 2012. The data was used for the Solar Pro software.

The fundamental goal is to evaluate the advantages of BIPV. BIPV modules supply ordinary rooftop tiles and are completely incorporated as a component of the building's rooftop. The presumptions will incorporate ordinary rooftop tiles in Azerbaijan. The proposed design is to add an environmental premise situation. The study gives vital data for Azerbaijan that is pertinent for comparable measured and resourced nations that are creating sun powered PV jolt systems.

3 Results and discussion

Solar PV comprises one of the direct usages of solar energy. Numerous developed countries have commenced wide applications of photovoltaic programmes (PVP). However, Azerbaijan is yet to initiate PVPs on a broader scope. Successful case studies from other countries can be used to develop a successful PVP, especially in residential houses. The efficiency of solar PV is influenced primarily by the geographic location as well as the climatic conditions of the country (Angelis-Dimakis *et al.*, 2011). For instance, the United States receive about 1,000−1,500 kWh/m2/year, France 1,200−1,400 kWh/m2/year, China 1,300−1,500kWh/m2/year, whereas Azerbaijan receives 1,500−2,000 kWh/m2/year (Ciarreta & Nasirov, 2012). Relative to other countries, it is evident that the amount of solar rays that Azerbaijan receives acts as an incentive for the large scale development of renewable sources of energy for environmental protection as well as social benefits. Solar PV modules can be placed on the rooftops of residential houses, which can entail either replacement of the whole or a part of the roof with solar PV modules (Hwang *et al.*, 2008; Fthenakis & Alsema, 2006). Domestic installation of solar PV models has been strongly promoted in such countries as Germany and Japan, which has resulted in significant environmental benefits. Just like any other energy generating technology, solar PV has environmental impacts that must be taken into consideration in order to ensure it is implemented in an environment friendly manner (Katzenstein & Apt, 2008). At the same time, it is imperative to note that the potential of solar PV to lessen the emissions of GHG and other environmental effects, associated with energy generation when compared with other sources, forms one of the most crucial reasons for the widespread implementation of residential solar PV in Azerbaijan (Zahedi, 2011). It is crucial to have an understanding of the environmental impacts and benefits associated with solar PV in order to develop a long-term programme for the use of solar PV in residential houses in Azerbaijan. The next section will explain the scenario usage results on land use, air and water pollution prevention, climate change and emission of GHG.

1.1 Land use

Energy and land are intricately related. This stems from the fact that during the development of energy systems, the biophysical features of land are likely to change (change in the land cover), the use of land is likely to become different (change in land-use), and land is likely to be utilised for a particular time duration (land occupation) (Fong *et al.*, 2010). Terrestrial ecosystems differ in terms of their net primary productivity, i.e., the rate at which organic carbon in plants is accumulated. For example, tropical evergreen forests have a net productivity rate of about 1−3.2 kg/m²/year, whereas deserts have a maximum net primary productivity rate of 0.6 kg/m²/year (Kaygusuz, 2009). Additionally, terrestrial ecosystems differ according to their ability to sequester carbon in soil. In instances where changes are observed in land-cover and land-use, such as disturbance of soil and clearance of vegetation, the belowground and aboveground pools are likely to release carbon into the Earth's atmosphere in the form of carbon dioxide (Tyagi *et al.*, 2013). As a result, the development of an energy-generation infrastructure on land that has already been contaminated or disturbed can lead to lower net carbon losses when compared with energy infrastructure developed on undisturbed lands. Other important land-use attributes associated with energy include reversibility and efficiency (Turney & Fthenakis, 2011). Efficiency of land-use (W/m^2) denotes the power of the energy installation with respect to its carbon footprint, where the carbon footprint denotes the land area that is changed or transformed following the energy installation relative to its conversion chain. Owing to the fact that energy systems are likely to have an effect on land through disposal, decommissioning, distribution, maintenance and operation, production, construction, processing, acquisition and extraction of materials, and materials exploration, the carbon footprints associated with an energy installation are likely to be high (Katzenstein & Apt, 2008). In addition, a piece of this land is likely to be utilised in a manner that restores land to its pre-disturbed state and may require longer durations of time, or land use may result in irreversible changes.

