Off-grid hybrid PV plants used to supply autonomuos internet base stations supporting the mitigation of GHG in Albania. Case study: Bulqiza district, Albania

Lorenc Malka[a], [a] Ilirian Konomi, [b]Majlinda Alcani, [b]Ardit Gjeta, [c]Elena Bebi
lmalka@fim.edu.al

[a] Department of Hydraulic & Hydrotechnic, Faculty of Civil Engineering, Polytechnic University of Tirana, Albania.
[b] Department of Energy, Faculty of Mechanical Engineering, Polytechnic University of Tirana, Albania.
[c] Department of Production and Management, Faculty of Mechanical Engineering, Polytechnic University of Tirana, Albania.

Abstract: *This work is focused to an off-grid PV-Genset-battery application as one of the most feasible technology to power internet access points antennas enabling to reduce GHG-s. Solar energy is clean, infinite and environment friendly source of energy. Remote areas especially in northern part of Albania is facing difficulties to the connection to the national electricity grid. Primarily diesel generators (Genset) are used for electricity power supply leading to negative effects into the surrounding. However, hybrid energy systems, such as PV-Genset-battery systems have a high potential to reduce CO_2 emissions, fuel costs and total cost of the system compared to the other options applied historically in telecommunication sector in Albania. Such systems are foreseen to play a key role in a stable, costless and emission-less way especially in off-grid applications. The performance, availability, costs and carbon intensity of photovoltaic power all indicate that this technology can make a very substantial contribution to reduce carbon emissions and gain carbon credits.*
***KEYWORDS**: PV- GENSET, INTERNET ACCESS POINTS ANTENNAS, CO2, GHG, RETSCREEN EXPERT.*

1. Introduction

The integration of distributed renewable energy in telecommunication sector and IoT can demonstrate various technical benefits to the energy sector but at the same time to the owners of the facilities. Benefits include the reduction of fossil fuel use and associated GHG emissions, the improvement of grid reliability and limitation of power outages, protection of critical loads, independence of foreign supply, and increased energy security coupled with a fixed energy cost which is immune to future tariffs and fossil fuel costs increases. This article presents a concrete PV-Genset-Battery off-grid system in process by an Albanian internet company spreading signal in Bulqiza District, part of Northern Albania. One of the challenges of the internet company was how to provide energy to the locations where the access point antennas for internet supply would be placed as there were key points for installation, facing some technical and economic difficulties to provide electricity access from the local distribution network already studied in our previous paper, but the effect on environmental related issues were not calculated. The carbon intensity of PV power varies between technologies according to the materials and processes used and module efficiency power generation by PV systems manufactured in Europe and deployed in southern Europe using c-Si, multi crystalline silicon and CdTe systems incur 38gCO2/kWh, 2gCO2/kWh and 15gCO2/kWh, respectively [1]. Around 5gCO2/kWh of this quantity is embedded in the BoS. In the case of concentrating PV systems, where a large quantity of steel is required to fabricate the collectors along with a small device area, the resulting carbon intensities are similar to silicon at (20÷40)gCO2/kWh for deployment in ideal locations. In all cases the carbon intensity is very much less than the carbon intensity of the grid electricity that is being displaced in any fossil fuel reliant countries; carbon intensity of grid power is around 500gCO2/kWh in the UK and some more over that in Balkan region. In Kosovo and North Macedonia electricity generation is highly dependent from lignite powered centrals corresponding a specific e emission factor (800-1500)gCO2/kWh. In our case study a specific emission factor of 297.8kgCO2/GJ is calculated.

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 [2]. 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.

Today, PV is one of the fastest-growing renewable energy technologies, and is ready to play a major role in the future global electricity generation mix and a contribution for some 3.8 million jobs, or nearly a third of the sector total [3]. Growing shares of those jobs are off-grid, supporting productive use in farming, food processing and healthcare in previously remote, isolated, energy-poor communities. In parallel, rural areas benefit from the feedstock production that underpins bio-energy and which accounts for the bulk of about 3.6 million jobs in that segment. Renewables accounted for an estimated 11.5 million jobs worldwide in 2019. 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 and reducing the negative effect on environmental. Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions [4].

