Electricity cost of solar photovoltaics, factors influencing the optimal functioning of the PV system. Case of study National Park of Theth, Albania

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Abstract— Energy from PV systems throughout Albania has started the last two years with a strong trend, especially after the government's incentives to support consumers and small businesses, especially in the tourism sector, since it is one of the key sectors for economic development. In this study, the situation for the application of on grid PV systems in the area of National Park of Theth, very attractive to all year tourisms, has been examined. The climate situation, and the various installations, on grid fixed and tracking system have been examined in detail. The performance of different PV installations is evaluated. Cost of electricity production is calculated as an indicator to evaluate the ratio between different systems, tracking system, vertical axis, inclined and two axes. The results show the best performance for two axis PV system. Difference in electricity cost eur/ (kWh) for PV on grid building integrated varies around 32% difference variation with slope angle, in higher altitude of selected location, cost of PV production is 18.1% higher compared to other potential solar areas, making it less attractive for large scale installed PV from investors. The cost in kWh for different technologies of PV systems on grid varies 0.061 eur/ kWh to 0.105 eur/ kWh, But on the other hand, compensating for the network switch, the low voltage problems of the main network, in the residential aspect, make it applicable for residential and small businesses, it is a fully justified investment.

Keywords—Photovoltaics systems; on grid PV systems; tracking system; vertical axis; inclined and two axes system; cost of electricity production

I. INTRODUCTION

The main source of energy in Albania comes from hydropower, but network problems are accumulated and losses exceed the value of 20% of production [1]. The development of winter tourism in Albania's mountainous areas, the part of the Alps, is one of the factors of economic growth in the areas, the tourism has increased in the past years. [2]. Power outages in Theth national park are very problematic, especially starting in October and till the end of spring season. In this study, is suggested the application of small photovoltaic implants in order to reduce the energy bill and the problem of lack of energy due to insulation of the area and as a cause of damaged network. The main goal is to present the climatic potential of this mountainous area with low average temperatures throughout the year, and evaluate the energy produced by photovoltaics. The Transmission System Operator of Albania (TSO) reported that the impact of renewable energy sources on the overall grid is not small, with capacity expected to increase significantly in the next years. According to the TSO document, in the end of 2023 the installed capacity is expected to reach 220 MW, an increase of almost 10 times compared to 2022 total capacity. Based on the market requirements, it is predicted that the connection capacities of wind and photovoltaic plants in the transmission network will reach by the end of 2023 more than 220.4 MW. In Albania only at the end of 2022, 291 businesses had connected to the network with photovoltaic small installations, under the pressure of the increase in the price of energy in the energy market from the main network [3].

There are many unexplored areas in Europe, especially in mountainous coordinates for potential of solar energy. A map for sustainability of solar power generation in Europe has been developed by comparing specific levelized cost of energy (LCOE) but with the conclusion that there are still unexplored areas, in terms of potential of radiation for PV system implementation within economic criteria [4]. According to another study, it is estimated that at least 25% of electricity production can come from photovoltaics, and currently this value in Europe stands at 5% [5]. 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. "Feed in tariffs" schemes for renewable energies should be widely implemented, and schemes where energy compensation is established by law. PV systems are specific suitable in countries when it combines government incentives, tariffs, initial investments and solar radiation. Photovoltaic systems together with storage systems can facilitate the network and this is an ideal solution especially for remote areas where network penetration is difficult. Photovoltaic systems are guaranteed by the manufacturers, their lifetime is up to 25 years [6, 7]. Is estimated up to 30% more electricity for double axis system compared to a fixed PV system. On the other hand, the optimal angle of the installation brings greater total annual energy compared to other cases, but the variation of the angle in some months results on greater energy, that is different from optimal yearly angle [8]. In general, many studies suggest areas where the solar potential is abundant, populated places close to the main grid [9]. The purpose of the study is to evaluate the performance of photovoltaic systems in the National Park in Albania, with the special climatic situation and on the other hand the unfavourable network energy conditions, to evaluate different types of installations and the change in cost per kWh for each selected type of photovoltaic systems. For different utility PV system is calculated the specific energy and cost for the selected location. Type of selected sun tracking systems PV in the study are chosen fixed system, vertical one and two axis system. The economic benefit in terms of PV electricity cost per kWh has been calculated. The comparison of configurations has been developed for the same size of selected system, 1 kWp. The total cost of the system in accordance with the study of market prices was set in an interval of minimum and maximum values including operation and maintenance costs.

