PROBLEMATICS OF SOLAR PV IMPLEMENTATION IN HIGH ALTITUDE AREAS OF VLORA

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Abstract

Photovoltaic (PV) systems have received a lot of attention in recent years due to their ability to efficiently convert solar energy into electrical energy, which offers significant benefits for the environment. Albania has great potential for solar energy. It receives around 2100-2700 hours of sunlight, making solar energy accessible. This study reviews the challenges of implementing photovoltaic systems in the mountainous areas of Vlora, specifically in the Llogora National Park, which is 910 meters above sea level. This area is highly frequented by tourists. Tourism is the most important sector in the park and has the greatest potential to be a source of sustainable income. The basic concept is the utilization of solar panels in businesses operating in this area. The energy network challenges and climatic conditions are detailed. The performance of PV system installation, energy costs, and types of panels that can be installed with one axis or two axes are evaluated. By using cost data per unit for materials and different subsystems, it is possible to identify an individual panel or panel system that minimizes the cost of produced energy. The cost per kWh for different PV system technologies in the network ranges is 0.111 EUR/kWh. However, on the other hand, compensating for network interruptions, and low voltage problems in the main network, which affect businesses in this area, is a good investment.

Key words*: Photovoltaic systems; cost of electricity production; mountainous areas; single-axis panels; dual-axis panels.*

Përmbledhje

Shqipëria merr rreth ***2100-2700 orë*** *rreze diellore brenda vitit, kështu që ka potencial të madh për energji solare. Ndikimi i burimeve të rinovueshme të energjisë në rrjetin e përgjithshëm nuk është i vogël, me kapacitet që pritet të rritet ndjeshëm në vitet e ardhshme. Në këtë artikull është paraqitur problematikat që kanë implementi i sistemve fotovoltaike në zonën malore të Llogorasë. Kjo e fundit është një zonë turistike në të cilën operojnë disa biznese si restorante dhe hotele. Duke qënë një zonë malore ka probleme me rrjetin energjitikë. Studimi është bazuar në një program softuerik stimulues i cili llogarit koston e energjisë elektrike për sistemet PV në rrjet duke marrë parasysh koston e investimeve, blerjen e produktit, instalimin, mirëmbajtjen dhe financimin. Programi PVGIS hulumton mbi rrezatimin diellor, sistemin e performancës diellore, prodhimin e PV në bazë të të dhënave për orë, mujore dhe vjetore. Është llogaritur energjia elektrike që planifikohet të prodhohet nga instalimi i sistemeve fotovolatike me anë të paneleve 1kWp. Të dhënat janë ilustuar në tabelat përkatëse. Nga konkluzionet arrijmë në përfundim se është një investim i mirë për bizneset nëqoftëse instalojnë sisteme fotovoltaike.*

Fjalë kyçe*: Sisteme fotovoltaike; kostoja e prodhimit të energjisë elektrike; zonë malore; panele me një aks; panele me dy akse.*

Introduction

Renewable energy sources have become a necessary alternative to meet the increasing and essential demand for energy in the past century. Over the past decade, solar energy has emerged as one of the most promising sources to replace fossil fuels in meeting the world's future energy needs. The International Energy Agency (IEA) estimates that solar energy could provide up to 11% of the world's electricity production by 2050. However, this depends on a large number of countries implementing incentive schemes to promote solar energy production in the decades to come, if investment costs decrease.

Different countries have taken significant steps to promote the use of solar energy. In Germany, there is a large number of citizen cooperatives for renewable energy production. For example, the citizen cooperative "Bürgerenergie Rhein-Sieg" has installed solar panels on land previously used as a landfill. Members of this cooperative buy cooperative shares and participate in the profits from the electricity generated, which is fed into the public energy grid. However, sharing energy with others still faces obstacles in Germany, particularly due to public grid regulations. China is a leader in solar energy production, having installed a capacity of around 2017 GW of photovoltaic panels, making it the country with the largest capacity in the world. Investments in solar energy in China are high, and this is part of their strategy to reduce pollution impact and ensure sustainable energy resources.

The United States also boasts a significant solar energy capacity. They are among the first countries in the world to install photovoltaic panels. Additionally, many U.S. states have various policies and programs to encourage the use of solar energy, including subsidies and tax incentives for installing solar panels. Therefore, these countries have taken various measures to promote solar energy, including citizen cooperatives, large investments, and supportive policies.

Albania's policies for photovoltaic systems include a range of measures to encourage the use and development of solar energy. Some of the key policies and measures are:

Feed-in Tariff for Photovoltaic Energy: The government has established a feed-in tariff that guarantees a set price for the energy produced by photovoltaic systems. This is aimed at incentivizing investors and energy producers to invest in photovoltaic technology.

