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Sustainability Analysis of a Standalone Solar Powered System

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Abstract

Energy is a very important variable that its conservation is of paramount interest. This paper studies the viability of power generation from solar source as a system that converts solar irradiance into electric energy. The conversion of solar energy to electrical energy is achieved by means of a solar panel made up of transducers called solar cell. Solar power system is an efficient renewable energy technology that is cost effective as well as environment friendly. The paper focused on the feasibility and sustainability analysis of an off-grid mini power plant which can help to reduce the reliance on grid power and allow inaccessible remote area to have regular power supply. The feasibility study of a 300KW PV power plant at Wudil, Kano State was conducted. For the study RETScreen software is used, using the RETScreen the benchmark analysis, emission and financial analysis were made. From the bench mark analysis the energy cost of production is reduced to 0.10USD/KWh and finally emission analysis shows a reduction of 3,412.6 t of CO2 from similar non-renewable energy installation the potential emission to the environment is achieved. Hence, this means the project is feasible and can be sustained financially, technically and environmentally friendly and it will help the country to achieve its goal in building clean energy

1. Introduction

Nigeria, with its developing economy and rapidly expanding population of over 150 million, has always faced shortage of energy. Even though it is among the countries that are highly endowed with natural resources that can be converted to electricity in the world, it is hardly ever able to meet the electricity requirements of its ever-so-rapidly increasing population [1].
Millions of Nigerians have no access to grid electricity. Those who do have grid access experience extremely unreliable Supply [1]. Due to the enormous renewable energy resource Nigeria is endowed with, it is high time Nigeria consider renewable ways to feed its population its fair-share of electricity [2].

Solar energy is one of the most promising renewable resources in Nigeria. Theoretically, Nigeria has a potential for electricity production from solar PV technology in the range of 207,000 GWh per year, if 1% of the land area were covered with PV modules[3]
Solar energy has emerged as the most viable and environment-friendly option for Nigeria to utilize for its energy requirements especially in the majority of its rural inhabitants who still live without electricity. A typical solar system is very easy to set up and entails installing solar panels correctly in order for it to work properly [2]. Quite a few people were already aware of its benefits and were really quick at setting their properties up with solar systems; in fact, the utilization of solar energy in Nigeria is nothing new and has existed in some household locations for quite some time now [3]. The result of the study conducted by [4] showed that solar power project is economically viable in Nigeria, making the life cycle cost per kWh, including the grid extension cost relatively low. Furthermore, [5] opined that electricity generated from solar energy can contribute to the country's economy and also eliminate or cut the pollution and toxic waste from the burning excess fossil fuel that releases large amount of CO2 into the atmosphere which affects human health and the environment. This study used RETScreen expert as tool for the solar energy analysis.
RETScreen Expert is software developed by government of Canada. It allows energy professionals and decision-makers to identify, assess and optimize the technical and financial viability of potential clean energy projects. It also analyse the actual performance of facilities, helps identify additional energy savings/production opportunities, and allows for the management of multi-facility portfolios. It can significantly reduce the financial and time costs associated with identifying and assessing potential renewable energy and energy efficiency projects [5][6][7]. RETScreen Expert models a full range of both traditional and non-traditional sources of clean energy as well as conventional energy sources and technologies, including energy efficiency (from large industrial facilities to individual houses), heating and cooling (e.g., biomass, heat pumps, and solar air/water heating), power (including renewables like solar, wind, wave, hydro, geothermal, etc. but also conventional technologies such as gas/steam turbines and reciprocating engines), and combined heat and power (or cogeneration). Integrated into the analytical worksheets are product, project, benchmark, hydrology and climate databases, as well as links to worldwide energy resource maps [7][8].

2. Methodology

2.1 Climate data and Location of the Power Plant

The location of the power plant is at Wudil town with Latitude of 11.8^{o}N and Longitude of 8.9^{o} E as shown in Table-1 the location is selected based on climate data that can justify its potential, the climate data is given by Table-2. The average daily solar radiation-horizontal of wudil is about 5.86kwh/m^2 [9].
Wudil town has a very good amount of solar radiation which can be utilized for electric generation throughout the year [9]. Based on the value obtained from the climate data available at RETScreen expert database, it is easily understandable that the location is suitable for solar power production.

Table-1: Climate Data Location and facility location

	Unit	Climate data location	Facility location
Name		Nigeria - Wudil	Nigeria - Kano - Wudil
Latitude	°N	11.8	11.8
Longitude	°E	8.9	8.9
Climate zone		1A - Very hot - Humid	1A - Very hot - Humid
Elevation	m	531	0

The facility location is with an elevation of **0** meters above sea level. The climate data is extrapolated to this elevation from RETScreen expert database to perform the exact calculations of the feasibility study and the extrapolated results are given by table-2.

