Off-grid hybrid PV configuration's role to supply internet access points antenna in remote areas. Case study: "Ostren i vogël - trebisht" villages, Bulqiza district, Albania

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Abstract: *As a result of the global pandemic situation COVID-19 many rural areas in Albania are suffering and will more especially the lack of internet services have engaged in development and cultivation of knowledge in the education sector, responsible in building a safer and more caring community. Even more Albania is indexed as a European country that still continue to experience the lowest rate user-penetration of internet especially in remotes areas. Despite its widespread use in urban areas, a very significant portion of the rural population still isn't connected to the internet. Immigration of the population from rural toward more urbanized areas and lack of reliable electricity supply and infrastructure are the main problems that hinder investors to offer internet services in remote regions. The performance analysis of a solar PV power plant is important aspect as far as concern with technology and economic analysis. Due to seasonal variation standalone system can't provide a continuous power supply. Therefore, in recent years PV energy systems that combine solar energy and other conventional conversion units are becoming promising more popular, efficient to fulfill load demand and representing a cost-effective technology.*

KEYWORDS: PV, INTERNET ACCESS POINTS, WIRELESS ACCESS POINTS, RETSCREEN EXPERT

1. Introduction

Due to the spread of the Covid-19 pandemic situation, many areas in our country experienced social isolation and also "computer isolation", complicating the process of on-line teaching in the education sector especially in many remote areas of our country. It is reasonable that internet access reduces social and economic inequalities, generating more jobs and providing a competitive advantage to international businesses. The increase of internet coverage and related services in all countries of the world is one of the key points of economic development of societies. In Albania, as it has happened in many countries around the world, the government authorizes according to a well-planned strategy private investor to provide broadband internet access throughout the country. The need for internet signal is not only in urban areas but also in remotes areas with a significant distance from the urban access points then the wireless network technology is inevitable. This article presents a concrete Hybrid - PV off-grid system planning to be developed by an Albanian company to provide internet signal in Bulqiza District, part of Northern Albania. One of the challenges of the local internet company was how to provide energy to the locations where the Internet Access Point Antennas would be placed as there were key points for installation, but it was impossible to provide electricity access from the local distribution network. In the post-communist period, though, energy exports fell, and internally Albania suffered from inadequate electrical service especially to large areas of the country. At present, 21st century, chronic energy shortages in Albania are evidenced and totally unaccomplished to requirements for a reliable energy system. In face of the investments executed and others in progress again the problem remains unresolved. Another critical problem is the level of technical and non-technical losses which still are introducing imaginable values leading to very low standards of energy system services and performance.

In the other hand the depletion of fossil fuel and the negative effect on the environment as well as the potential techno-economic merits of "*hybrid combinations*" identified as a good solution moving towards reliable and more feasible energy systems based on renewables [1]. As the need for clean, sustainable energy increases, and renewable technologies get ever more advanced, more projects had been developed in greater sizes and complexities, including on-grid and off-grid solutions based on renewables. A renewable energy project in remotes areas is performed in a real case study [2].

Firstly, a quick and inexpensive initial examination is performed on the pre-feasibility analysis which will determine if the proposed project presents a good chance of satisfying the proponent's requirements for profitability or cost-effectiveness and therefore merits the more serious investment of time and resources required by a feasibility analysis. Photovoltaics (PV), also called solar cells, are electronic devices that convert sunlight directly into electricity. The modern solar cell is likely an image most people would recognize – they are in the panels installed on houses and in calculators. They were invented in 1954 at Bell Telephone Laboratories in the United States. Solar PV installations can be combined to provide electricity on a commercial scale, or arranged in smaller configurations for mini-grids or personal use. Using solar PV to power mini-grids is an excellent way to bring electricity access to people who do not live near power transmission lines, particularly in developing countries with excellent solar energy resources.

The cost of manufacturing solar modules has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form of electricity. As a result, PV is one of the fastest-growing renewable energy technologies, and is ready to play a major role in the process of electricity transition. Solar panels have a lifespan of roughly 30 years, and come in variety of shades depending on the type of material used in manufacturing.

1.1 Site background and weather information.

The territory of Albania lies in the western part of the Balkan Peninsula, with a long coastline, Adriatic and Ionian Sea running along the western part of it. It is located at the latitude of 39^{o}38'-42^{o}38' and longitude of 19^{o}16'-21^{o}04'. Fortunate to this geographical position, Albania belongs to the Mediterranean climate zone with hot and dry summers, with long sunny days from an average of 240-260 to a maximum of 280-300 days a year and mild winters with abundant rainfall. The Hydro-Meteorological Institute has declared weather data based on the climatological-statistical treatment of actinometrical and heliographic information for the assessment of the territorial distribution of solar radiation (see graph in figure 3 and table 1). In our case study the installation place will be located in Bulqiza district between the villages of *"Ostren i Vogël"* and *"Trebisht"* (41°25'37.1"N and 20°30'29.6"E) as it is shown in the map in figure 1. The area has an altitude of 847m above sea level and the measured average annual air temperature results 11.4^{o}C. Atmospheric mean pressure value and wind velocity measured at 10m altitude results 92.7kPa and 2.7ms^{-1}. This location is selected as a strategic point for full signal coverage of both villages in the area.

The main problem is tied to the distance of electricity supply from the national distribution grid. The energy that would be needed to power the equipment was the 24V, DC current.

Figure 1: *The location Instalation's point of the "Internet Access Point Antenna", covering both villages "Ostren i Vogël" and "Trebisht"*

So, at this point it was achieved to provide power from the integrated photovoltaic panel but the other challenge was that the panel provides power only on sunny days and not during night hours. To resolve this weak point of PV systems, the storage energy system (ESS) composed of a set of batteries in parallel will be used to provide energy to the access point antenna in optimal conditions. The batteries should be charged to a certain size managed and scheduled by integrating a controller in the PV - Genset - Battery system.