Subsidies and tax incentives: There have been and continue to be subsidy programs and tax incentives for the installation of photovoltaic systems. These include tax breaks and lower tariffs for the importation and installation of solar panels.

Legality and permits: There are clear regulations and procedures for licensing and installing photovoltaic systems. These include various permits and project approvals at local and national levels.

Various programs and projects: The government has undertaken various projects and programs to develop solar energy infrastructure and to improve awareness and capacity in this field.

Technical assistance and support: There has been technical support and assistance for local communities and businesses wishing to invest in solar energy, including training and technical advice.

These policies and measures have been important in increasing the use of solar energy in Albania and in improving environmental protection, contributing to the diversification of energy sources and reducing dependence on traditional sources.

Solar energy in Albania is widely available but not yet fully developed. The main source of energy in Albania comes from hydropower plants, but network problems have accumulated and losses exceed 20% of production. The development of winter tourism in the mountainous areas of Albania is one of the factors driving economic growth in the region, as tourism has increased in recent years.

In Llogara National Park, tourism is the most important sector and has the greatest potential to be a sustainable source of income. During the period January-August 2023, this park was visited by 110,087 tourists, of whom 15,674 were foreigners and 94,413 were locals. Along National Road 8, there are several restaurants, hotels, and a complex of wooden cabins. Specifically, there are 20 entities with restaurant activity, and 7 of them also have rooms. The number of rooms is 109.

Power outages in Llogara National Park are quite problematic, especially starting from October until the end of the spring season. This study suggests the application of small photovoltaic implants to reduce energy bills and the problem of energy shortages. The main aim is to utilize solar panels in businesses operating in this area. The Albanian Transmission System Operator (TSO) reported that the impact of renewable energy sources on the overall grid is not insignificant, with capacity expected to increase significantly in the coming years.

According to the TSO report, by the end of 2023, installed capacity is expected to reach 220 MW, nearly a 10-fold increase compared to the total capacity in 2022. Based on market demands, it is predicted that the connecting capacities of wind and photovoltaic plants to the transmission grid will reach over 220.4 MW by the end of 2023. In Albania, by the end of 2022 alone, 291 businesses were connected to the grid with small photovoltaic installations, under pressure from rising energy prices in the main grid energy market. There are many unexplored areas in Europe, especially in mountainous coordinates, for solar energy potential.

According to another study, it is estimated that at least 25% of electricity production could come from photovoltaics, and currently, this figure stands at 5% in Europe. Currently, the possibility of increasing the percentage of energy from PV is a combination of climatic conditions, investment costs, energy tariffs, appropriate legislation, and government incentives undertaken and supported. Photovoltaic systems, along with storage systems, can ease the grid, which is an ideal solution, especially for remote areas where grid penetration is difficult.

Photovoltaic systems are guaranteed by manufacturers, their lifespan is up to 25 years, and they are estimated to provide up to 30% more electricity for a dual system compared to a fixed PV system. On the other hand, the optimal angle of installation yields a greater total annual energy compared to other cases, but changing the angle in some months results in greater energy, which is different from the annual optimal angle.

Photovoltaic systems with a single axis and dual axes are two different types of solar installations. **Single-Axis Photovoltaic Systems:** These systems track the sun in only one direction (e.g., from east to west). They are simpler to install and manage. Their performance varies throughout the day and seasons because the panels track only one direction. They benefit more from changes in the sun's angle throughout the year. Economic feasibility is higher in these areas, especially in places with ample sunlight throughout the year.

Dual-Axis Photovoltaic Systems: These systems track the sun in both vertical and horizontal directions (up-down and east-west). This allows them to follow the sun at all times of day and throughout the season. Their performance is more consistent, but their installation and management are more costly. They benefit more from changes in both sun angle and light intensity. Economic feasibility may be lower due to the higher installation and maintenance costs of the system. In high-altitude areas, single-axis photovoltaic systems may be more suitable due to cost-effectiveness and performance.

In summary, the choice between single-axis and dual-axis photovoltaic systems depends on factors such as location, cost-effectiveness, and desired performance consistency. Single-axis systems are simpler and more cost-effective in regions with consistent sunlight, while dual-axis systems offer more consistent performance but at a higher initial investment and maintenance cost.

This study calculates the economic benefit regarding the cost of PV electricity per kWh. The comparison of configurations is developed for the same size of the selected system, 1 kWp. Similar studies have been conducted in other mountainous areas of Albania, specifically in the mountainous region of Theth. The potential for PV system production in the grid, global solar radiation on a plane in Theth National Park (Fixed Corner) (using the PVGIS tool), ranges from 57.12 kWh/m^2 to 206 kWh/m^2. Simulation results indicate that a dual-axis PV tracking system is the optimal choice for maximizing solar radiation output in PV deployment.