Residential solar PV has insignificant impacts on land use. Under the sustainable scenario, solar PVs are installed on residential buildings, which means that insignificant pieces of land will be affected through residential solar PV usages (Mekhilef, Saidur & Safari, 2011). In order to reduce the land-use impacts associated with the residential usage of solar PVs further, BIPV can be used. This comprises PV systems generating electricity and functioning as a component of the building. Therefore, building components such as roofs, facades, walls and windows can be designed in the form of solar PVs, such as solar tiles and solar shingles. The land requirements of residential solar PV usages are insignificant when solar PVs are installed on rooftops (either partially or completely) and when integrated in buildings (Miles, Hynes & Forbes, 2005). Table 1 shows the estimates of the direct land requirements for various solar energy technologies during 2030 and 2050 under the sustainable scenario. It is imperative to note that one does not know exactly how the precise mix of land use practices and solar energies will evolve (Pacca, Sivaraman & Keoleian, 2007). If priority is minimal land use, the lower range values can be achieved. It is also worth mentioning that, among various solar technologies, solar PV installed on rooftops has no direct land use. Moreover, indirect land use is negligible due to the fact that solar PVs are installed on rooftops and integrated in buildings.

Table 1. Land requirement for various solar energy technologies (Azerbaijan State Statistic Committee Report, 2012).

	Direct land usage per annual electricity production	**Solar generation as of 2030 in Terawatt hour**	**Direct solar land usage as of 2030 in hectares**	**Solar generation as of 2050 in Terawatt hour**	**Direct solar land usage as of 2050 in hectares**
Solar PV installed in rooftops	0	164	0	318	0
Utility scale solar PV	800-2,500	341	270,000-850,000	718	570,000-1,800,000
Concentrating solar power	700-1,800	137	96,000-250,000	412	290,000-740,000

1.2 Emissions of air pollutants

All types of electricity-generating technologies, including thermal technologies, discharge pollutants in the course of their lifecycle; however, solar energy technologies produce little or no pollutants in the air during operation (Orujova, 2014). One of the emissions of greatest concern with respect to the generation of electricity includes particulate matter (PM): NO_x (nitrogen dioxide and nitric oxide) and SO_x (sulphur oxides) (Kaygusuz, 2009). Particulates that are no more than 2.5 microns in size can result in a myriad of health problems, such as cardiovascular disease, bronchitis, asthma, impaired lung function and premature death among others. PM also changes water and soil chemistry while at the same time interfering with nutrient balances. Moreover, the impacts associated with the emissions of PM can be observed at distances far from their originating source. Replacing fossil energy sources with solar technologies such as PV has the potential for significantly reducing the emissions of particulate matter (Otanicar, Taylor & Phelan, 2012).

Mercury emissions can have deleterious effects on the nervous system of infants and unborn babies. Power plants that burn coal produce about 40% of mercury emissions; therefore, substituting coal-derived sources of electricity with solar technologies, such as concentrating solar power (CSP) and PV, has the potential for lessening mercury emissions (Panwar & Kothari, 2011). NO_x also results in a number of environmental and health problems. These include particulate matter, toxicity of air, ground level ozone, deteriorating quality of water, climate change, acidic precipitation and respiratory ailments, such as lung and heart diseases (Angelis-Dimakis *et al.*, 2011; Parida, Iniyan & Goic, 2011). Electricity generation has been reported to be a significant source of NO_x. For solar technologies like PV that do not yield NO_x and SO_x emissions during operations, estimates of these emissions rely significantly on the presumptions regarding the sources of power used in the manufacturing of solar PV equipment. Overall, it is evident that the life cycle emissions of SO_x and NO_x are relatively small when compared with emissions from fossil fuels (Patel, 2005; Tsoutsos, Frantzeskaki & Gekas, 2005).

In the course of decommissioning, it is possible to recycle solar PV cells in order to curb the contamination of the environment by such toxic materials found in the PV cell as silica dust, arsenic and cadmium. In instances involving damaged PV cells or inappropriate handling of the equipment, exposure to industrial wastes is a possibility (Parida, Iniyan & Goic, 2011). This can cause harm to the natural environment as well as people. For instance, inhaling silica dust for relatively longer periods can result in silicosis, which can be fatal in severe cases. Moreover, chemical spills from the materials like herbicides, fluids for heat transfer, cooling liquids and dust suppressants can cause pollution of ground water as well as deep-water reservoirs. The manufacturing process of solar PV cells involves the use of various hazardous materials used in the cleaning and purification of semi-conductor surfaces (Prakash & Bhat, 2009; Solangi *et al.*, 2011). These chemicals are the same as those utilised in the semi-conductor sector, such as acetone, hydrogen fluoride, nitric acid, sulfuric acid and hydrochloric acid among others. The type and the quantity of utilised chemicals are determined by the type of the PV cell, the extent of cleaning required and the proportions of silicon wafer in the PV cell. As a result, solar PV manufacturers must set up measures to ensure proper disposal of manufacturing waste chemicals. Thin film solar PV modules contain several chemicals that are more toxic than those utilised in the conventional silicon PV cells, such as cadmium telluride and gallium arsenide among others. These toxic chemicals are supposed to be handled properly in order to prevent serious environmental damage. Nevertheless, it is important to note that manufacturers of PV embark on the recycling of these materials instead of disposing them (Solangi *et al.*, 2011).

