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Retscreen Analysis of Solar Energy Project in Lafiagi, Kwara State, Nigeria

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I. Introduction

Developing countries have strongly expanded their power sectors during the last three decades. However, more than two billion people living in rural areas still surfer the choice of grid-based electricity service. Given the high cost of grid extension to utilities throughout the developing world, progress in expanding electricity service to served rural areas remains slower than population growth (Lensen, 1993). Off-grid renewable energy system represent an important option for the reducing the electricity gap in rural parts for developing world.

The lack of access to electricity poses a substantial barriers to achieving the millennium development goals (MDGs). For example, to achieve universal primary education, educational facilities need electricity for teaching aids and good lighting for reading in homes; to reduce child mortalities and improve maternal health, health facilities need refrigerators to store drugs, vaccines and electricity for proper lighting and effective service delivery. Studies have shown that there is a high correlation between annual per capital electricity consumption and human development index (Meisen and Akin, 2008). The situation is nor different in Nigeria. In 2009, about 50.6% of Nigerians lacked access to electricity (IEA, 2011), although at the different geopolitical zones, the situation is significantly different.

World Bank (2011) notes that off-grid electrification is usually considered when providing electricity access to small, low-income rural communities far from the existing grid, with discrete settlement pattern. Foley (1990) listed the gains of off-grid electrification to included pumping of water in the village, heating, lighting and cooking which provides the necessities of life to these rural dwellers. Different technical options can be considered in executing off-grid models (Kerridge *et al.,* 2008; Bhattacharyya, 2012). The use of each technology depends on the domestic resources available. Communities with solar radiation will likely use solar energy while communities closer to a river will prefer the use of mini hydroelectric project.

Some studies consider the viability of off-grid electrification using solar PV panels in a hybrid mix, usually with a back- up diesel engine (Shaadid and Elhadidy, 2008). However, because of high cost of diesel and greenhouse gases emission, the study will not consider the hybrid solar PV/Diesel option. Several studies have been conducted to determine the feasibility, viability and risk involvement in implementing off-grid electrification. Sanneh and Hu (2009) analysed the use of solar PV in lighting rural and peri- urban homes in Gambia. They identified different methods of financing the project. Rehman *et al.,* (2007) used RET Screen to analyses the cost of generating electricity using PV panels in locations having different average solar radiation levels in Saudi Arabia. Mirzahosseini and Taheri (2012) study the environmental, technical and financial study of solar power plant in Iran using RET Screen. Three different scenario were considered based on the electricity tariff in Iran and the result showed a positive cash flow where credit was obtained by reducing greenhouse gases and the electricity tariff is 175cent/KWh. Akpan (2012) access the off-grid electrification in Nguru, Nigeria using solar PV. The study developed four scenarios. The result of the first scenario indicates positive net present value and annual life-cycle saving of $2839 and $266/yr respectively. In the second scenario, the viability of the project increases where there is a government start-up grant to cover a percentage of the initial total cost. Third and the fourth scenario showed a good project viability where the cost of the solar panel reduces. This paper presents the feasibility and greenhouse emission analyses of off-grid electrification using RET Screen software of Natural Resources Canada and the data of National Aeronautic and space Administration (NASA) for a household in Lafiagi, Kwara state, Nigeria.

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II. METHODOLGY

a) Study Location

The location for this research is Lafiagi, Kwara state, in the west central Nigeria on the south bank of the Niger River. It has a latitude 8.9^{0} and longitude 5.4^{0} with an average annual solar radiation of 5.29 KW/m^{2}/d (Table 1). The major criterion for selection was the availability of meteorological data for the location. Meteorological data for this location was obtained through RET Screen software from NASA. It is a market Centre for rice, yams, sorghum, millet, corn (maize), sugarcane, kola nuts, peanuts (groundnuts), palm produce, fish, cattle, and cotton The town is also a collecting point for the rice grown on the fadamas ("floodplains") of the Niger and for dried fish. Cotton and tobacco are local cash crops, and cotton weaving is traditionally important. Lafiagi has a government maternity clinic and dispensary population. The Map of Lafiagi is shown in figure 1. The energy needs by household in this community are mainly for cooking, where about 97.7% is gotten from fuel wood (NBS, 2009): lighting, where kerosene is the major source; and agricultural activities and water pumping, which are usually done manually (Chikaire et al., 2011).