1.2 Renewable Energy Resources, Global RES Policies and Albanian RES initiative

Renewable energy sources, including solar, wind, hydro, biofuels and other future renewable sources are at the centre of the energy transition towards a less carbon-intensive and more sustainable energy system [3]. Solar energy has played a significant role in the last decade in the process of energy transition in many countries worldwide. Solar photovoltaic has attracted massive amount in the global power sector investment over the last couple years, especially in EU-28 countries. To reduce import of electricity, improve its security of supply and to attain the Paris Agreement, the responsible ministry and its sub-ordinate institutions has approved the ***"The National Energy Strategy 2018-2030"***, consisting on 6 possible scenarios of energy's transition process toward sustainable and reliable energy by shifting Albania to decentralized renewable energy market, and energy efficiency. According to this strategy, the share of RES is intended to reach a target of 42% of the total energy consumption in 2030 as actually this contribution is approximately 30%. The first goal can be achieved by large scale integration of RES capacities, especially wind and PV generation capacities [4] The RES share in global electricity generation reached almost 27% in 2019, renewable power as a whole still needs to expand significantly to meet the SDS share of almost half of generation by 2030. This requires the rate of annual capacity additions to accelerate [3]. The second goal, compared to the baseline scenario in 2016, should be fully in line with EU objectives, its commitment is to reach a reduction of 11.5% of CO_2 emissions by the end of 2030. Under the pressure of an increased awareness related to environmental issues, technological progress and the liberalization of the energy market, in the last 15 years has been rapid progress in the development of wind and solar exploitation technologies in Albania [4]. Nevertheless, according to [5] the total annual energy consumption in Albania is 24TWh/year, meanwhile electricity occupies only 31% of its total, which is provided from domestic hydro sources, 60% (389.15ktoe) and the rest is imported in the regional energy market (250.66 ktoe) (ERE, 2018). The leading sector in electricity consumption is the residential sector which occupies around 55% of the total national electricity consumption and the rest belongs to the industrial, services and other sector of the economy. Globally, RES, especially solar PV generation increased 22% (+131TWh) in 2019 and makes the second-largest absolute generation growth of all RES technologies, slightly behind wind and ahead of hydropower. Despite decelerating growth due to recent policy changes and uncertainties in China (the largest PV market), 2019 was identified as the year of record growth of total PV capacities. By the end of 2019, over 580 GW of solar PV plants had been installed, worldwide. About 98 GW of newly installed capacities of PV plants were commissioned in 2019 [6]. As competitiveness continues to improve, solar PV is still on track to reach the levels envisioned in the SDS, which will require an average annual growth of 15% in the way to 2030 [7]. Considerable interest in RES and significant increases in cost of imported oil and very frequent services of related technologies have compelled various countries to search for low-cost energy sources. This must be met by improved technologies hybrid combinations such as wind turbines, PV and synergies between different energy systems. Photovoltaics (PV) is a key technology option for a decarbonised and sustainable power sector and of course limiting the global average temperature rise to 1.5^{o}C to achieve carbon neutrality by 2050 [8]. Most of those options rely on renewable necessarily supported from energy storage systems (ESS) [9]. The electricity sector in our country remains the brightest spot for RES with the strong growth of solar photovoltaic's and wind energy in recent years, already a significant contribution comes from hydropower plants. Electricity accounts for only a fifth of global energy consumption, and the role of RES in the transportation and heating sectors remains critical to the energy transition [3]. Despite significant steps forward in some African's countries such as Kenya, Ethiopia and Rwanda are evaluating off-grid PV model as a fast and feasible solution to supply more than 600 million residents suffering access to electricity in sub-Saharan Africa [10].

2.0 PV electricity generation: Off - Grid applicability

Solar PV offers better benefits and reliable solutions for consumers in rural areas who do not have access to the electricity grid [11], [12]. Another study [13] has shown that the economic benefit is assessed based on the LCOE which represents a good starting point to compare benefits and competitiveness of different technologies**.** In the work developed by [14] PV systems are a cost-effective option in small off-grid applications, providing power, to rural homes in developing countries, especially to provide power to remote telecommunications and IoT systems worldwide. The studies have demonstrated that a solar PV module combined with diesel engine (hybrid) has relatively lower LCOE than a pure diesel generator-only. The IEA estimates that to achieve the goal of universal electricity access, 70% of the rural areas that currently lack electricity will need to be connected using mini grid or off-grid PV concept. Photovoltaic (PV) system is a combination of photovoltaic module, electric power converters, and storage devices. PV systems are composed of photovoltaic cells, usually a thin wafer or strip of semiconductor material, that generates a small quantity of current when sunlight strikes them. These power systems are relatively simple, modular, and highly reliable due to the lack of moving parts. In our work the PV array is combined with fossil fuel-driven engines (Genset) as it is shown in figure 2.

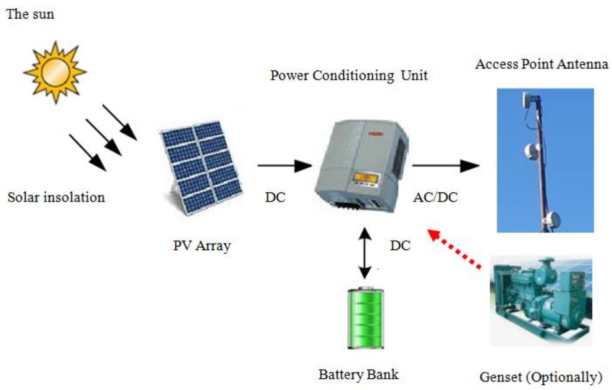

Figure 2: *The proposed schematic configuration of a typical hybrid off-grid PV system. Three (3) Access Point Antenna installed in the site.*

Off-grid applications include both stand-alone systems, and hybrid systems, which are similar to stand-alone systems but also include a fossil fuel generator (Genset) to meet some of the load requirements and provide higher reliability, as shown in Figure 2. The most significant share of the total capital cost is related to the expenses of the storage energy system (EES), which makes one of the most significant components in LCOE evaluation. According to [14],[15],[16] battery cost is predicted to be reduced to more than 60% by 2030 [9]. Consumers using solar PV technology are in the spotlight of some additional benefit from reduced externalities cost caused by greenhouse gas emissions from diesel and other fossil fuel powered generators [13] but this issue is well explained in our next scientific paper.
Solar energy is one of the greatest attractions among the renewable energy resources used for electrification. Photovoltaic systems can be installed at any place where sufficient energy potentials are available. To quantify the potential value of technological advances to the photovoltaics sector [17], examines the impact of changes to key PV module and system parameters on the levelized cost of energy (LCOE).