Table-2: Climate Data of the Facility Location

	Heating design temperature		16.3						
	Cooling design temperature		34.7						
	Earth temperature amplitude		17.2						
Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	23.1	18.4%	1.16	5.55	95.1	3.4	25.6	0	405
February	24.9	16.4%	0.59	6.29	95.0	3.3	27.7	0	418
March	28.1	26.5%	0.97	6.65	94.8	3.6	31.2	0	561
April	28.2	51.1%	29.62	6.69	94.7	3.7	30.8	0	545
May	26.9	67.2%	94.71	6.37	94.8	3.5	28.6	0	524
June	25.1	78.1%	167.75	5.93	95.0	3.0	25.9	0	452
July	24.0	81.8%	255.15	5.45	95.1	2.8	24.6	0	434
August	23.9	81.4%	302.06	5.16	95.1	2.7	24.6	0	432
September	24.6	76.9%	192.58	5.53	95.0	2.4	25.3	0	438
October	25.8	56.6%	27.66	5.77	95.0	2.7	27.1	0	489
November	25.9	25.6%	0.56	5.65	95.0	3.1	27.8	0	477
December	23.6	20.1%	1.58	5.35	95.1	3.6	25.6	0	423
Annual	**25.3**	**50.2%**	**1,074.40**	**5.86**	**95.0**	**3.1**	**27.0**	**0**	**5,597**

Source: RETScreen expert database

2.2 Power Plant Capacity

The intended capacity of this study is limited to 300kW. It will help the country reach its target of expanding energy.

2.3. Software

RETScreen Expert is can be used to evaluate various types of power projects. It permits analysis with a wide range of renewable and conventional (fossil) fuels (which can be used in parallel), including wind; hydro; solar; landfill gas; biomass; bagasse; biodiesel; biogas; hydrogen; natural

gas; oil/diesel; coal; municipal waste, etc. the software involves various steps of analysis, but in this study only relevant steps will be discussed.[6][8]

Step 1 – Location
In this step the selection of the project location is done. This includes the location's latitude and longitude, altitude and relevant climate data. All these are incorporated in the software database

Step 2- Facility
This section describe the type of facility to be used for the analysis, the facility capacity and the technology involved. In this section, the user enters information about fuels require for the project. The fuel use for this study is solar energy.

Step -3 Energy
This section provides technical information about the project. This includes the products (in this case solar panel) manufacturer, number of units used, the capacity per unit and the capacity factor. The user clicks in the ribbon on the equipment they want to describe to access the data entry forms.

Step - 4 Emission Analysis
Base on the information provided in this section the software calculate the expected greenhouse gas emission that can be avoided in tons.
Within some of the forms provided in the software the user can select more than one Level to perform the calculations. When more than one level is available, the user selects the type of level by clicking on the appropriate button at the top of each form. The application or level chosen will typically depend on the availability of input data and the stage of project development.

Step 5 – Summary
This section summarizes key results (e.g., electricity export revenue, simple payback, etc.) based on the information entered in the previous steps (i.e., Fuels & schedules and Technology), including detailed information for each fuel type used.

3.0 Results and Discussions

3.1Benchmark Analysis
Benchmarking analysis is a specific type of market research that allows organizations to compare their existing performance against others and adopt improvements that fit their overall approach to continuous improvement [12]. And according to[1]At present, there is no significant utility scale solar power generation in Nigeria, but this analysis shows that it can compete at the lower cost range with coal generation (before external costs are considered) at USD 10-11cents/kWh. Fourteen solar PV companies signed power purchase agreements (PPAs) at USD 0.11/kWh with NBET in 2016, with a combined capacity of 1 GW.