The cost of manufacturing solar panels has plummeted dramatically in the last decade, making them not only affordable but often the cheapest form to be replaced and integrated in existing power systems. 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 installation of proposed access point antennas.

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 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.

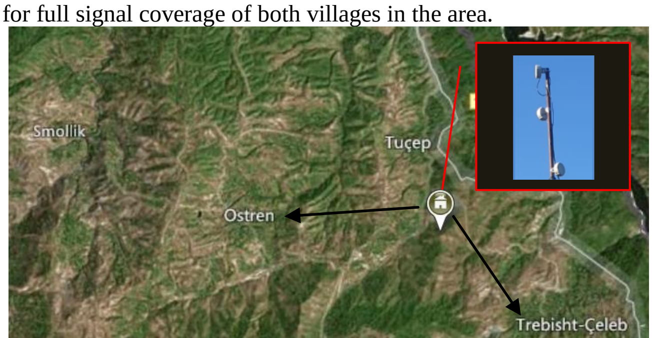

Figure 1: *The location Instalation's point of the "Internet Access Point Antenna", covering both villages "Ostren i Vogël" and "Trebisht"*

The main two problems are related to the distance of electricity supply from the national distribution grid and of course the contribution on mitigation process towards a cleaner and safer environment.

So, at this point it was achieved to provide power from the a hybrid PV system but the other challenge was that such systems can reduce to a satisfactory level the release of carbon dioxide into the surrounding environment. This requires some actions in the field of PV plants gaining the potential to collectively overcome the national regulatory gap by fostering targeted low-carbon investments at regional level in Albania.

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

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 [5Renewable energy sources, including solar, wind, hydro, biofuels and other future renewable sources are at the centre of the transition towards a less carbon-intensive and more sustainable energy system [6]. 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. Action to reduce the impact of climate change is critical. The Paris Agreement sets a goal to limit the increase in global average temperature to well below 2°C above pre-industrial levels and to attempt to limit the increase to 1.5°C. Implicit in these goals is the need for a transition to a low-carbon energy sector, which accounts for two-thirds of global emissions. RES, coupled with energy efficiency gains, can provide 90% of the CO_2 emissions reductions in the roadmap to 2050. Renewable energy is therefore a key component of Nationally Determined Contributions (NDCs) – the central implementation tool for countries under the Paris Agreement. At present, the level of detail contained in NDCs differs from country to country, with little in-depth analysis and limited quantitative information about the role of renewable energy in meeting greenhouse gas (GHG) emission reduction targets [7]. Based on the targets projected in global level Albania is making efforts to reduce import of electricity, improve its security of supply and to attain the Paris Agreement. The Albanian ministry of Energy and Transportation and its dependecy institutions has compiled the ***"The National Energy Strategy 2018-2030"***, consisting on 6 possible scenarios of energy's transition process toward a sustainable and reliable energy by shifting Albania to decentralized renewable energy market, and energy efficiency. This strategy, requires a RES of 42% to the total energy consumption by the end of 2030. The RES share actually is approximately 30%. The first goal can be achieved by large scale integration of RES capacities, especially wind generation capacities[5]. 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 which requires the rate of annual capacity additions to accelerate [8].

In the graph in figure 2 the global installed PV capacity is given. The growth of PV capacity worldwide tends an exponential progress and results 14 times more in 2019 compared to 2010.

The second national energy 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. Considerable interest in RES and significant increases in cost of imported oil and very frequent services of related power generation technologies have compelled various countries to search for low-cost energy sources and improved technologies such, wind turbines, PV and synergies between systems to achieve lower cost of electricity generation. Also, limiting the global average temperature rise to 1.5°C will require all sectors of the economy with increasing need for energy to reach zero carbon dioxide (CO2) emissions early in the second half of this century. Photovoltaics (PV) is a key technology option for realising a decarbonised power sector and sustainable energy supply [9]. Most of those options rely on renewable necessarily supported from energy storage systems (ESS) [10]. Despite significant steps forward in Kenya, Ethiopia and Rwanda, close to 600 million people are still without access to electricity in sub-Saharan Africa evaluating off-grid PV model as a fast and feasible solution [11].