3.0 Energy model selection

PV projects so far have been easily applicable for on-grid level including both central-grid and isolated-grid PV systems. In this work the off-grid applicability of the PV project considering stand-alone (PV-battery) and hybrid (PV-Battery-Genset) systems is investigated (see figure 2). Thus, an accurate methodology comprehending in-depth analysis of the benefits must be applied and always required. In fact, actually, there are several models available for conducting a technical and financial viability analysis of potential energy projects. RETScreen Expert a clean-energy awareness, decision-support and capacity-building tool [18] is chosen. The core of the tool consists of standardized analysis that can be used to evaluate the energy production, life-cycle costs and GHG emission reductions for various types of renewable energy technologies (RETs). RETScreen Expert uses a computerized system with integrated mathematical algorithms and top to bottom approach. RETScreen Expert energy tool requires less detailed information and less computational power. For instance, other models like EnergyPLAN, use an hourly distribution over a yearly period producing 8784 individual values, whereas RETScreen Expert uses the monthly average GSR levels with only 12 values (refer figure 3). A comparison between RETScreen Expert tool and more in-depth models using hourly values showed that they produce very narrower yearly results, less than 5% differences are evidenced [3], [19]. The RETScreen energy tool is still in a continuous improvements process to subjugate the barriers to clean energy technology implementation especially at the preliminary feasibility stage.
By selecting the site location on the map, RETScreen Expert model automatically generates data and information on several important climate indicators. PV plant location is strongly influenced by many factors as the spreading waveform and strength of the internet signal is deterministic. First is analyzed the capacity and structure of 5 (see table 2) various PV technologies and then is selected the most suitable module, as matching the recommendations and global trends. This selection is made taking into account both technical and economic context of various PV technology cell, influenced from solar radiation potential in the area. Methodology 2 to actualize the techno-economic analysis is chosen [3.]. Firstly, it is required to set into the model the values of the respective solar potential in the area which may be represented by the monthly average values (figure 3).

3.1 Solar Power Potential at the proposed site location

The initial step of the plant design is to evaluate whether the site is adequate or not for fulfilling the system's energy demand throughout the year. Designing the PV plant starts with the evaluation of some parameters that are considered important in recent years to use solar for power generation. Based on [20] and its Earth Science research program has long supported satellite systems providing important weather data which can easily accessed into RETScreen Expert energy model. These data include long-term climatologically averaged estimates of meteorological quantities and surface solar energy fluxes.
The variation of the average daily solar radiation referring 2018-2019 for the proposed installation place is presented in figure 3.

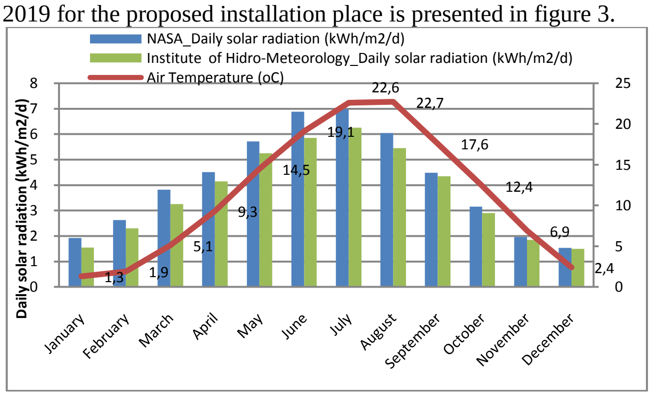

Figure 3: *Average daily solar radiation (kWh/m2/d) measured at proposed site.*

The average daily solar radiation (kWh/m^2/d) and mean air temperature in the graph in figure 3 is presented. The highest values are observed during the summer season of the year, while the lowest values fall in the winter months. Respectively, the highest solar radiation value of 6.98 kWh/m^2/d is attained in July, while the lowest value 1.54 kWh/m^2/d hits in December. The annual mean solar radiation and temperature values offered by Albanian Institute of Hydro-Meteorology for the chosen location, Bulqiza district, is defined by an average solar radiation of 3.72 kWh/m²/d resulting 11% lower than that obtained by the model.

Table 1: *The site-specific solar energy data. Bulqiza district. [Solar database and PV software©2019 Solargis]*

Specific photovoltaic power output	*PVOUT specific*	*1357*	*kWh/kWp*
Direct normal irradiation	DNI	1502	kWh/m^2
Global horizontal irradiation	GHI	1503	kWh/m^2
Diffuse horizontal irradiation	DIF	616	kWh/m^2
Global titled irradiation at optimum angle	GTI opta	1728	kWh/m^2
Optimum tilt of PV modules	OPTA	34/180	^{o}
Air temperature	TEMP	11.3	^{o}C
Terrain Elevation	ELE	847	M

From Global Solar Atlas, energy planers can generate suitable site information for preliminary studies in EU-28 countries [21], as they consider default values for many factors that are important for a design of a photovoltaic system. For more professional and detailed estimation it is used RETScreen Expert tool that allow configuration of the proposed RETs projects using more detailed solar and weather data as primary inputs to the simulation (figure 4).

3.2 Basics of Solar Energy Theory

Before entering into the details of the PV model, it will be useful to review briefly some basic concepts of solar energy engineering. Many of the variables derived in this section will be used in several parts of the model. For the most part, the equations in this section come from a standard textbook on the subject, Solar Engineering of Thermal Processes, by Duffie and Beckman (1991), to which the researchers can address various technical aspects.

3.2.1 Declination

The declination is the angular position of the sun at solar noon, with respect to the plane of the equator. Its value in degrees is given by Cooper's equation:

$$\delta = 23.45 \sin\left(2\pi \frac{284+n}{365}\right) \quad (1)$$

where ***n*** is the day of year (i.e. n=1 for January 1, n=32 for February 1, etc.). Declination varies between -23.45° on December 21 and +23.45° on June 21.