II. Method of Study

A. PVGIS tool

The detailed study of photovoltaic systems in terms of design, production output, and economic parameters can be developed with different simulations software, or with simulation methods according to the appropriate models. Their detailed accuracy can be realized by comparison with the data of the installed PV system [10]. In order to evaluate the electricity and other parameters is used PVGIS tool, Geographical Information System supported from European Commission and Joint Research Centre (JRC). PVGIS tools is a simulation tool and many studies have been referred to, drawing results in different aspects, the comparison of terrestrial and satellite measurements from the database of PVGIS. In the study, the database of SARAH 2 was chosen, the hourly values for global horizontal (W/m2) are compared and validated with ground measurements from a set of select ground measurements from BSRN [Baseline Surface Radiation Network]. The estimation model in PVGIS is anisotropic of two components. PVGIS calculates the cost of electricity for on-grid PV systems. Parameters in calculations to be taken into account are the cost of investments including the purchase of the product, installation, maintenance and financing, the comparison is made with the lifetime of the system, in the last systems it is suggested from fabrication to 25 years. Different comparative studies for the accuracy of the calculation and simulation data conclude that this tool is very scientific [11], [12], [13], [14]. In this study on grid PV system are considered. The data are obtained from geostationary satellites – METEOSAT [15]. This data covers the measured period from 2005 to 2020. PVGIS 5 also provides the solar radiation data on optimally inclined surfaces using the model described in this article.

B. Input data

The calculations in this work have been performed for on-grid photovoltaic systems, in accordance with the study of demand/offer in the photovoltaic market in Albania, increasing installed power of such systems in the private residential sector, as well as small business. Off-grid systems are not included for the main reason of the increased cost of batteries and their reduced life cycle, increasing the total cost of the system. The parameters of the configuration system with PVGIS include hourly, monthly and annual solar radiation data, averaged values of a typical year for the sun and wind. The geography of the selected position can be analyzed by identifying the exact coordinates. PVGIS uses data from the PVGIS-SARAH2 database selected for this study. For calculations and simulations, several types of module production have been chosen, crystalline silicon, CIS, CdTe. Installed power of photovoltaics is 1kWp, system losses in the value of 14% as a default in the inputs. For mounting position of the PV, fixed system, free standing system, buildings integrated are selected in the study. Slope of PV module is the fixed angle from horizontal plane. As inputs for calculations are:

a. One-axis tracking sun system.

b. Two-axes with modules to degrees of freedom for the rotation.

The result from PVGIS gives yearly values of energy production, and their parameters from simulations.

C. Cost Calculation for the PV rezidential project.

Levelized cost of electricity (*LCOE*) or levelized cost of energy is a measure in financial economy to compare different sources of energy in terms energy production, as the total cost of all included system (fabrication, installation, oparation) per unit of total amount of the life time expentancy. It can compare different projects of the same technology or different systems sources, wind, solar, etc. Discount rate is a specific economic criteria in evolution yearly in the criteria of *LCOE* exact calculation and reflect the risk for each project. Discount Rate *r* is an important indicator in the evolution of the cost of the system; it indicates the profitability of the total investment. In the discount rate calculations it will be a constant parameter, in fact in reality it depends on capital, taxes etc., for the purpose of the study, this economic parameter was not detailed. In the calculations the total cost of the PV system, include cost of the total PV components for installation, and include the operation and maintenance cost. In this study, some economic parameters were taken into consideration in the calculation of the cost of photovoltaic production, but the parameters that have variability in time are not included, so we will refer to it as production cost in eur/kWh and not LCOE, to be correct with the results.

III. RESULTS

A. Grid connected PV system performance in Theth's National Park.

Since the purpose of the study is to enable the installation of on-grid systems in residences and small tourist businesses in the area, the part of battery storage systems has not been discussed, which is specific and requires a different treatment due to the increase in system costs. With storage and battery life of about 5 years. For which the cost of the system increases, the payback years, and thus the LCOE.

PVGIS tool is intended for researching on solar radiation, solar performance system, PV production on basis on hourly, monthly and yearly data. Different system mounting of photovoltaics can be analyzed in terms of radiation data, temperature, energy production, variability year to year, and realize simulations for different configurations systems. Specifically for different type on grid PV system is calculated specifically yearly energy produced; size of the system was 1kWp as unit for the comparisons of results. It is important to understand this unit correctly, as the power produced by PV under standard conditions; the corresponding temperature is 25C, system loss 14%. In the table 1 are summarized the input from PVGIS.