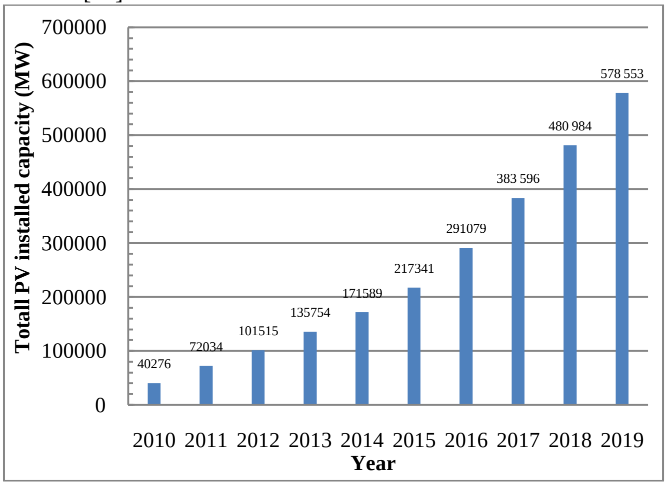

Figure 2: *The global installed capacity trends of the PV systems.*

2.0 Off - Grid PV systems applications

Solar PV offers better benefits and reliable solutions for consumers in rural areas who do not have access to the grid [12], [13]. The economic benefit is assessed based on the LCOE which represents a good starting point to compare benefits and competitiveness of different technologies [14]. Photovoltaic systems are cost-effective in small off-grid applications, providing power, to rural homes in developing countries, off-grid cottages and motor homes in industrialised countries, and remote telecommunications, monitoring and control systems worldwide. According to Kunaifi et al [15] are good basis of LCOE data for off-grid technologies in Indonesia. The studies have demonstrated that a solar PV 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 solutions. Photovoltaic systems can be combined with fossil fuel-driven (Genset) motors.

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. Bias in the data is eliminated since it considers access to fuel, access to transmission lines, and the optimal usage of each plant [16]. The studies have demonstrated that a solar PV combined with diesel engine (hybrid) has relatively lower LCOE than a pure diesel generator-only. Nevertheless, the capital cost of the battery, which is one of the most significant components in LCOE evaluation [15], [17]***, [18]*** is predicted to be reduced to more than 60% by 2030 [19]. 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 [16].

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 (PV) sector [20], examines the impact of changes to key PV module and system parameters on the levelized cost of energy (LCOE).

3.0 Materials and Methods

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. Thus, an accurate methodology comprehending in-depth analysis of the benefits must be applied and always required. The need for a pile of datas including physical characteristics, financial viability, environmental advantage, carbon credits, social or other self-interests of the project, will help the energy planers to a mature decision. Actually, there are several models available for conducting a set of analysis including environmental impact and benefits. RETScreen Expert is a clean-energy awareness, decision-support and capacity-building tool [21]. The model uses a computerized system with integrated mathematical algorithms and top to bottom approach. It provides a cost analysis, GHG emission reduction analysis, financial summary, sensitivity analysis, provides a low-cost preliminary assessment of RES projects with a small set of a detailed information.

A comparison between RETScreen Expert tool and more in-depth models using hourly values instead of monthly values showed that they produce roughly the same results, with an annual difference of less than 5% for projected energy production [22], [23]. The RETScreen Software has been developed to overcome the barriers to clean energy technology implementation at the preliminary feasibility stage.

First is analyzed the capacity and structure of the various PV systems and then select the most suitable module type and model, respectively matching on recommendations and trends. This selection is made taking into account both technical and economic context, such as solar radiation potential in the area affecting technical parameters of the PV module. Methodology 2 as the more suitable to perform the techno-economical analysis is chosen [5]. It is first required to set the model the values of the respective solar potential in the study area which may be represented by the monthly average values for the metering stations provided by the model.