3.2.2 Solar hour angle and sunset hour angle

The solar hour angle is the angular displacement of the sun east or west of the local meridian; morning negative, afternoon positive. The solar hour angle is equal to zero at solar noon and varies by 15 degrees per hour from solar noon. The sunset hour angle ω_s is the solar hour angle corresponding to the time when the sun sets and given by equation 2:

$$\omega_s = -\tan\psi \tan\delta \quad (2)$$

ψ represents the latitude of the site specified by the user.

3.2.3 Extraterrestrial radiation and clearness index

Solar radiation outside the earth's atmosphere is called extraterrestrial radiation. Daily extraterrestrial radiation on a horizontal surface, H_0, can be computed for day ***n*** from the following equation:

$$H_0 = 86400 \frac{G_{sc}}{\pi}\left(1 + 0.33\cos(2\pi \frac{n}{365})\right) \quad (3)$$

$$(\cos\psi \cos\delta \sin\omega_s + \omega_s \sin\psi \sin\delta)$$

where G_{sc} is the solar constant equal to 1,367 W/m2, and all other variables have the same meaning as explained in equation 1 and 2. Before reaching the surface of the earth, radiation from the sun is attenuated by the atmosphere and the clouds. The ratio of solar radiation at the surface of the earth to extraterrestrial radiation is called the clearness index, defined in equation 4:

$$\overline{K}_T = \frac{\overline{H}}{\overline{H}_0} \quad (4)$$

where $\overline{H}$ is the monthly average daily solar radiation on a horizontal surface and $\overline{H}_0$ is the monthly average extraterrestrial daily solar radiation on a horizontal surface. $\overline{K}_T$ values depend on the location and the time of year considered; they are usually between 0.3 (for very overcast climates) and 0.8 (for very sunny locations).

3.2.8 Calculation of average efficiency

The array is characterized by its average efficiency, η_p, which is a function of average module temperature Ta_c:

$$\eta_p = \eta_r \left[1 - \beta_p (T_c - T_r\right] \quad (14)$$

where η_r is the PV module efficiency at reference temperature T_r(=25°C), and β_p is the temperature coefficient for module efficiency. T_c is related to the mean monthly ambient temperature T_a through Evans' formula (Evans, 1981):

$$\left[T_c - T_a\right] = (219 + 832\overline{K}_t)\frac{NOCT - 20}{800} \quad (15)$$

where NOCT is the Nominal Operating Cell Temperature and K_t the monthly clearness index. η_r, NOCT and β_p depend on the type of PV module considered. Such values can be manually entered into the model, but for "standard" technologies, assumed values are given in Table 2.

Table 2: *PV module characteristics for standard Technologies.*

PV module type	η_r *(%)*	*NOCT (°C)*	β_p *(%/°C)*
Mono - Si	13.0	45	0.4
Poly - Si	11.0	45	0.4
a-Si	5.0	50	0.11
CdTe	7.0	46	0.24
CIS	7.5	47	0.46

The equation above is valid when the array's tilt is optimal (i.e. equal to the latitude minus the declination). If the angle differs from the optimum the right side of equation (15) has to be multiplied by a correction factor C_f defined by:

$$C_f = 1 - 1.17 \times 10^{-4} (s_m - s)^2 \quad (16)$$

where s_M is the optimum tilt angle and **s** is the actual tilt angle, both expressed in degrees.

3.2.10 Off-Grid Model

Off-grid renewable power can come from a variety of sources, ranging from large isolated power grids to solar lights and solar home systems. In addition to households, off-grid renewables provide power for water pumping, street lighting, telecommunications towers, rural schools and clinics, as well as for remote commercial and industrial facilities and other uses [22].

The off-grid model represents stand-alone systems with a battery backup, with or without an additional genset. The conceptual framework of the model is shown in Figure 4. Energy from the PV array is either used directly by the load, or goes through the battery before being delivered to the load. The remainder of the load is provided by the genset if there is one, that is, stand-alone and hybrid systems differ only by the presence of a genset that supplies the part of the load not met directly or indirectly by photovoltaics.

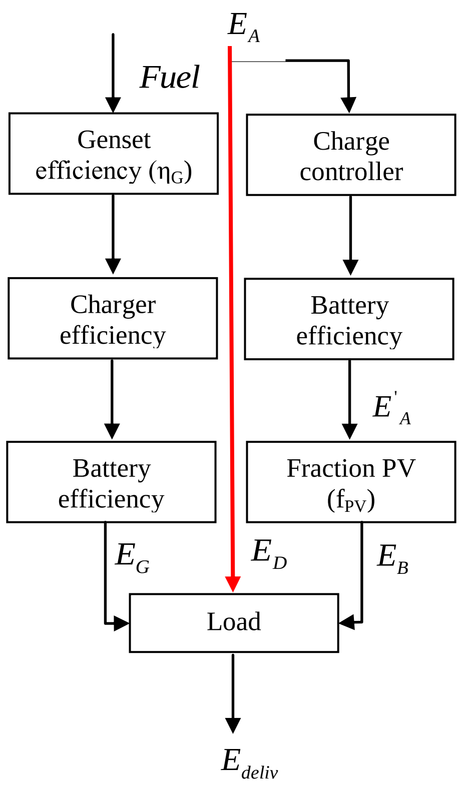

Figure 4: *Flowchart for PV Off-Grid Model.*

3.2.11 Load calculation

The user specifies the total DC demand, D_{DC}, and the total AC demand, D_{AC} (both are expressed in kWh/d). AC energy demand is converted to a DC equivalent by dividing its value by the inverter efficiency. Hence the total equivalent DC equivalent $D_{DC,equ}$ is:

$$D_{DC,equ} = D_{DC} + \frac{D_{AC}}{\eta_{inv}} \quad (20)$$

where η_{inv} is the efficiency of the inverter which in our case study is assumed 0.98.

The final result of this calculation is a division of the DC equivalent electrical demand in three elements (eq.21):

$$D_{DC,equ} = D_{matched} + D_{continuous} + D_{battery} \quad (21)$$

where:

$\boldsymbol{D}_{matched}$ is the part of the demand that is met directly by the PV modules whenever there is enough energy produced; $\boldsymbol{D}_{continuous}$ is the part of the demand that is constant throughout the day; and $\boldsymbol{D}_{battery}$ is the part of the demand that will be met primarily by the battery.