Solar PVs installed on rooftops have been established to be effective in reducing heat flux resulting in energy savings and leading to human comfort attributed to cooling. Similarly, solar PVs installed on rooftops and integrated in buildings have insulating properties, which can be used to mitigate illnesses and mortality associated with heat waves.

3.1 Water consumption

The consumption of water differs in various solar technologies and location. Table 2 shows the projected consumption of water by various solar technologies. From the table, it is evident that various solar configurations can result in a significant reduction of water consumption when compared with the traditional sources of energy. Solar PV consumes little water, if any, in the course of operations. Some types of solar PV panels require washing in order to ensure optimal performance (Pacca, Sivaraman & Keoleian, 2007). CSP and concentration of PV need water to rinse reflectors, mirrors and panels in order to maximise production of energy, whereas the amount of water consumed during the manufacture of solar PV is yet to be established. It is evident that water used in the manufacture of solar PV can be purified and returned to the water environment. Moreover, the amount of water required for extracting, processing and transporting nuclear technologies and fossil energy is significantly higher when compared with the water required for solar energies (Kaygusuz, 2009). The solar technology that consumes a huge amount of water is CSP. CSP is used in cooling. The water consumed in CSP cooling is determined by the availability of water, climatic conditions, location, the cooling system and the technology. The types of cooling systems used in CSPs include hybrid, dry and wet. Wet cooling provides the best performance at the lowest possible cost, although it requires huge amounts of water. Dry cooling consumes less water, although it is costly and less efficient during hot days. Water consumption is an important environmental issue in Azerbaijan; therefore, developers of solar PV and CSP will have to acquire water rights from those holding rights to water (Pacca, Sivaraman & Keoleian, 2007). Nevertheless, in residential solar PV installation, the amount of water consumed is insignificant when compared with other solar technologies and sources of energy.

Table 2. Water consumption by various solar energy technologies (Azerbaijan State Statistic Committee Report, 2012).

	Solar generation as of 2030 in Terawatt hour	**Solar-related consumption of water as of 2030 in billion m³**	**Solar generation as of 2050 in Terawatt hour**	**Solar related consumption of water as of 2050 in billion m³**
Solar PV installed in rooftops	164	0-0.0030	318	0-0.0060
Utility scale solar PV	341	0-0.0064	718	0-0.0136
Concentrating solar power	137	0.0530-0.2839	412	0.1590-0.8600

3.2 Climate change and greenhouse gas emissions

Worldwide, climate change, mainly attributed to human-related GHG emissions, poses a significant threat to the environment. Increased global temperatures can result in water and air pollution. Global warming can also lead to an increase in ground level ozone, evaporation of surface water and an increase in dust originating from dry soil contributing to dangerous PM emissions. Following a long-term plan, considerable reductions in the emissions of GHG are anticipated. Together with other efforts across the globe, the reductions in GHG emissions can result in significant slowing of worldwide climate change (Fthenakis & Alsema, 2006).

The radiative balance of the Earth's atmosphere can change when the albedo of a solar PV module is different from the albedo of the land atmosphere. Albedo denotes the percentage of solar energy in the form of shortwave radiation that is reflected into space from the Earth (Fong *et al.*, 2010). It denotes the reflectivity of the surface of the Earth. Owing to the high absorptivity associated with solar PV modules, it can be said that they have effective albedo ranging between 0.18 and 0.23, which is a function of the conversion efficiency and the inherent reflectivity of the panels. In fact, a solar PV installation of 1 TW has the potential of reducing the surface albedo, which can in turn increase temperatures by about 0.4 degrees Celsius in deserts (Patel, 2005). In cities, the average albedo ranges between 0.15 and 0.22 and, as a result, solar PV arrays have the potential for increasing the albedo and producing a cooling effect (Prakash & Bhat, 2009). Despite the fact that land-atmosphere, regional- and local impacts are crucial and must be taken into consideration, especially in ecosystems that are environmentally sensitive, the environment friendly impacts associated with substituting carbon-related sources of energy with solar energy on a global scale cannot be undervalued. When solar PVs are used as a substitute for fossil energy globally, the lessened radiative forcing is found to be 30 times larger when compared with the increased radiative forcing resulting from decreased albedo. In addition, with an increase in the efficiency of solar PV systems over time, their effective albedo will also rise (Ciarreta & Nasirov, 2012; Prakash & Bhat, 2009).