3.1 General Solar Power Potential at proposed site.

In our first work a detailed techno-economic assessment of the hybrid PV system of this case study is performed. Results shows that the irradiation potential in the proposed location is adequate for supplying the system's energy demand in yearly scheduling. Designing the PV plant starts with the evaluation of parameters that are considered important in recent years to use solar for power generation. From [24] and its Earth Science research program has long supported satellite systems providing important weather data capable to be fully integrated in RETScreen model. These data include long-term climatologically averaged estimates of meteorological quantities and surface solar energy fluxes. These satellite and model-based products have been shown to be accurate enough to provide reliable solar and meteorological resource data over regions where surface measurements are sparse or nonexistent. The highest values are observed during the summer season of the year, while the lowest values are observed in the winter months. The highest solar radiation value 6.98 kWh/m^2/d is reached in July, while the lowest value 1.54 kWh/m^2/d hits in December. The annual mean solar radiation and temperature values calculated and declared from Albanian Institute of Hydro-Meteorology for Bulqiza district is defined by an average solar radiation of 3.72 kWh/m²/d, which results 11% lower than that obtained by the model.

In the table 1 the main technical parameters of the PV cell technology panel is given providing a capacity factor at the construction site of 15.2%. 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 and also reducing the GHG. The difference between the costs of producing PV energy and the costs of producing electricity from diesel is normally quite large directly proportional to CO2 emission level. Simulations are then used to calculate the highest possible savings in yearly fuel consumption that could lead lower specific emission compared to the other options available.

Table 1: *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

3.2 Emission reduction analysis and strategies

The model performs a GHG emission reduction analysis depending on whether the clean energy system under consideration generates electricity or provides other energy requirements. The only difference lies in transmission and distribution losses, which are incurred only by electricity generating systems. The reduction Δ_{GHG} is calculated as follows in equation 1:

$$\Delta_{GHG} = \left(e_{base} - e_{prop}\right) E_{prop}(1-\lambda_{prop})(1-e_{cr}) \qquad (1)$$

where e_{base} is the base case GHG emission factor, e_{prop} is the proposed case GHG emission factor, E_{prop} is the proposed case annual electricity produced, λ_{prop} is the fraction of electricity lost in transmission and distribution for the proposed case, and e_{cr} the GHG emission reduction credit transaction fee. For both the base case and proposed case system, the transmission and distribution losses are deemed to be negligible for on-site generation, such as off-grid and water-pumping PV applications.

3.2.1 GHG emission factor – base case electricity system

For the base case electricity generation system is strictly required the calculation of the GHG emission factors, defined as the mass of greenhouse gas emitted per unit of energy produced. For a single fuel type, the following formula in equation (2) is used to calculate the base case electricity system GHG emission factor, e_{base}:

$$e_{base} = \left(e_{CO_2} GWP_{CO_2} + e_{CH_4} GWP_{CH_4} + e_{N_2O} GWP_{N_2O}\right) \frac{1}{\eta}\frac{1}{1-\lambda} \qquad (2)$$

where e_{CO2}, e_{CH4}, and e_{N2O} are respectively the CO2, CH4 and emission factors for the fuel/source considered, GWP_{CO2}, GWP_{CH4}, and GWP_{N2O} are the global warming potentials for CO2, CH4 and N2O, η is the fuel conversion efficiency and λ is the fraction of electricity lost in transmission and distribution. The GHG emission factor will vary according to the type and quality of the fuel, and the type and size of the power plant. In cases for which there are a number of fuel types or sources, the GHG emission factor e_{base} for the electricity mix is calculated as the weighted sum of emission factors calculated for each individual fuel source given in equation (3):

$$e_{base} = \sum_{i=1}^{n} f_i e_{base,i} \qquad (3)$$

where n is the number of fuels/sources in the mix, f_i is the fraction of end-use electricity coming from fuel/source i, and e_{base}, *i* is the emission factor for fuel *i*, calculated through a formula similar to equation (2):

$$e_{base,i} = \left(e_{CO_2,i}GWP_{CO_2} + e_{CH_4,i}GWP_{CH_4} + e_{N_2O,i}GWP_{N_2O}\right)\frac{1}{\eta,i}\frac{1}{1-\lambda,i} \qquad (4)$$

where $e_{CO_2,i}$, $e_{CH_4,i}$ and $e_{N_2O,i}$ are respectively the CO2, CH4 and N2O emission factors for fuel/source i, η,i is the fuel conversion efficiency for fuel i, and λ,i is fraction of electricity lost in transmission and distribution for fuel i.