Note that $D_{continuous}$ will be met either directly by the PV modules (during the day when there is enough sunshine) or through the battery (at night, or when there is not enough sunshine). The critical PV absorption level P_{crit}, defined as the load corresponding to the constant energy demand:

$$P_{crit} = \frac{D_{continuous}}{24} \quad (22)$$

where $D_{continuous}$ is expressed in Wh and P_{crit} is expressed in W.

3.212 Energy breakdown

The energy delivered directly to the continuous load is given in equation 23:

$$E_{continuous} = (1-\Phi)\,E_A \quad (23)$$

where E_A is the energy available from the array; and the energy delivered to the matched load is:

$$E_{matched} = \min(D_{matched}, E_A - E_{continuous}) \quad (24)$$

The energy delivered directly to the load is therefore:

$$E_D = E_{continuous} + E_{matched} \quad (25)$$

and the energy delivered to the battery is:

$$E_A - E_D \quad (26)$$

4.0 Energy going through the battery

The fraction of the load that a system with battery backup will provide depends on two variables: the array size and the battery size. Loss of load probability (LOLP) represent the probability of the system which fail to meet. There are many methods for LOLP calculation such as Bucciarelli (1986) and Klein et al. (1987) and Markov transition matrices more complicated method. Unfortunately none of these are suitable for RETScreen energy model. In this regard a practical approach was introduced by employing a number of computer simulations for a dummy stand-alone system with night-only load where WATSUN-PV model was chosen. The survey was applied in different array sizes and battery storage capacities from one to six days.

The average battery efficiency during the simulations, as revealed by an analysis of all simulation results, was at 85%. The array/load ratios were multiplied by this quantity to reflect the loss of energy in the batteries, the idea here being that, since all the energy delivered to the load has to go through the battery first (night-only load), the effective energy produced by the array has to be reduced by battery inefficiencies.

$$E'_A = (E_A - E_D)\eta_c \eta_b \quad (27)$$

The usable battery capacity Q_U is related to the nominal capacity Q_B:

$$Q_U = Q_B f_B \quad (28)$$

where $f_B(T_B, r)$ is the usable fraction of capacity available, which depends on battery temperature T_B and on discharge rate r (derived from CANMET, 1991). The average discharge rate is taken as 24n where n is the number of days of autonomy. Energy delivered by the genset is simply the difference between the load and what can be provided by the PV array, either directly or through the battery:

$$E_G = L - E_D - E_B \quad (29)$$

This quantity is capped by the actual size of the generator, i.e. the generator cannot deliver more than $24 C_G \eta_R$ Wh per day, where C_G is the capacity of the generator in W, and η_R the charger efficiency.

The energy used by the Genset, Q_G, expressed either in L/d or m^3/d, is simply:

$$Q_G = \frac{E_G}{\eta_R \eta_G \eta_b} \quad (30)$$

where η_G is the average Genset efficiency. The presence of the battery efficiency, η_b, in the denominator of equation (30) simply accounts for the fact that most of the energy from the genset will be stored in the battery before reaching the load.

4.1 PV array - Battery - Genset scaling

The sizing methodology of the PV generator and other system components depends on various parameters such as the desired solar fraction or whether it is an autonomous unit or grid-connected. The components' capacity depends on site specific restrictions, budget limitations and the objective of the PV hybridization. There are general design recommendations. The optimum orientation of a PV array in the Mediterranean region throughout the year is to face south. However, the selected orientation depends on other considerations such as the consumer's load profile. Sizing the system component's results in rough estimations of the capacities required, but the final design will be influenced by the available products in the market, the connection of the equipment and the site-specific climatic conditions. For stand-alone systems, the array is sized so that its output as defined previously is greater than 1.2 times the load for all months of the year. For hybrid system, the suggested array size is 25% of that for the stand-alone system; in addition the size is capped so that the array never provides more than 75% of the load. Battery sizing is based on the desired number of days of autonomy. If L is the equivalent DC load, ***n*** the number of days of autonomy and ***d*** the maximum depth of discharge, the usable battery capacity should be:

$$Q_U = \frac{Ln}{d\eta_b} \quad (31)$$

where η_b is the battery efficiency. As explained before the usable fraction of capacity available depends on battery temperature T_B and on discharge rate, r. If $f_B(T_B, r)$ the usable fraction of capacity available, then the design battery capacity is:

$$Q_B = \frac{Q_U}{f_B} \quad (32)$$

This value is calculated on a monthly basis and the maximum over the year is taken as the suggested battery size. Finally, the suggested genset capacity is taken as the maximum of the AC demand and:

$$\frac{1}{8}\frac{Q_B}{\eta_R} \quad (33)$$

where η_R is the charger efficiency. This corresponds to the power required to charge the battery in 8 hours.

5.0 Some techno-economic selection's aspects of Hybrid - PV system for Internet Access Point Antenna

The selection of the PV must meet different criteria simultaneously:

- generate high quality electricity according to specific standards;
- withstand the high variability of solar radiation characteristics;
- require less maintenance interventions and costless;
- compete economically with other energy sources;
- fast and cost effective compliance.

Given the above requirements, the selection of the PV system is carried out carefully. After evaluating the possibilities for cost-effective technical solutions for the operation of this network, the only alternative was the hybrid PV system.

From the RETScreen Expert database and technical information obtained from the manufacturer, comparisons were executed to determine the most efficient PV module among five alternative types taken in this study. The main technical characteristics for the selected PV module is given in table 3.

Table 3: *Presentation of the technical indicators of the PV cell technology.*

Model Type		**WRS250-ST60FPower**
Max power at STC (Pmax)	W	250
Power tolerance	W	0÷0.5
Optimum operating current (Imp)	A	8.36
Optimum operating voltage (Vmp)	V	28.89
Short circuit current (isc)	A	9.01
Open circuit voltage (Voc)	V	37.62
Nominal operating cell temp (NOCT)	^{O}C	45
Maximum system voltage	V	1000
Standard Operating Temperature (Tc)	^{O}C	25
Specific energy (E)	W/m^2	1000
Dimension	mm	1660x990x34
Weight	Kg	19.0
Cell technology		Multi-Si
Application class		Class A

In the table 3 the main technical parameters of the PV cell technology panel is given providing a capacity factor at the construction site of 15.1%. The capacity factor is the basic technical criterion in selecting the type of PV panel as it is the main indicator that directly influences the annual energy generated by the PV system.

