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Environmental Effect of Operating Solar Photovoltaic Electricity with that of Diesel Generator in Mararaba –Loko Zone (A) Village of Nasarawa State of Nigeria

Lawal M[1], Andi M.M[2], Adeleke D.A[3], Chukwunyeaka C[4], Ogunniyi S.A[5], Isah S[6]

ABSTRACT: *Carbon dioxideemission bydiesel electricity generator and solar photovoltaic powering system feeding a rural area had created a lot of environmental effect on the environment. The environmental effect of operating these two system were presented in this paper. The average solar radiation was determined from solar photovoltaic geographical information system (PVGIS) and the total load demand was determined from the load demand analysis of the survey carried out in Mararaba-Loko Zone (A) Village of Nasarawa State. The resultof this analysis shows that emissions associated with solar photovoltaic system was found to be* 9×10^{-3}*g* $CO_{2equivalent}$ *compared to the emission from a diesel generator which was found to be 573,883,380g* $CO_{2equivalent}$*. In this analysis, solar photovoltaic system stood out as the most sustainable power source.*

Keywords: *Carbon dioxide emission, System generation, Greenhouse gases, PV-module, Diesel generator.*

I. INTRODUCTION

The rapid growth in population, urbanization and industrialization are the major driving force for utilities to increasing power generation in the country.To keep balancing in demand and supply of energy because of the increasing population and infrastructure, utilities are putting more efforts to generate the electricity by combustion of subsidized fossil fuels. Around 95% of total electrical power in the country is generated by combustion of fossil fuels which are having significant contribution in production of CO_2 and other pollutants(Parmal*et al*, 2010). Electricity was introduced to Nigeria date back to 1896 when electricity was first produced in Lagos. In 1929, Nigeria Electricity Supply Company (NESCO) was established and commenced operations in the same year as an electric utility company with the construction of a 2MW hydroelectric power station at Kurra Falls near Jos. The installed generating capacity now increases to 3,801MW within this period(Wasiu, 2013).Electricity is one of the basic requirements for everyday life. However, most of the rural areas in Nigeria still uses diesel or other fossil fuelled generators as their major source of electricity generation (Benjamin *et al.*, 2013). Moreover, global climate change associated with energy production has intensified global concerns on the subject for sustainable development which caused the production of carbon monoxide, sulfur-dioxide and nitrogen-oxide that affect the environment. According to the World Health Organization, as many as 160,000 people die each year from the devastating effect of the global warming created in the environment (Hajat*et al.*, 2009).Maximizing utilization of renewable energy source, minimizing the cost of generating energy and minimizing the pollutant emissions are subject of the study(Parmal*et al*, 2010). This study is carried out to reduce the emission produce from diesel generator in remote villages of the country.

II. PREVIOUS WORK

Emmanuel (2011) made an analysis on the use of diesel generators and the pollution caused to the environment. The poisonous gases include NO, CO, unburnt hydrocarbons and CO_2 which is responsible for global warming. Nigeria is about the 7th largest market in the whole world and a terminus for all manners of diesel/fossil fuel powered generators worldwide. Telecommunication industry in Nigeria had problem of power supply, they installed 2 diesel generators at a base station with one working at a time, due to the epileptic power. These generators are run for months and therefore, incurred high operating costs from fuel and replacement of parts. These problems bring in search for alternative sustainable and economically viable power supply options like the solar PV system.Parmal*et al*, (2010)this paper presents a case study in Oman to reduce the carbon dioxide emission by diesel-photovoltaic based power system feeding to a house located in remote area. Model of

a hybrid power system comprising of a photovoltaic module, along with a diesel generator and essential auxiliary devices is proposed. The actual average solar radiation and residential load data, collected from the meteorological department and local utility office are used in this case study. The simulation result of the hybrid system is attractive to reduce carbon dioxideemission by 38% when compared to the diesel system alone, and by 2.67 % compared to the main interconnected system .The study also includes operational and per unit energy cost estimates. It is seen that the diesel-photovoltaic hybrid system is attractive in terms of operational costs, which is lower by 29.44% compared to the diesel system; while per unit energy cost is 12.08% lower.