The GHG emission factor for the electricity mix will apply from year 1 up to the year of change in baseline, as specified by the user, unless no changes are specified; in this case, the emission factor will apply throughout the life of the project. When a change in the baseline emission factor is specified, the new factor for the year that the change in baseline takes place, and the years that follow will be determined by (e*):

$$e^{*}_{base} = e_{base} r_{change} \qquad (5)$$

where r_{change} is the percentage change in the base case (baseline) GHG emission factor for the year that the change in baseline takes place, and the years that follow.

3.2.2 GHG emission factor – proposed case electricity system

The calculation of the proposed case electricity system GHG emission factor, e_{prop}, is similar to that of the base case GHG emission factor, with the exception that for off-grid systems the fraction of electricity lost in transmission and distribution is set to zero. e_{prop} is therefore calculated through equation (2) with λ=0, in the case of a single fuel/source, or through equations (3) and (4) with all λ_i=0, in the case of a mix of fuel/sources. Alternatively, the proposed case GHG emission factor of 3%, before transmission and distribution losses are applied.

4.0 Silmulation of the PV-Genset system

Emission factors will vary for different types and qualities of fuels, and for different types and sizes of power plants.. The electricity mix factors thus account for a weighted average of the fuel conversion efficiencies and T&D losses of the different fuel types.

For fuel type selected, diesel 2, 100% single fuel mix, units are given in (kg/GJ) as it is shown in table 2.

Table 2:*Emission factors for the chosen fuel type taken in the study (Diesel 2)*

Fuel Type (Base case)	Fuel Mix	CO2 emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Electricity Generation efficiency(%)	T&D losses(%)	GHG emission factor (tCO2/MWh)
Fuel Mix	100 %	70	0.002	0.0006	25.3	7	1.07
Electricity Mix	100 %	297.8	0.0087	0.0024		7	1.07

In the baseline case the diesel 2 fuel type is chosen in the simulation of the system. A typical Genset could have an electricity generation efficiency of 25.3% and CO_2 emission factor results 297.8kg/GJ. Specific emission factor for N_2O for the selected fuel type is 0.0006 kg/GJ resulting to 0.0024 kg/GJ and 0.0087 kg/GJ of CH_4.

The GHG emission factor results 1.07 tCO_2/MWh for a 7% T&D losses.

Table 3: *Calculation of CO_2, CH_4 and N_2O for the base case system.*

Fuel Type (Baseline GHG Summary)	Fuel Mix	CO2 emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption (MWh)	GHG emission factor	GHG emission (tCO2)
Electricity	100%	297.8	0.0087	0.0024	0.31	1.075	0.3302

In the table 3 the GHG emission for the base case system by multiplying the fuel consumption by the GHG emission factor. The model also calculates the GHG emission for the base case system by multiplying the annual system losses by the global warming potential. The annual GHG release in environmental results 0.3302 tCO2.

4.1 GHG reduction credit

In this case study the optional GHG reduction credit, per equivalent tonne of CO_2 (tCO_2) is considered. It is used in conjunction with the net GHG reduction to calculate the annual GHG reduction revenue. Prices for GHG reduction credits, per equivalent tonne of CO_2 (tCO_2), vary widely depending on how the credit is generated and how it will be delivered. Other factors which have an impact on price may include: voluntary or mandatory emissions reduction; private or public purchase of credits; credits traded within, for example, the European Union Greenhouse Gas Emission Trading Scheme (EU ETS), other national, transnational, or regional schemes; type of technology used to generate the emissions reductions; and others. As of May 2014, prices including rates for carbon taxes varied between \$1 to \$168 per tonne of CO_2 [25].

The model escalates the GHG reduction credit rate yearly according to the GHG reduction credit escalation rate starting from year 1 and throughout the GHG reduction credit duration as it is given in the table 4.