The increase in the prevalence of extreme weather and changing climate envelope models pose a significant challenge to the usage of solar PV in residential settings in Azerbaijan. Solar PV technologies make use of both diffuse and direct light in converting solar energy to electrical energy. However, high ambient temperatures can lessen the efficiency of panels in a linear fashion. As a result, cool places having high amounts of solar irradiance are considered the best locations for harnessing solar energy using PV (Miles, Hynes & Forbes, 2005; Tyagi *et al.*, 2013). At present, the combined uncertainty of solar PV is about 8% in the course of its lifetime efficiency. Uncertainty is likely to rise when projections of climate change are considered. The efficiency of concentrating solar PV enhances with an increase in ambient temperature and direct light. As a result, climate changes also have an effect on the output of CSP. In general, substitution of carbon energy sources with solar energy is likely to mitigate climate change through the reduction of GHG emissions (Otanicar, Taylor & Phelan, 2012; Panwar & Kothari, 2011).

4 Conclusion and recommendations

Azerbaijan depends largely on fossil energy, which is not environmentally friendly. This makes a case for the development of renewable sources of energy. To this end, solar energy comprises one of the promising substitutes to fossil energy in Azerbaijan. The environmental impacts associated with solar PV have been documented in this paper. It can be concluded that:

1) Solar PV has the potential for considerably lessening GHG emissions when compared with other sources of energy, owing to the fact that they produce no noise pollutants and little, if any, chemical pollutants in the course of their usual operation.

2) The effect of an energy generating technology depends on a number of variables including biodiversity, sensitive ecosystems, type of land and the topography of the area. Land use impacts are usually witnessed in the construction phase. However, this is not the case with solar PV in residential settings. In residential settings, solar PV has negligible impacts on land use. Under the scenario, solar PVs are installed on residential buildings, which means that insignificant pieces of land will be affected through residential solar PV usages.

3) Residential solar PV has minimal impacts with respect to emissions affecting the quality of air. Rooftop solar PV installations have been proved to have a cooling effect, which results in energy savings and leads to human comfort because of the cooling effect.

4) Despite the fact that residential solar PV installations offer an effective approach to influence climate change, there is room for improvement. Besides the traditional rooftop installations, solar PV can be used in architecture and design. This can be achieved through building integrated solar PV, which is characterised by solar PV systems functioning as components of a building. In this respect, the design of solar PV systems can take the form of roofs, facades, walls and windows. Examples include solar tiles and solar shingles. These products can be used by architects to offer both style and function.

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Darnus sprendimas didinti saulės fotoelektros naudojimo dalį gyvenamuosiuose namuose Azerbaidžane

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Azerbaidžano Respublika, kaip didžiausia Pietų Kaukazo regiono valstybė, turi potencialą vystyti ir naudoti atsinaujinančios energijos šaltinius, paremiant aplinkosauginį iššūkį, susijusį su klimato kaita, bei gerinant aplinkosauginę šalies situaciją. Saulės fotoelektra – tai vienas iš tiesioginio saulės energijos panaudojimo būdų. Šiame straipsnyje pateikiamas darnaus fotoelektros panaudojimo scenarijus gyvenamuosiuose namuose, kad būtų sumažintas neigiamas poveikis aplinkai, susijęs su žemės panaudojimu, vandens vartojimu, oro tarša ir t. t. Pasak autoriaus, fotoelektrinės sistemos gali tarnauti kaip funkciniai ir dizaino gyvenamojo namo komponentai, kaip stogai, sienos ir langai.

Raktiniai žodžiai: atsinaujinanti energija, fotoelektros inžinerija, darnaus energijos vartojimo scenarijus, palankus aplinkai, energijos efektyvumas.