Ajeigbe*et al.,* (2012) made a study and reveal that the, earth has twice as much carbon in it than it had two hundred years ago with much of theincrement occurring within the last 30 years. This carbon is being generated by human activities chiefly from burning of fossil fuel. With increasing energy demand, the tendency to burn more fossil fuel to meet this demand will only increase, thus this paper looks into the application of energy efficiency in meeting the energy needs without necessarily increasing power generation from fossil fuel thus abating the rapid increase of Green House Gases (GHG) in the atmosphere. It proffers suggestions that government at all level must implement energy efficiency and conservation policies in order to achieve energy efficiency in the energy sector and consequently reducing GHG emission and global warming.

III. METHODOLOGY

i. Load survey of the village was carried out by estimating for each and every household, 15% tolerance was considered (ECN, 2010) and losses of 5% were taken into consideration (Albadi*et al*., 2014) which gave a total load demand in Mararaba-Loko Village of Nasarawa State.
ii. Equal capacities of photovoltaic and diesel generating set were selected based on the total load demand calculated in (ii).
iii. The systems were compared based on the emission Per-Kilowatt release to the environment.

3.1 Environmental Effect of Running Solar Photovoltaic System and Diesel Generator

3.1.1Effect of solar photovoltaic systemon the environment

Photovoltaic System takes up its energy from the sun. The sun provides great resources for generating clean and sustainable electricity. This system works without toxic pollution and does not results to global warming, because it needs no fossil fuel for its operation (zero emission) except for the emission associated with other stages of solar life cycle called indirect emission of the system. This includes extraction, manufacturing and transportation of the materials (Upstream processes), plant and system operation (operational processes) and plant system decomposition and recycling of the system (Downstream processes). In indirect emission of photovoltaic system, carbon dioxide emission was estimated to be *40gCO_2 equivalen*t perkilowatt-hour (NREL, 2012).

This implies that, for 1kW of electricity generated from photovoltaic system *40gCO_2equivalent* is emitted and added to the existing greenhouse gasses in the space.

According to Fukurozaki*et al.,* (2013) and David *et al*., (2012), equation 1 and 2 were used to determine the amount of CO_2 emitted from a photovoltaic system to the atmosphere.

$$GHG = \frac{W}{I \times \eta \times PR \times LT \times A} \quad \text{..... (1)}$$

Where:

GHG = Mass emission of greenhouse gas weight by global warming potential per unit electricity generated
W= Mass of greenhouse gas emitted over the life time (g $C0_2$ equivalent)
I= Irradiation of the area (kWh/m^2/yr)
ɻ=Life time average module efficiency
PR =Performance ratio
LT=System life time
A=Area of the total photovoltaic system module (m^2)

W = 40gCO_2 from (NREL, 2012). I = 4.0kWh/m^2/day, PR= 0.85 from (Solar server, 2010) ɻ=0.13, LT=30 years
A= 343.964m^2

$$GHG = \frac{40 \times 2{,}125{,}494}{4 \times 0.13 \times 0.85 \times 30 \times 343.964}$$

$$GHG = 18641\ g\ CO_{2\ equivalent}$$

Therefore,

$$\text{Amount of } CO_2 \text{ emitted to the atmosphere} = \frac{LCCO_2(g\ CO_2\ Equivalent)}{AEO\ (kWh/Years \times PV_{LifeTime})} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
$LCCO_2$ = Total life cycle CO_2 emission
AEO = Average Energy Demand
PV life time = PV Life Span

$$Amount\ of\ CO_2\ emission\ at\ the\ life\ span\ of\ 30\ years = \frac{18641}{194.109 \times 365 \times 30} = 9 \times 10^{-3}\ g\ CO_{2\ equivalent}$$