5.1.1 *Economic aspects of PV systems*

Three key factors are essential when designing wind power plants. First there must be a sufficient source of solar potential in the proposed region, the PV technology must be promising as well as cost effective. Studies has shown that it is cost-effective for small loads (<10 kWp) need lower capital costs than grid extension and have lower O&M costs than gensets and primary batteries [23]. This section deals with the economic aspects of building a PV system with an installed capacity of 2*250W able to provide more than 0.17 MWh/year of electricity needed by the Internet Access Point Antennas devices.

Any factor that leads to lower total lifecycle costs, or that yields greater kWh over the chosen analysis period, lowers the LCOE of a PV system. The total lifecycle cost in the numerator is a function of the initial capital cost (which primarily includes the module, the installation hardware and labour, and transaction costs for system installers and financers), as well as ongoing operation and maintenance expenses (which oftentimes includes inverter replacement) and decommissioning costs including module collection and recycling. The total lifecycle energy production (the kWh in the denominator) is a function of location as well as module and system reliability and performance. A full LCOE calculation also incorporates appropriate discount rates—to account for the time value of money in the net present value calculation—as well as any state incentives that can help to offset the project's total lifecycle costs [17].

The global weighted-average LCOE of utility-scale PV plants declined by 82% between 2010 and 2019, from around \$0.378/kWh to \$0.068/kWh in 2019, with a 13% reduction year-on-year in 2019. At an individual country level, the weighted average LCOE of utility-scale solar PV declined by between 66% and 85% between 2010 and 2019.

5.2 PV Project Costs

Although the cost of PV panels energy has dropped dramatically in the last 10 years, technology requires a higher initial investment than traditional fossil fuel generators. Approximately 55% of the cost goes to module, 15% to inverter and the rest is belongs to BoS and installation costs (see graph in figure 5).

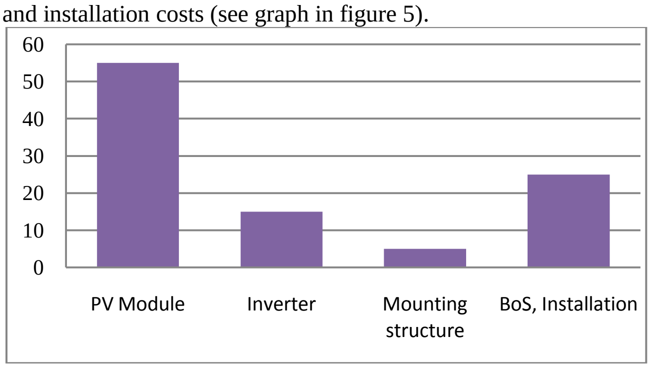

Figure 5: *Cost breakdown of PV system components (%)*

The main components of the system are given in the table 4. The main characteristics of the selected PV cell are given in table 3.

Table 4: *System components and technical parameters*

*PV Module WRS250-ST60FPower (2*125W)*
Access Point Mikrotik (12 – 24 Volt) 2W-50W
Switch Mikrotik (12 – 24 Volt) 10 W
Access Point 3X10W
Roouter Mikrotik(1)5x Ethernet, 850MHz CPU, 64MB RAM2 W
Solar charge controller
Battery set (4X12V, 60 A)
Inverter MW (LRS-350-24) AC-DC

The inverter is used to convert AC 220 Volt AC to DC 24 Volt. The batteries has a key role to store the energy produced by the photovoltaic panel. The amount of batteries used for this system 4 batteries, 12 Volt 60 A, two batteries are connected in series to obtain 24 Volts and then the two pairs of batteries are connected in parallel in order to increase the capacity of the batteries.

In order to have a smart charging of the batteries, a controller which keeps under control the capacity of the batteries and the time when they would be charged by the panel is used. A Microtic

Switch and a Microtic Access Point are included. The total number of Access Points 3.

5.3 Capital Investment Cost

With very rapid reductions in solar PV module and balance of system costs, utility-scale solar PV is now increasingly competing head-to-head with alternatives and without financial support. Lower solar PV module prices and ongoing reductions in balance of system costs remain the main driver of reductions in the cost of electricity from solar PV. The costs for renewable energy technologies reached new lows again last year. Solar and wind power have emerged as the most affordable power source for many locations and markets, with cost reductions set to continue into the next decade. Improved manufacturing processes, reduced labour costs and enhanced module efficiency (new technologies) are the key drivers of lower module costs. In addition, as project developers gain more experience and supply chain structures continue to develop in more and more markets, declining BoS costs have followed. This has led to an increased number of markets where PV systems are achieving competitive cost structures and resulted in falling global weighted-average total installed costs. In 2019, significant total installed cost reductions have occurred across all the major markets such as China, India, Japan, Republic of Korea and the United States. An increasing number of cost competitive projects in India led to weighted average total installed costs of $618/kW in 2019, around a fifth lower than in China. However, competitive costs structures are not confined to established markets anymore. Between 2010 and 2019, total installed costs have declined between 74% and 88% in markets where historical data is available back to 2010. The global capacity weighted-average total installed cost of projects commissioned in 2019 was $995/kW, 18% lower than in 2018 and 79% lower than in 2010 (see graph in figure 6). Based on the costs of the developed projects around the globe, studies by IRENA, studies by well-known authors as well as the RETScreen Expert database yearly variation of total installation cost and LCOE is given graphically in figure 6.