Table 4: *Calculation of the carbon credit revenue*

	\$/tCO2	*120*
GHG reduction credit duration	Yrs	25
GHG reduction credit escalation rate	%	2.5
Gross annual GHG emission reduction	tCO2	0.3203
GHG credits transaction fee	%	2
Net annual GHG emission reduction	tCO2	0.3139
GHG reduction revenue	\$	37.671

Carbon credit instruments often coexist with other heterogeneous policies that may directly or indirectly contribute to reducing GHG emissions by addressing areas such energy or infrastructure. In our study they have to be planned to interact and complement other strategic priorities at local and national levels. The GHG reduction credit duration is acceped to be applied all into the whole lifetime of the proposed hybrid PV system with a reduction credit escalation rate of 2.5%. From the calculation the net annual GHG results 0.3139tCO2 leading to 37.671$ of GHG reduction revenue. The credit transaction fee is accepted 2%. In the graph in figure 3 the results of the simulations of the hybryd system compared to that of the base case (genset alone) is given. The proposed system, hybrid PV offers the lowest possible scenario for the mitigation of GHG emissions resulting to 0.0099 tCO2 compared to baseline scenario 0.3302tCO2.

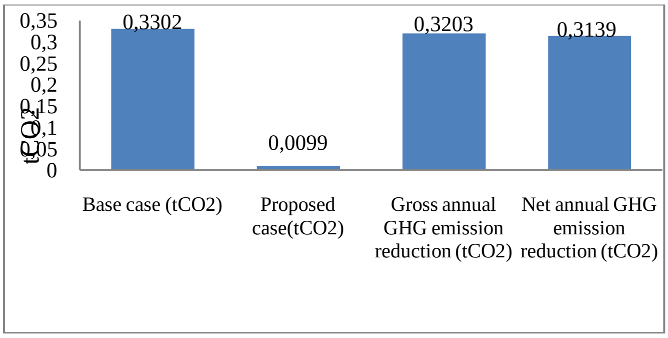

Figure 3: *Results of the simulation of the baseline scenario and hybrid PV system.*

The simulation shows that an amount of 0.3 tCO2 is reduced by the proposed acces point antenna powered by a hybrid PVsystem equivalent to 137 litres of gasoline not used or 0.1 acres of forest absorbing carbon.

7. Conclusion

The present paper address various aspects related to hybrid PV energy systems for an autonomous power supply of the access point antenna for two remotes villages in Bulqiza district, including an universal understanding of the GHG emission mitigation process. Diesel powered generators and photovoltaic (PV) technology can be combined in perfect harmony extracting the maximum solar radiation. Although these technologies have rarely been in demand by the same users in the past applying Genset stand alone systems. Nowadays, benefits coming from the hybrid-PV system is becoming extremely beneficial from both technical and cost point of view and of course environmentally friendly. The perspective of a wide use of green power motivates the investors in our Albania to evaluate the possibility of fabricating integrated stand-alone devices. In particular, solar energy is one of the most promising renewable powers, and it is widely used in autonomous wireless communication systems. In this paper, the feasibility of a single integrated autonomous internet access point antenna device, discussing its potentiality remotes areas in Albania is analyzed.

From the result of the study 0.3 ton CO2 is reduced equivalent to 137 litres of gazoline not consumeed or 0.1 acres of forest absorbing carbon. The impact of such systems in all telecomunication sector is very deterministic and should be at the center of developments in the telecommunication, agriculture and other services sector in Albania.

As a conclusion, off-grid hybrid photovoltaics (PV) concept should be a key center technology option and solution in the way to deep decarbonisation of the power sector in Albania.

8. References

[1] Nelson, Jenny, Ajay Gambhir, and Ned Ekins-daukes. 2014. “Solar Power for CO2 Mitigation.”(11)

[2] IEA, “World Energy Investment 2019 Edition,” (2019) and Sawle Y 2017 Review of hybrid renewable energy systems with comparative analysis of off- grid hybrid system Renewable and Sustainable Energy Reviews 81(2) 2217-35 http://dx doi org/10 1016/j rser 2017 06 033

[3] Renewable, International, and Energy Agency. 2020. Renewable Energy and Jobs – Annual Review 2020.]