TABLE I. PROVIDED INPUTS IN PVGIS

Latitude/Longitude	42.389,19.782
Horizon	Calculated
Database used	PVGIS-SARAH2
PV technology	Crystalline silicon/ CIS
PV installed	1kWp
System loss	14%

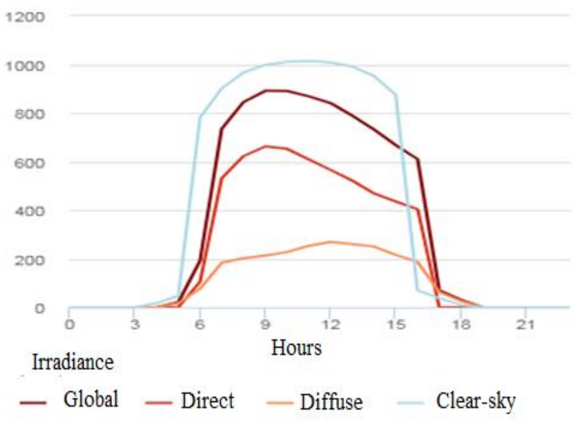

Fig. 1. Daily average irradiance [kW/m^{2}] on fixed plane with slope 35° and azimuth 0°

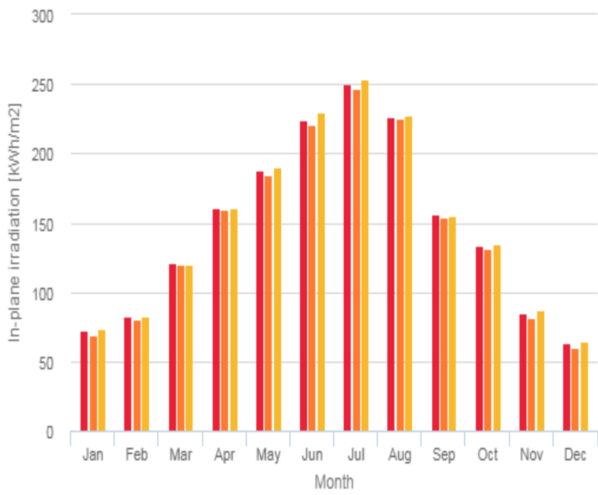

Fig. 2. In plane irradiation for three types, vertical axis, inclined axis, two axis