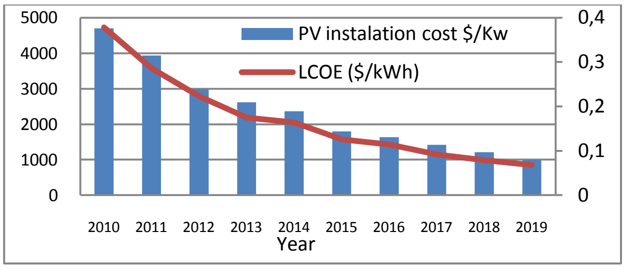

Figure 6: *Global weighted average total installed costs, capacity factors and LCOE for PV, 2010–2019 [IRENA,2019]*

An important driver of improved competitiveness historically, the downward trend in solar PV module costs continued during 2019. By the end of 2009 and 2019, crystalline silicon module prices declined between 87% and 92% for modules sold in Europe, depending on the type. The weighted average cost reduction could be in the order of 90% during that period. More recently the cost of mainstream module technology declined 14% between December 2018 and December 2019, reaching $ 0.27/W. A wide range of costs exists, however, depending on the type of module considered, with costs for December 2019 varying from as low as $0.21/W for the lower cost modules to as high as $0.38/W for all black modules. The cost of high efficiency crystalline modules at $0.37/W was slightly above thin film offerings, which sold for $0.36/W during that period. These costs declines and the advances in the ability to securely operate the grid with high shares of variable renewables are not only decarbonising the electricity sector, but are unlocking low-cost decarbonisation in the end-use sectors in conjunction with increased electrification. The cost of crystalline solar PV modules sold in Europe declined by around 90% between the end of 2009 and 2019. Total installed system costs in the commercial rooftop markets where data is available decreased by between 64% and 86% between 2010 and 2019. On average, in 2019, balance of system costs (excluding the module and inverter) made up about 64% of total installed costs. In 2019, total BoS costs ranged from a low of 48% in India to a high of 76% in the Russian territories. Overall, soft cost categories for the evaluated countries made up around 40% of total BoS costs and about a quarter, on average, of the total installed costs. In 2016, these values were a third and 17% respectively.

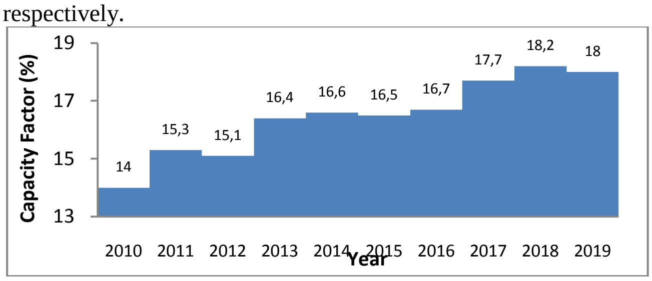

Figure 7: *Global weighted average capacity factors for utility-scale PV systems by year of commissioning, 2010–2019.*

The global weighted-average capacity factor for new, utility-scale solar PV, increased from 13.8% in 2010 to 18.0% in 2019. This was predominantly driven by the increased share of deployment in sunnier locations. After increasing steadily every year between 2010 and 2018, the capacity factor seems to be stabilising around the 18% mark (Figure 7) [6]. The development of the global weighted-average capacity factor is a result of multiple elements working at the same time. Higher capacity factors in recent years have been driven by the shift in deployment to regions with higher irradiation, the increased use of tracking devices in the utility-scale segment in large markets and a range of other factors that have made a smaller contribution (e.g., reduction in system losses). The verification will also be performed with the financial data obtained from the IRENA and RETScreen Expert model cost database. Thus it is easily to evaluate the influence of all the financial parameters considered in the analysis.

5.4 Operation and Maintenance Costs

The Operation and Maintenance costs of utility-scale solar PV plants have declined in recent years. However, in certain markets, the share of O&M costs in total LCOE has risen, as capital costs have fallen faster than O&M costs. O&M cost declines have been driven by module efficiency improvements leading to reduced surface area required per MW of capacity. At the same time, competitive pressures and improvements in the reliability of the technology have resulted in system designs optimised to reduce O&M costs and improved O&M strategies that take advantage of a range of innovations from robotic cleaning to "big data" analysis of performance data to identify issues and preventative interventions ahead of failures driving down O&M costs and reducing downtime. For the period 2018-2019, O&M cost estimates for utility-scale plants in the USA have been reported at between $(10-18) /kW per year [24]. Recent costs there seem to be dominated by preventive maintenance and module cleaning, with these making up as much as 75% and 90% of the total, depending on the system type and configuration. The rest of the O&M costs can be attributed to unscheduled maintenance, land lease costs and other component replacement costs. The current benchmarks without inverter replacement are $11.5/kW/yr (residential),$12.0/kW/yr(commercial), $9.1/kW/yr (utility-scale, fixed-tilt), and $10.4/kW/yr (utility-scale, tracking), significantly below previous O&M, only benchmark estimates [25].

Average utility-scale O&M costs in Europe have been recently reported at $10/kW per year, with historical data for Germany suggesting O&M costs came down 85% between 2005 and 2017, to $9/kW per year. This result suggests there has been a reduction of between 15.7% and 18.2% with every doubling of the solar PV cumulative installed capacity [26].

6.0 Assumptions and Calculations

The objective of this economic analysis is to provide the information needed to make a judgment or a decision. The most complete analysis of an investment in a RES technology requires the analysis of each year of the life of the investment, taking into account relevant direct costs, indirect and overhead costs, taxes, and returns on investment, plus my externalities, such as environmental impacts, that are relevant to the decision to be made. The decision-making criteria of the potential investor must also be considered and highly evaluated. In this case the financials parameters are dependent on country context and best global experience in related projects as it is shown in table 5:

Table 5: *Main financial parameters system chosen for the Hybrid PV case study.*

Financial parameters	*Unit*	*Value*
Fuel cost escalation rate	(%)	2
Inflation rate	(%)	2.5
Discount rate	(%)	11
Reinvestment rate	(%)	9
Debt term	(yrs)	15
Debt ratio	(%)	70
Debt interest ratio	(%)	7
Project life	(yrs)	20
Electricity benchmark price	(€/MWh)	100

The assumptions for fuel cost escalation rate is projected 2% of annual average rate of increase, in the baseline case and proposed case fuel costs over the life of the project. The inflation rate of 2.5% and the discount rate over the lifetime of the project of 11% is considered. The model considers the re-investment rate of 9%. The project life of the PV project, is considered 20 years and a debt ratio of 70% is accepted. The debt interest rate of 7% is accepted. In our work the debt term is considered 15 year, which is the number of years over which the debt is repaid shorter than the project life. Using a Monte Carlo simulation a sensitivity analysis on NPV, B/C ratio, PBP for financial parameters considered in table 5 with high accuracy is performed. This analysis is conducted for 5 different technologies of PV modules and the simulation's results are given in table 6.