(Source: Encyclopedia Britannica)

Figure 1: Map of Lafiagi

Table 1: Annual Climate date for Lafiagi, Nigeria

	Unit	Climate data location	Project location
Latitude	°N	8.9	8.9
Longitude	°E	5.4	5.4
Elevation	m	240	240
Heating design temperature	°C	20.0	
Cooling design temperature	°C	33.1	
Earth temperature amplitude	°C	12.9	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		27.1	38.2%	5.74	98.1	2.4	29.9	0	531
February		27.5	46.1%	5.91	98.1	2.4	30.4	0	490
March		26.9	67.7%	6.01	98.0	2.6	29.1	0	525
April		26.3	78.5%	5.78	98.0	2.5	27.6	0	489
May		25.9	81.4%	5.43	98.1	2.2	26.8	0	492
June		24.9	83.8%	4.92	98.3	2.1	25.6	0	448
July		24.1	84.1%	4.44	98.4	2.2	24.6	0	437
August		24.0	83.5%	4.26	98.4	2.2	24.6	0	434
September		24.4	84.0%	4.55	98.3	2.0	25.1	0	432
October		24.7	81.3%	5.12	98.2	1.9	25.5	0	457
November		25.4	68.9%	5.72	98.1	2.2	26.7	0	462
December		26.4	46.3%	5.67	98.1	2.2	28.5	0	509
Annual		25.6	70.4%	5.29	98.2	2.2	27.0	0	5,705
Measured at	m					10.0	0.0		

Source: RETScreen software

b) RET Screen Software

The RET Screen 4 International Clean Energy Project Analysis Software is an innovative energy alertness, decision support and capacity building tool. It is managed under the leadership and ongoing financial support of CANMET ENERGY research Centre of Natural Resources Canada's NRCan. RET Screen is developed in collaboration with a number of other governmental and multilateral organizations, and with technical support from large network of specialists from industry, government and academia, such as NASA, REEEP, UNEP, DTIE, GEF, SWERA, PCF, EEF, WB andLeonardo ENERGY Initiative. (RET Screen, 2005). The first version of the RET Screen software was released in May 1998. Since then, it has become the most popular and widely used RE feasibility analysis software in the world. (RET Screen, 2005). RET Screen is the most comprehensive product of its kind, allowing engineers, architects, and financial planners to model and analyze any clean energy project. Decision-makers can conduct a five step standard analysis, including energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis. The technologies included in RET Screen's project models are all-inclusive, and include both traditional and non-traditional sources of clean energy as well as conventional energy sources and technologies.

c) Specification for Energy Model Worksheet

Introduction of electricity in to rural community will lead to steady switching of energy sources for both household and commercial use. For household energy use, it is expected that the source of lighting will gradually shift from kerosene lamps to modern energy-saving electric bulbs. (IEA, 2011). In addition, the demand for electricity for productive uses will be created, and electricity will also be needed for other uses that improve the living standard of the people e.g. pumping water and in health facilities. This study employs the life cycle approach to estimate the lifecycle of an off-grid electrification project using solar PV panel and compare it with the cost of paying for grid-electricity [₦16.11/KWh]. As the life span of modern solar PV panels is between 20 and 30 years, the research assumes the project life of 25 years (Table 2). Within these year, the demand for electricity is expected to increase gradually. This is done for three inter-related reasons:

i. The need to ensure effective capacity utilization to curb energy wastage;
ii. Solar PV panels are modular so increasing the generating capacity of the project to meet an increasing demand will not be difficult;
iii. And the cost of solar panels is decreasing steadily so it will be cheaper to add additional capacity in the future to meet increasing demand.

Table 2: The load specification analysis

Description	AC/DC	Intermittent resource-load correlation	Base case load W	Hours of use per day h/d	Days of use per week d/w	Proposed case load reduction %	Proposed case usage time reduction %
5*15W*LCD BULB*1 HOUSEHOLD	AC	Negative	75.00	7.00	7	1%	1%
2*50W*STANDING FAN*1 HOUSEHOLD	AC	Negative	100.00	5.00	7	1%	1%
1*50W*TV*1 HOUSEHOLD	AC	Negative	50.00	5.00	7	1%	1%
1*40W*RADIO SET*1 HOUSEHOLD	AC	Negative	40.00	1.00	7	1%	1%
1*DVD*40W*1 HOUSEHOLD	AC	Negative	40.00	5.00	7	1%	1%
1*750W*REFRIGERATION*1 HOUSEHOLD	AC	Negative	750.00	8.00	7	1%	1%
1*350W*OTHERS*1 HOUSEHOLD	AC	Negative	350.00	5.00	7	1%	1%

The capacity of the inverter used is 2kW, with 90% efficiency and 5% miscellaneous loss. Similarly, the study uses a 12V,200Ah battery, with 90% efficiency, 80% maximum depth of discharge, 90% charge controller efficiency, and 2 days of autonomy. The tracking mode of the solar panels is assumed to be fixed at a slope of 8.9^0 and azimuth of 0.0^0. Furthermore, the research uses a mono-silicon photovoltaic panel manufactured by Sungen (model: mono-Si -SGM-160D; power capacity: 130W) and assumes a maximum point tracker control method (Figure 2).