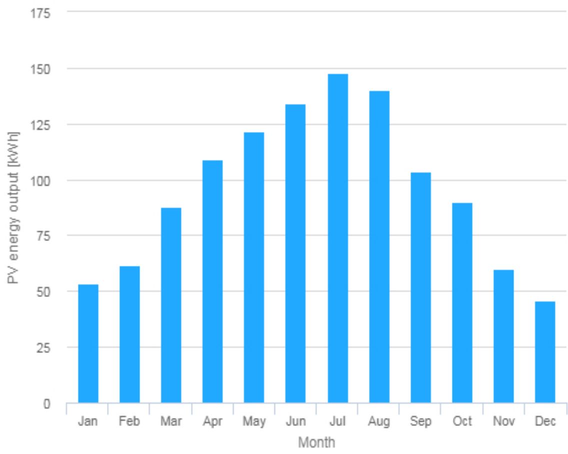

Fig. 3. Monthly energy output, on grid PV

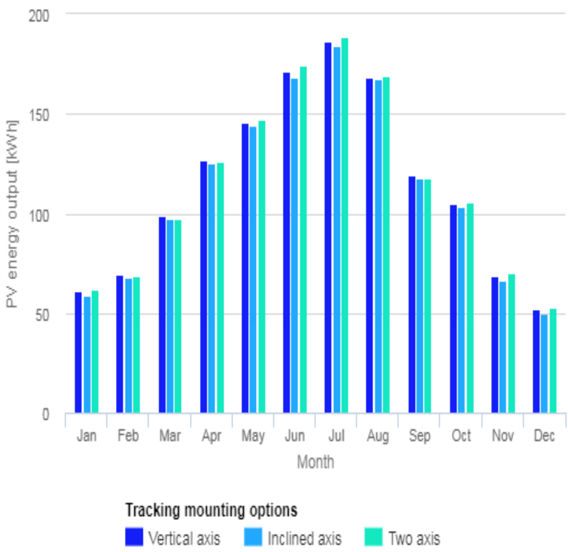

Fig. 4. PV output in vertical axis, inclined axis, two axis system

TABLE II. RESULTS OF SIMULATIONS, PERFORMANCE OF THE TRACKING PV SYSTEM

Type of tracking system	Vertical Axis, Si	Inclined Axis, Si	Two Axis, Si	Vertical Axis, CIS	Inclined Axis CIS	Two Axis CIS	Vertical Axis, CdTe	Incline d Axis CdTe	Two Axis CdTe
Slope Angle (^{0}) (opt)	35	45	---	50	35	---	45	35	---
Yearly PV energy production [kWh]:	1373.11	1349.53	1380.25	1534.9	1528.53	1563.12	1398.43	1376.11	1409.49
Yearly in-plane irradiation [kWh/m²]:	1762.83	1732.7	1777.1	1952.32	1944.2	1993.88	1762.86	1732.7	1777.1
Year-to-year variability [kWh]:	73.9	73.2	76.0	83.6	83.2	85.9	78.4	77.6	80.4
Angle of incidence [%],	-1.75	-1.73	-1.66	-1.65	-1.66	-1.59	-1.74	-1.73	-1.66
Spectral effects [%]:	0.96	0.95	0.96	----	----	----	1.51	1.51	1.51
Temp. and low irradiance [%]:	-8.69	-8.71	-9.03	-7.05	-7.07	-7.37	-7.52	-7.43	-7.61
Total Loss [%]	-22.11	-22.11	-22.33	-21.38	-21.38	-21.6	-20.67	-20.58	-20.69

TABLE III. SIMULATION OUTPUT FROM FIX-ANGLE PV SYSTEM (BUILDING INTEGRATED)

Slope Angle	**10^o**	**20^o**	**30^0**	**40^o**	**50^o**	**60^o**	**70^o**	**80^o**	**90^o**
Azimuth Angle	-17(opt)	-17(opt)	-17(opt)	-17(opt)	-17 (opt)	-17(opt)	-17(opt)	-17 (opt)	-17(opt)
Yearly energy production [kWh]	1093.81	1203.51	1154.31	1217.99	1186.93	1130.57	1048.93	942.79	813.19
Yearly in-plane irradiation [kWh/m²]	1447.5	1562.64	1535.22	1584.06	1542.71	1466	1356.47	1218.68	1056
Year-to-year variability [kWh]	49.69	58.08	56.69	63.27	63.71	62.41	59.56	55.15	49.34
Angle of incidence [%],	-2.65	-2.75	-2.37	-2.54	-2.61	-2.78	-3.12	-3.78	-4.88
Spectral effects [%]	0.92	0.95	0.98	1.01	1.04	1.07	1.1	1.14	1.19
Temp. and low irradiance [%]	-10.57	-8.78	-11.32	-9.18	-9.08	-8.74	-8.21	-7.57	-6.97
Total Loss [%]	-24.43	-22.98	-24.81	-23.11	-23.06	-22.88	-22.68	-22.64	-22.99
PV electricity (kWh) Min cost Instalation	0.066-0.082	0.063-0.079	0.064-0.078	0.065-0.078	0.066-0.081	0.070-0.085	0.075-0.091	0.084-0.102	0.098-0.118
PV electricity (kWh) Max cost Instalation	0.097-0.116	0.093-0.112	0.092-0.110	0.092-0.111	0.095-0.114	0.100-0.120	0.108-0.129	0.120-0.144	0.139-0.167

From the results for the three PV technologies, crystalline silicon, CIS, CdTe, the highest performance is for CIS modules, and for two axes tracking system. The market price of this technology is above the average price, so the cost of production of PV system also increases.

Solar potential is considered sufficient for energy use to be greater than a minimum of 1100kWh · m^{-2} per year. The lowest radiation values correspond in the winter months, but the annual balance exceeds the lower limit of the minimum radiation criterion.

TABLE IV. SIMULATION OUTPUT FROM FIX-ANGLE PV SYSTEM (FREE STANDING)

Slope Angle	10°	20°	30°	40°	50°	60°	70°	80°	90°
Azimuth Angle	-15(opt)	-15(opt)	-15(opt)	-15(opt)	-15 (opt)	-15(opt)	-15(opt)	-15 (opt)	-17(opt)
Yearly energy production [kWh]	1137.08	1184.29	1204.76	1198.46	1165.59	1107.04	1023.13	914.82	783.96
Yearly in-plane irradiation [kWh/m²]	1447.5	1508.04	1535.22	1527.77	1485.52	1409.4	1302.75	1167.56	1008.91
Year-to-year variability [kWh]	52.49	57.03	60.16	61.80	61.92	60.47	57.42	52,84	46.94
Angle of incidence [%],	-2.65	-2.46	-2.37	-2.36	-2.44	-2.6	-2.99	-3.64	-4.74
Spectral effects [%]	0.92	0.95	0.98	1.00	1.03	1.06	1.09	1.13	1.19
Temp. and low irradiance [%]	-7.03	-7.26	-7.44	-7.51	-7.43	-7.21	-6.87	-6.51	-6.27
Total Loss [%]	-21.45	-21.47	-21.53	-21.55	1.03	-21.45	-21.46	-21.65	-22.3
PV electricity (kWh) Min	0.065-0.079	0.063-0.076	0.061-0.075	0.062-0.075	0.064-0.077	0.067-0.081	0.072-0.088	0.081-0.098	0.094-0.115
PV electricity (kWh) Max	0.093-0.112	0.089-0.107	0.088-0.105	0.088-0.106	0.091-0.109	0.096-0.115	0.103-0.124	0.116-0.139	0.116-0.139