3.1.2 Effect of diesel generator to the environment

The amount of carbon dioxide produced from the combustion of every litre of diesel fuel consumed depends on the type of generator and characteristic of diesel fuel .It usually falls between 2.4kg/l and 2.8kg/l range irrespective of the characteristic of the fuel used (Agajelu,2012). For electricity generation in Mararaba-Loko Zone (A) Village, the amount of carbon dioxide emitted to the atmosphere when one kilowatt of power is generated is 0.27($kgCO_2$/kWh)(Volker Quaschning.de, 2015). Data of various carbon dioxide emission rates per kilowatt hour were represented in table 3.1

Therefore, the amount of carbon dioxide emitted to the atmosphere in 30 years of running 27kVA Perkins diesel **g**enerator is calculated using equation (3.):

Table: 3.1 Emission of various Fuels in kg/kWh

S/N	Fuel type	Emission of CO_2 in (kg/kWh)
1	Diesel	0.27
2	Petrol	0.25
3	LPG	0.23

Source: (Volker Quaschning.de, 2015)

$$CO_2\ Emission\ rate = Emission\ in\ g/(kWh) \times Life\ cycle\ energy\ demand\ (kWh) \ldots\ldots\ldots\ldots (3)$$

CO_2 Emission = 270×2,125,494
CO_2 Emission Rate = 573,883,380 $gCO_{2equivalent}$

IV. RESULTS AND DISCUSSION

Table 4 .1Analyses of Electrical Load Demand Survey Conducted in Mararaba- Loko Zone (A) Village of Nasarawa State.

Table 4.1 Power Demand /Load Estimation of Mararaba- Loko Zone (A) Village

Electrical Load	Quantity	Rating(W)	Total power(W)	Hour of Usage per day	Energy demand per day(Wh/day)	%Energy consumption
Lighting point	286	14	4004	10	40040	20.62758553
Fan	108	65	7020	12	84240	43.39829683
TV set	51	85	4335	5	21675	11.1664065
Radio	51	30	1530	10	15300	7.882169297
DVD	23	25	575	5	2875	1.481126584
Decoder	23	25	575	5	2875	1.481126584
Antenna	28	5	140	5	700	0.360622125
15% Tolerance			2727	7	19089	9.83416534
5% Losses added			1045	7	7315	3.768501203
Total			**21951**		**194109**	100

Total Load demand for Mararaba- Loko Zone (A) Village ≈ 22kWp
Energy Demand per day= 194.109kWh/day

Local Government = Karu Local Government of Nasarawa State
Longitude and Latitude of the Area =Latitude $8^0.51^1$N and Longitude $7^0.36^1$E
Numbers of households = 52 numbers

Table 4.2 Carbon dioxideEmission Rate of Photovoltaic

Diesel Generator System for 30 years

PV LT(Year)	ACO_2 (gCO_2eq)	CO_2 ER (gCO2eq)
1	2.63E-01	1.91E+07
2	1.32E-01	3.83E+07
3	8.77E-02	5.74E+07
4	6.58E-02	7.65E+07
5	5.26E-02	9.57E+07
6	4.39E-02	1.15E+08
7	3.76E-02	1.34E+08
8	3.29E-02	1.53E+08
9	2.92E-02	1.72E+08
10	2.63E-02	1.91E+08
11	2.39E-02	2.10E+08
12	2.19E-02	2.30E+08
13	2.02E-02	2.49E+08
14	1.88E-02	2.68E+08
15	1.75E-02	2.87E+08
16	1.64E-02	3.06E+08
17	1.54E-02	3.25E+08
18	1.46E-02	3.44E+08
19	1.38E-02	3.64E+08
20	1.31E-02	3.83E+08
21	1.25E-02	4.02E+08
22	1.19E-02	4.21E+08
23	1.14E-02	4.40E+08
24	1.09E-02	4.59E+08
25	1.05E-02	4.78E+08
26	1.01E-02	4.97E+08
27	9.74E-03	5.17E+08
28	9.40E-03	5.36E+08
29	9.07E-03	5.55E+08
30	8.77E-03	5.74E+08