[4] Wild-scholten, Mariska De. 2013. “Life Cycle Assessment of Photovoltaics Energy Payback Time Mono.” (October)

[5] Malka, Lorenc et al. 2020. “An Approach to the Large-Scale Integration of Wind Energy In.” 10(5): 327–43].

[6] [Renewable energy market update, IEA, Paris https://www.iea.org/reports/renewable-energy-market-update

[7] Energy, Renewable, I N Nationally, and Determined Contributions. UNTAPPED POTENTIAL FOR CLIMATE ACTION RENEWABLE ENERGY IN NATIONALLY

[8] [IEA (2020), Renewable Power, IEA, Paris https://www.iea.org/reports/renewable-power].

[9] [Jäger-Waldau, A., PV Status Report 2019, EUR 29938 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12608-9, doi:10.2760/326629, JRC118058.].

[10] [Renewable, International, and Energy Agency. 2017. ELECTRICITY STORAGE AND RENEWABLES : COSTS AND MARKETS TO 2030.].

[11] [IEA (2019), SDG7: Data and Projections, IEA, Paris https://www.iea.org/reports/sdg7-data-and projections].

[12] N. U. Blum, R. Sryantoro Wakeling, and T. S. Schmidt, “Rural electrification through village grids - Assessing the cost competitiveness of isolated renewable energy technologies in Indonesia,” Renew. Sustain. Energy Rev., vol. 22, pp. 482–496, (2013), doi: 10.1016/j.rser.2013.01.049;

[13] D. P. Kaundinya, P. Balachandra, and N. H. Ravindranath, “Grid-connected versus stand-alone energy systems for decentralized power-A review of literature,” Renew. Sustain. Energy Rev., vol. 13, no. 8, pp. 2041–2050, (2009), doi: 10.1016/j.rser.2009.02.002].

[14] [N. U. Blum, R. Sryantoro Wakeling, and T. S. Schmidt, “Rural electrification through village grids and (S. Borenstein, “The private and public economics of renewable electricity generation,” J. Econ. Perspect., vol. 26, no. 1, pp. 67–92, (2012), doi: 10.1257/jep.26.1.67)].

[15] [K. Kunaifi, A. Veldhuis, and A. Reinders, The Electricity Grid in Indonesia: The Experiences of End-users and Their Attitudes Toward Solar Photovoltaics. (2020)]

[16] [S. Borenstein, “The private and public economics of renewable electricity generation,” J. Econ. Perspect., vol. 26, no. 1, pp. 67–92, (2012), doi: 10.1257/jep.26.1.67].

[17] A. S. Mundada, K. K. Shah, and J. M. Pearce, “Levelized cost of electricity for solar photovoltaic, battery and cogen hybrid systems,” Renew. Sustain. Energy Rev., vol. 57, pp. 692–703, (2016), doi: 10.1016/j.rser.2015.12.084,

[18] T. T. D. Tran and A. D. Smith, “Incorporating performance-based global sensitivity and uncertainty analysis into LCOE calculations for emerging renewable energy technologies,” Appl. Energy, vol. 216, pp. 157–171, (2018), doi: 10.1016/j.apenergy.2018.02.024],

[19] [IRENA, Electricity storage and renewables: Costs and markets to 2030, (2017).].

[20] [Jones-albertus, Rebecca et al. 2020. “Technology Advances Needed for Photovoltaics to Achieve Widespread Grid Price Parity.” (2016): 1–12.]

[21] [RETScreen. Financial and risk analysis, 2004. Retrieved: July 20, 2015 from URL:http://www.retscreen.net/ang/financial_and_risk_analysis_with_retscreen.php].

[22] [E,Bebi, Malka, Lorenc et al. 2020. “An Approach to the Large-Scale Integration of Wind Energy In.”10(5):327–43.,

[23] Tisdale M, Grau T, Neuhoff K. Impact of renewable energy act reform on wind project finance: Discussion Paper 1387 (Vol. 2014).Berlin,2014].

[24] [NASA. Surface meteorology and solar energy: a renewable energy resource, 2015, NASA Langley]

[25] [World Bank. 2014. State and Trends of Carbon Pricing 2014. Washington, DC: World Bank].