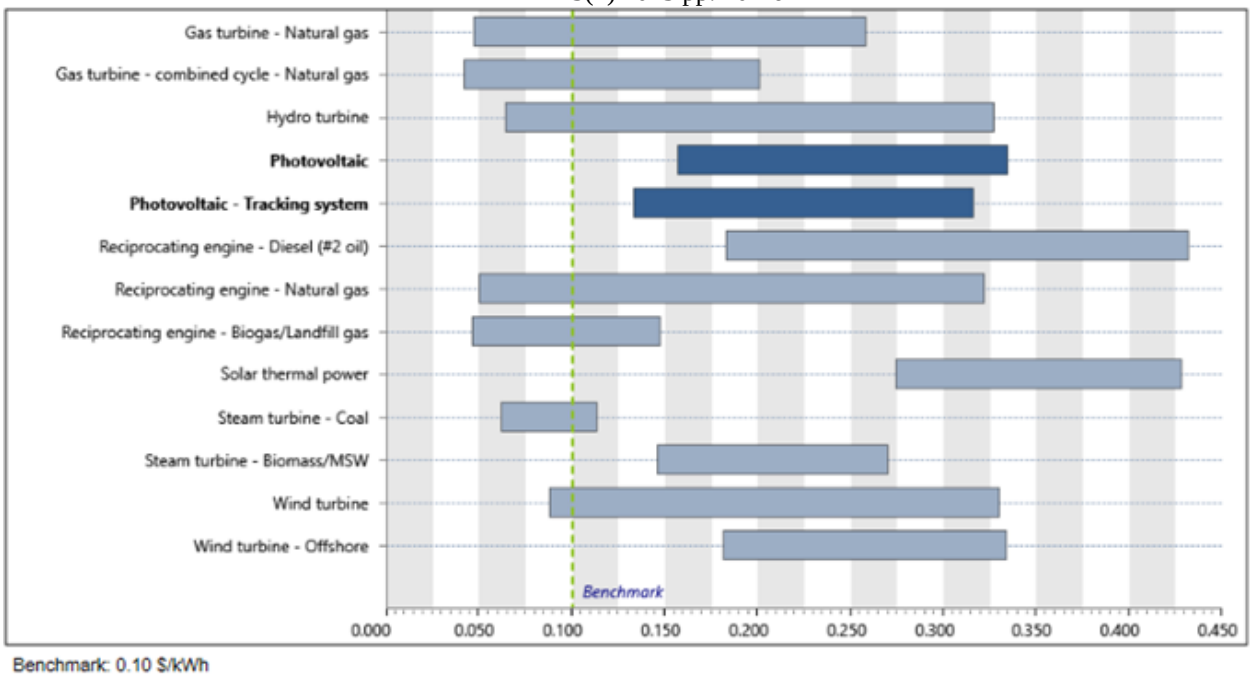


Figure-1: Benchmark Analysis

From the bench mark analysis in Fig. 1 the cost of production for 1kwh photovoltaic power plant is about 0.10 USD which is much less than the proposed planned power generation options in the country as stated by [1]. Therefore, it is clear that photovoltaic power plant at wudil, kano state is feasible regarding the cost of power production and this is a positive result.

3.2 Energy Analysis

The Energy analysis is made based on the bench mark analysis and the climate data presented in sections above. The target plant capacity is about 3,000 KW, this means the plant should deliver constantly 3000KW of power. And the electricity supplied is calculated to be 7,889 MWh and this is given by table-3 below.

Table-3: Energy Capacity

Power system - Total		
Capacity	3,003	kW
Electricity	7,889	MWh

3.3 Emission Analysis

The main target of installing renewable energy sources as power means is reducing the Greenhouse Gas emission [15]. And this study also investigates how much GHG will be reduced, if the location is solely depending on natural gases instead of renewable energy for the same amount of 7,889 MWh annually. The gross annual greenhouse gas reduction is about 93% and this is a meaningful value, this is shown in fig.2 and installing a 3,000 KW PV power plant will reduce the GHG emission from 3669.4 Tco_2 to 256.9 tCO_2 annually and this is shown in Fig.3.