Study methods

There are several different simulation software programs available to conduct a detailed study of photovoltaic systems, which include design, production, and economic parameters. In this study was used the PVGIS program, the Geographic Information System supported by the European Commission and the Joint Research Centre (JRC). PVGIS is a simulation tool used in many studies, producing results on various aspects, and comparing ground and satellite measurements from the PVGIS database. In the study, the SARAH 2 database, provided values of hourly global horizontal irradiance (W/m^2), which are compared and validated with ground measurements from a selected group of sites from the Baseline Surface Radiation Network (BSRN).

The evaluation model in PVGIS is a two-component anisotropic model. It calculates the cost of electricity for PV systems in the grid. Parameters considered in the calculation include investment costs, including product purchase, installation, maintenance, and financing, compared with the system's lifespan, which is suggested to be up to 25 years in the latest systems. Various comparative studies on the accuracy of calculation and simulation data conclude that this tool is highly scientific. Data was obtained from geostationary satellites with coordinates of the Llogara area.

Results from PVGIS

In this study, we focused on grid-connected photovoltaic systems in the Llogara area, near the city of Vlorë, with geographic coordinates 40.210,19 580. Since the aim was the implementation of photovoltaic systems, specifically in businesses in this area, the PVGIS program investigates solar radiation, solar performance, and PV production based on data hourly, monthly, and yearly basis.

Latitude/Longitude:	40.210,19.580
Horizon	Calculated
Database used:	PVGIS-SARAH2
PV technology	Crystalline silicon

PV installed:	1 kWp
System loss:	14%

Table 1. Provided inputs in PVGIS

Slope angle:	**35 º**
Azimuth angle:	0^0
Yearly PV energy production:	1331,28 kWh
Yearly in-plane irradiation:	1683,39kWh/m^2
Year-to-year variability:	45.25 kWh
Angle of incidence:	-2,5 %
Spectral effects:	0,79%
Temperature and low irradiance [%]:	-6,43%
Total loss: [%]	-20.92%
PV electricity cost [per kWh]:	0,111 per kWh

Table 2. Fix-Angle PV

In table 1 and 2, the data from PVGIS are summarized. Specifically, the annual energy production has been calculated; the system size is 1 kWp as a unit for comparing results.

The corresponding temperature is 25°C, and system losses are assumed to be 14%. The electrical energy planned to be produced by the installed 1 kWp panel is shown in Table 2. For fixed-angle PV systems with a selected angle of 35 degrees, the annual production and annual irradiation are shown.

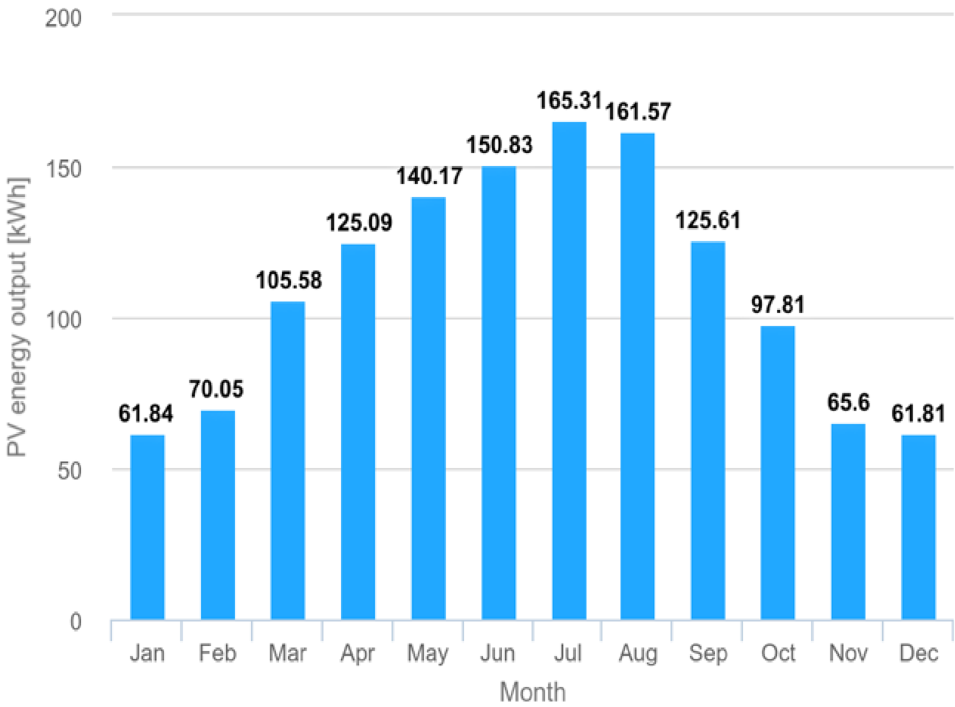

Figure 1.Monthly energy from fixed-angle PV system.