Proposed case power system				
				Incremental initial costs
Inverter				
Capacity	kW	2.0	Peak load - annual - AC	
Efficiency	%	90%		
Miscellaneous losses	%	5%		
Battery				
Days of autonomy	d	2.0		
Voltage	V	12.0		
Efficiency	%	90%		
Maximum depth of discharge	%	80%		
Charge controller efficiency	%	90%		
Temperature control method		Ambient		
Average battery temperature derating	%	0.1%		
Capacity	Ah	200	2,222	
Battery	kWh	2		
Technology		Photovoltaic		
Resource assessment				
Solar tracking mode		Fixed		
Slope	°	8.9		
Azimuth	°	0.0		

(Source: RETScreen International.)

Figure 2: RET Screen Energy Model sheet

d) Specification for Financial Worksheet

This study uses the Nigerian average monthly inflation rate for 2015 of 9.0% (CBN, 2015) with a loan term of 20 years at an interest rate of 13%. Additionally, the study uses a discount rate of 8% and a fuel cost escalation rate of 6%.

In this research, the analysis was carried out to determine the ability of the potential projects to earn income and sustain an economic growth for a 25 year project analysis period. This was done using the RETScreen software which facilitates the project evaluation process with its financial parameters input items (e.g. discount rate, debt ratio, etc.), and its calculated financial viability output items (e.g. Internal rate of return IRR, simple payback, etc.). The following financial parameters were used for the solar energy resource analysis.

Table 3: Financial parameters with solar financial analysis

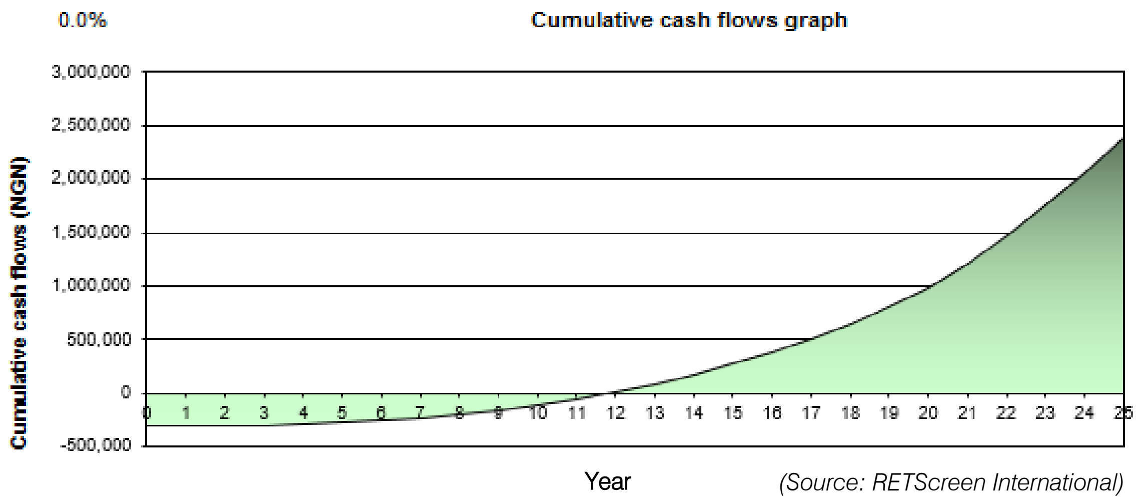
Financial parameters Units Value used Description
Inflation rate%9.0Projected annual average rate of inflation over the life of the project.
Project lifeYr25Duration over which the financial viability of the project is evaluated
Debt ratio% 50 Reflects the financial leverage created for a project
Debt interest rate% 13 Annual rate of interest paid to the debt holder at the end of each year of the term of debt.
Debt termYr20Number of the years over which the debt is repaid.
INITIAL COSTS
Power system (83.9%)NAIRA₦520, 180.00Cost of the proposed power system.
Other (16.1%)NAIRA₦99,820.00Other cost such as installation etc
Total initial costs (100%)NAIRA₦620,000.00Complete cost to purchase, transport and install equipment.
Incentives and grantsNAIRA0.00Any contribution, grant, subsidy, etc, that is paid for the initial cost (excluding credits) of the project.

Annual costs and debt payments
O and M (savings) costsNAIRA0.00Annual operation and maintenance costs
Fuel cost – proposed caseNAIRA₦18,614.00
Debt payments – 20yrsNAIRA₦44,130.00Annual amount paid for the debt
TOTAL ANNUAL COSTSNAIRA₦62,744.00Total annual expenditures
Annual savings and income
Fuel cost – base caseNAIRA₦57,480.00
Total Annual savings and income₦57,480.00

III. Result And Discussion

a) Financial Analysis

Figure 3 shows the cumulative cash flow for solar energy project in Lafiagi, Nigeria.