TABLE V. FIX-ANGLE, (BUILDING INEGRATED) OPTIMAL OPTION, THETH

Slope Angle	**32° (*opt*)**
Azimuth Angle	-17 (opt)
Yearly PV energy production [kWh]:	1155
Yearly in-plane irradiation [kWh/m²]:	1536.63
Year-to-year variability [kWh]:	57.19
Angle of incidence [%],	-2.36
Spectral effects [%]:	0.98
Temp. and low irradiance [%]:	-11.36
Total Loss [%]	-23.13
PV electricity (kWh) Min	0.064
PV electricity (kWh) Max	0.110

TABLE VI. FIX-ANGLE PV SYSTEM (FREE STANDING) OPTIMAL OPTION, THETH

Slope Angle	**32° (*opt*)**
Azimuth Angle	-15 (opt)
Yearly PV energy production [kWh]:	1205.79
Yearly in-plane irradiation [kWh/m²]:	1536.74
Year-to-year variability [kWh]:	60.70
Angle of incidence [%],	-2.36
Spectral effects [%]:	0.98
Temp. and low irradiance [%]:	-7.47
Total Loss [%]	-21.54
PV electricity (kWh) Min	0.061
PV electricity (kWh) Max	0.105

TABLE VII. FIX-ANGLE PV SISTEM (BUILDING INEGRATED) OPTIMAL OPTION, FIER.

Slope Angle	**35° (*opt*)**
Azimuth Angle	0° (opt)
Yearly PV energy production [kWh]:	1417.56
Yearly in-plane irradiation [kWh/m²]:	1944.11
Year-to-year variability [kWh]:	54.74
Angle of incidence [%],	-2.65
Spectral effects [%]:	0.82
Temp. and low irradiance [%]:	-13.61
Total Loss [%]	-27.08
PV electricity (kWh) Min	0.060
PV electricity (kWh) Max	0.090

TABLE VIII. FIX-ANGLE PV SYSTEM (FREE STANDING) FIER.

Slope Angle	**35° (*opt*)**
Azimuth Angle	0° (opt)
Yearly PV energy production [kWh]:	1480.67
Yearly in-plane irradiation [kWh/m²]:	1944.11
Year-to-year variability [kWh]:	58.29
Angle of incidence [%],	-2.65
Spectral effects [%]:	0.82
Temp. and low irradiance [%]:	-9.77
Total Loss [%]	-23.84
PV electricity (kWh) Min	0.057
PV electricity (kWh) Max	0.086

Comparison has been made, with the same situation and input of values for the district of Fier, where the solar potential in this area has optimal values.

From the results, yearly PV energy production in Fier of 1944.11kWh for the PV system (free standing), 20.96% more than the situation in Theth. Photovoltaic energy production is 18.53% more in Fier for the building integrated system and 18.7% more. Cost of PV is 18.1% higher for the mountainous area of Theth, this is estimated for the maximum cost of the initial investment according to today's market conditions in Albania.

IV. CONCLUSION

According to the presented results, the output production potential of on grid PV systems, global solar in plane irradiation In Theth National Park (fixed Angle) (PVGIS tool) varies from 57.12kWh/m2 - 206kWh/m2 compared with Fier District (optimal solar potential in Albania) 101.07kWh/m2 - 226.38kWh/m2 varies from 45.7kWh-154.44kWh (December-July) for Theth National Park, compared to Fier District 82.89 Wh-163.62kWh. PV electricity cost compared between two different climatic solar potential is 18.42% higher than in Theth location. From the simulation it results that two axes tracking PV is the best option in extracting the maximum solar radiation as PV output. As expected, spectral effects are less sensitive in mountainous areas, as well as losses from other system effects, but slightly different, 23.47% in Fier District, 22.33% in Theth. The best interval; for cost of electricity varies 0.061 eur/kWh to 0.105 eur/Kwh, in Theth, these values depend on the cost of technology, installation.

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