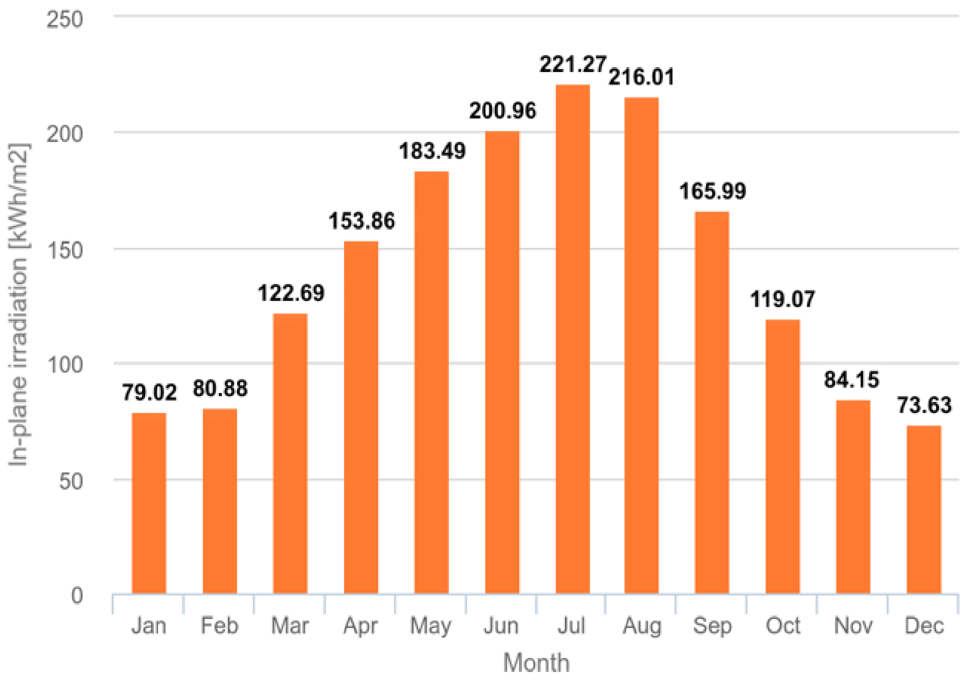

Figure 2. Monthly in plane irradiation for fixed-angl

The graph constructed with the energy data obtained for each month is presented in Figure 1. The winter season is the period with the lowest productivity in terms of energy production from the PV system. The season with the highest productivity is the summer season.

The values of electric energy production range from the nominal value of 61.8 kWh to the maximum value of 165.31 kWh (Fig. 1). The months of July and August, which have the highest sunlight radiation, have the highest energy production values from the PV system with a fixed angle. Meanwhile, the months with lower sunlight radiation, January and December, are the months that produce less electric energy with the PV system (Fig. 2).

Below is presented a table with the data on solar radiation energy and the monthly energy obtained from this PV system. Three different variables have been calculated (Tab.3).

- E_m: Average monthly electricity production from the defined system [kWh].
- H(i)_m: Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m²].
- SD_m: Standard deviation of the monthly electricity production due to year-to-year variation [kWh].

Month	E_m	SD_m	SD_m
January	61.8	72.3	11.7
February	61.8	72.3	11.7
March	61.8	72.3	11.7
April	61.8	72.3	11.7
May	61.8	72.3	11.7
June	61.8	72.3	11.7
August	61.8	72.3	11.7
September	61.8	72.3	11.7
October	61.8	72.3	11.7
November	61.8	72.3	11.7
December	61.8	72.3	11.7

Table 3. Monthly PV energy and solar irradiation

Conclusion

The Llogora area is a zone with solar potential considered sufficient for energy usage to exceed a minimum of 1683.39 kWh/m2 per year. The results are based on the PVGIS program and fixed-angle PV systems. The annual production of PV energy is estimated to be 1331.28 kWh per year. In mountainous areas, spectral effects are expected to be less pronounced, specifically in the study area, which is 0.79%.

From the calculations made, the summer season with the highest radiation has the highest values of electric energy production with fixed-angle PV systems compared to the winter season, but the annual balance exceeds the lower limit of the minimum radiation criterion. Considering all results from PVGIS, we believe it's a good investment for businesses in this area since the cost of energy from PV systems is lower than the cost of purchasing electric energy.

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