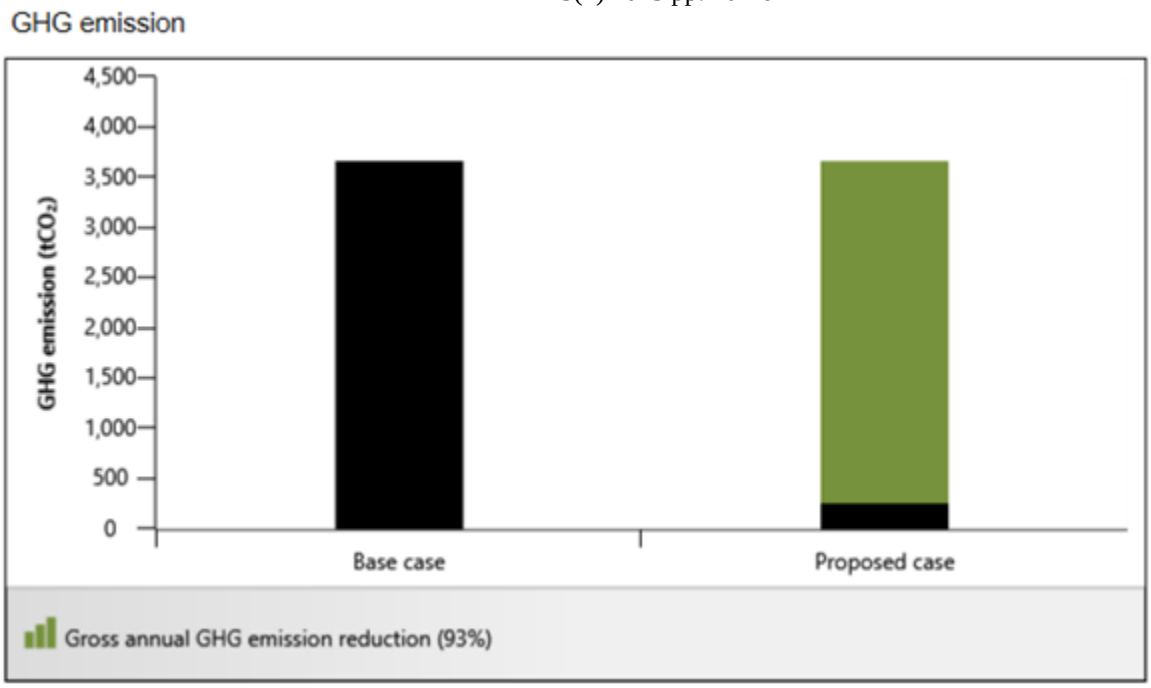
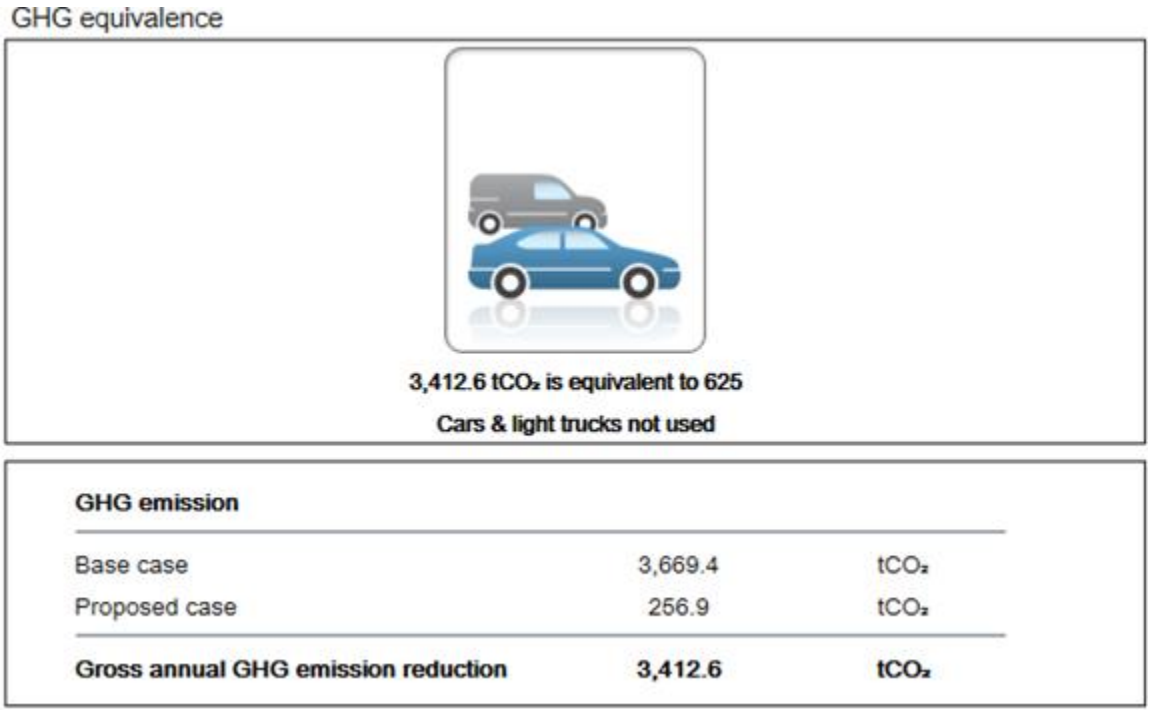


Figure-2: GHG emission reduction



GHG emission		
Base case	3,669.4	tCO_2
Proposed case	256.9	tCO_2
Gross annual GHG emission reduction	**3,412.6**	**tCO_2**

Figure-3: GHG reduction Equivalence

4. Conclusion

The feasibility study of a 3,000KW PV power plant in Wudil, kano Nigeria has been completed and the following conclusions are made based on the results.

From bench mark analysis employing a PV power plant at Wudil will reduce the energy cost of production from 0.11 USD/KWh to 0.10 USD/KWh.

Installing this plant in Wudil, Kano Nigeria will reduce the GHG emission from 3669.4 Tco_2 to 256.9 tCO_2 annually. And, this result shows that the plant has a great role in reducing the GHG in a meaningful manner.

From the above, it is concluded that the project is feasible technically, financially and environmentally. And, it will play a great role for the country to achieve its goal of increase in energy production.

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