(Source: RETScreen International)

Figure 3: Cumulative cash flow graph

RET Screen uses the above financial parameter alongside with the energy generated per year to access the financial viability for Lafiagi, Nigeria and the following result is obtained:

Table 4: Financial viability analysis

Financial viability Unit
Pre – tax IRR – equity%13.2%
Pre – tax IRR – assets%8.4%
Simple paybackYr16.0
Equity payback Yr11.8 (< than the project)

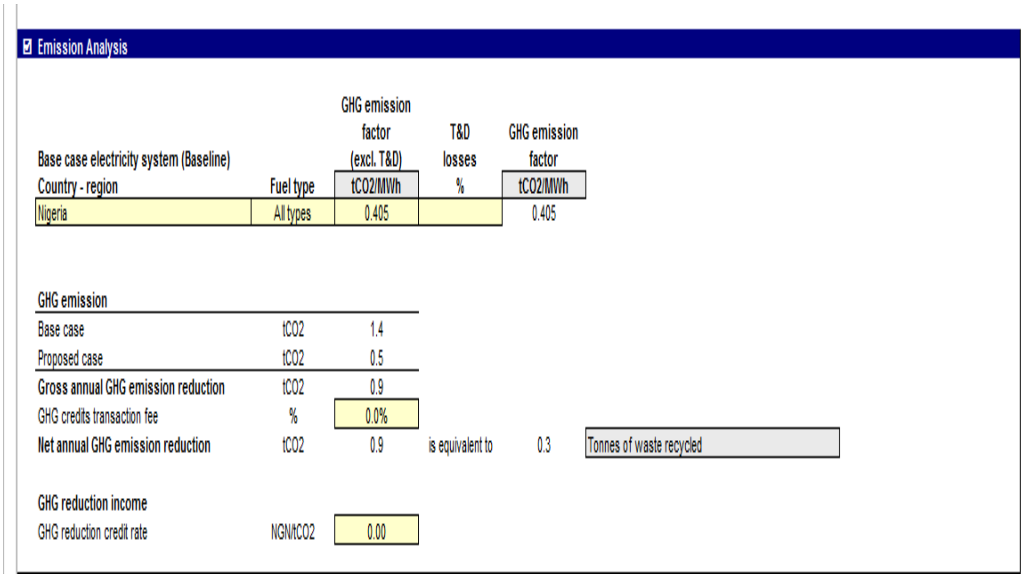
Source: RETScreen international

The Financial analysis for Lafiagi in Kwara State yielded a strong positive pre-tax IRR on equity and a positive pre-tax IRR on assets as shown in table 4. Such a result indicates that the project would be economically viable for commercial purposes. A simple debt payback can only be guaranteed in the project life span, whereas an equity payback can be completed within 12 years of the project life cycle. This shows that the equity payback is less than the project life which means the project will also be financially viable.

IV. Emission/Environmental Analysis

The environmental analysis seeks to assess the emission offsets in the environment that can be achieved through the use of renewable energy instead of conventional fossil fuel. RETScreen looks at the most current documented rates of emissions for electricity generation and other sources for Nigeria, mainly the emission of Green House Gases (GHG). Furthermore, it brings out the best use of renewable energy in terms of minimizing CO2 and other pollutants. Similar analysis were done for the solar resources. Figure 4 showed that the potential for environmental protection by offsetting GHG emissions by solar energy projects assessed in this research was very small. The reason for this is that RETScreen's calculation is based on a GHG emission factor with (0.045) or without (0.039) TandD losses per MWh of electricity generated.

Emission analysis for solar energy across the entire nation was not convincing with most of the areas giving an approximate value of 1.5t/CO2/yr.



Source: RETScreen International

Figure 4: Emission analysis

Because the results of the emission analysis were similar and only differed slightly in terms of amount of gasoline not consumed and others, certain results were summarized and presented in Table 5.

Table 5: Greenhouse Gases offsets by solar in Lafiagi, Nigeria

Greenhouse gases description CO_2 Equivalent value
Electricity exported to grid kWh/yr
GHG emission reduction (tCO_2/yr)0.90.9
Net GHG emission reduction (tCO_2/yr)0.90.9
Cars and light trucks not used0.90.2
Litres of gasoline not consumed0.9387
Barrels of crude oil not consumed0.92.1
People reducing energy consumption by 20%0.90.9
Acres of forest land absorbing carbon dioxide0.90.2
Hectares of forest absorbing carbon dioxide0.90.1
Tonnes of waste recycled0.90.3

V. CONCLUSION

Based on the government's target of ensuring 80% electricity coverage in Nigeria, this study examined the viability of using solar photovoltaic panels in a decentralized off grid electrification project for a typical rural community in Kwara state, Nigeria. The study compare the total cost of providing electricity using solar PV panels for 20 years with initial electricity load of 1.5KW with that of paying electricity tariff assuming grid connection is ascertained. The result shows that the project is economically viable at the usual commercial interest rate.

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