6.1 Results and financial analysis

From the graph in figure 8 the influence of discount rate 11% in NPV is performed and extended over a 35% sensitivity analysis. It is clearly shown that NPV is reduced for lower electricity export rate.

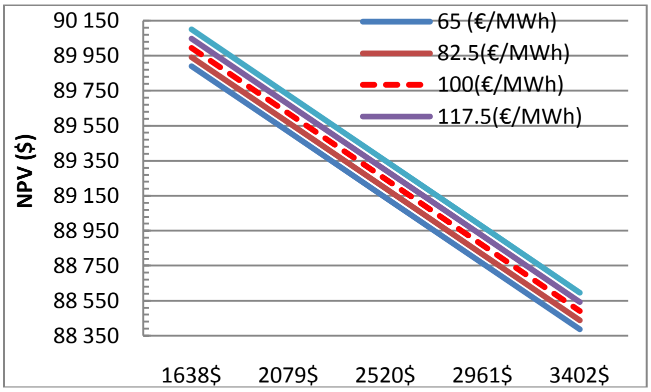

Figure 8: *Total investment cost ($) and NPV at 11% discount rate and extended 35% sensitivity analysis.*

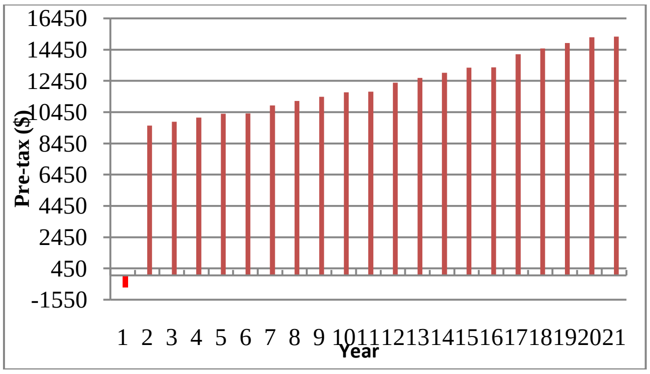

Figure 9: *Yearly and cumulative Cash flow analysis for the proposed hybrid PV system.*

From the simulation it is indicated the yearly and cumulative cash flow graphs plotted in figure 9. These cash flows over the project life are calculated in the model and reported in the yearly cash flows table including all expected costs (replacement cost) and credits taken in the study.

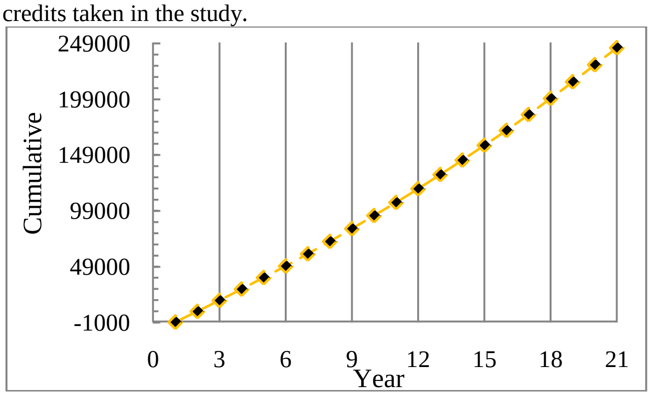

Figure 10: *Pay Back Period evaluated for the selected type of the PV module.*

The simple payback, which represents the length of time that it takes for a proposed facility to recoup its own initial cost, out of the revenue or savings it generates is calculated. From the results of the study based on a comparison applied to 5 different technologies, model WRS250-ST60FPower represents the lower possible PBP 0.21 years (see graph in figure 10 and table 6).

Table 6: *Comparison analysis of 5 different PV models taken in the study.*

	Electr.	*Electr. export revenue*	*Simple Payback*	*NPV*	*Total initial cost*
	(MWh)	*($)*	*(yrs)*	*($)*	*($)*
Multi Si	0.38	37.7	0.26	89242	2520
Mono Si	0.37	37	0.26	89243	2515
CdTe	0.33	32.8	0.26	89251	2478
WRS250	**0.33**	**33**	**0.21**	**89651**	**2011**
aSi	0.31	31.2	0.26	89257	2462

7. Conclusion and Recommendations

Hybrid PV configuration to supply Access Point Antennas to assist rural and remote areas in Albania was presented. This solution represents an alternative to simplify the installation process and to facilitate the wireless expansion communication anywhere, reducing the cost of electrical wiring and data, wireless network infrastructure design, installation time and maintenance. Other important outcomes from this proposed system are: greater accessibility to equipment, reduced time for flaws detection and reducing visits to the site. The perspective of a wide use of green power motivates the scientific community to study the possibility of fabricating hybrid-PV modules providing autonomous wireless internet and communication systems.

RETScreen Expert, an advanced computer software which a basic energy model used for small different off-grid PV configurations is chosen. After searching for possible solutions for the operation of this network, the only alternative was the hybrid photovoltaic system, working even in the absence of sunlight as well as at night is presented in table 4.

The aim is to cover an annual electricity demand of 0.17 MWh/yr and providing qualitative and uninterrupted internet signal for both villages, "Ostren i Vogël" and "Trebisht" in Bulqiza district. The solar irradiation at the proposed location results (3.7÷4.1)kW/m^2/d. By employing methodology 2 in RETScreen Expert, poly-Si cell technology, model "WRS250-ST60F Power" represents the most cost-effective option among the five other types selected in the study.

The PBP and NPV for the selected type of PV module is calculated, 0.21(yrs) and 8965($), respectively avoiding approximately 400$/yrs compared to the on-grid option.

As a conclusion the application of off-grid hybrid PV, especially in telecommunication, agriculture and other sectors is very important in the energy transition process in Albania, creating sector independency of supply, thus fulfilling its energy commitment by the end of 2030 [27].

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