Where.
PV LT = Photovoltaic life time
ACO_2 = Amount of carbon dioxide release from photovoltaic system to the atmosphere
CO_2 ER = Amount of carbon dioxide release from diesel generator to the atmosphere

Photovoltaic Generator Emission Graph

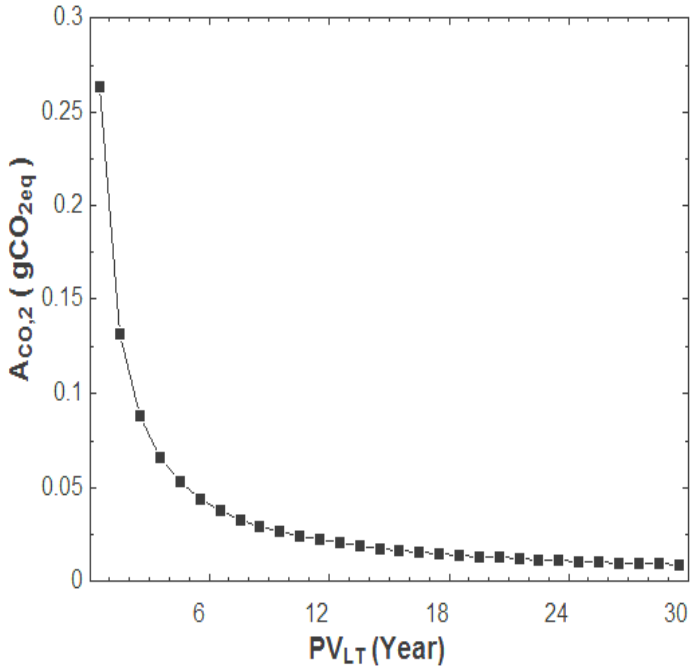

Figure 4.1: CO2 Emission Rate in Photovoltaic Plant in Mararaba- Loko Village

Diesel Generator Emission Graph

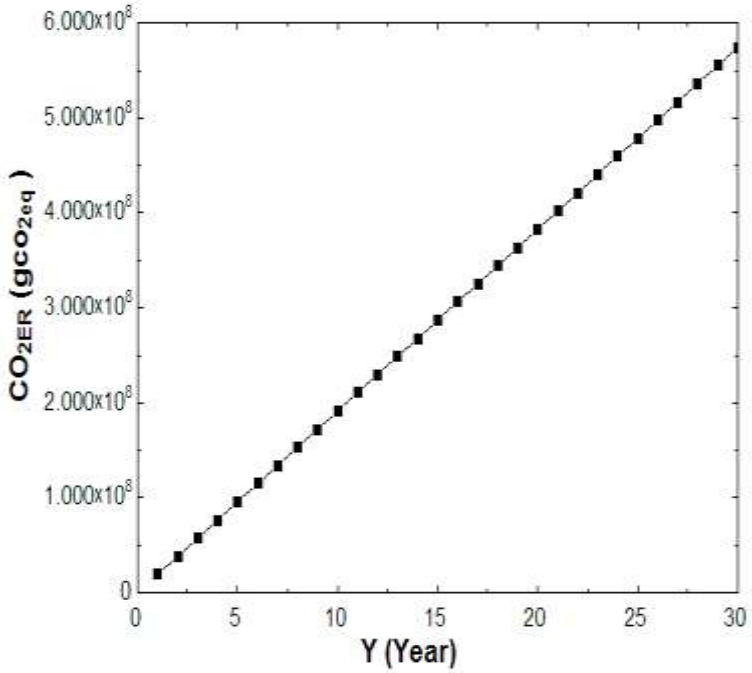

Figure 4.2: CO_2Emission Rate in a DieselGenerator in Mararaba- Loko Village

V. DISCUSSION

Table 4.1 shows the village load analysis and the power rating of the selected systems for powering the village. It gave details energy demand to be 194.109 kWh/day and output energy for the duration of 30 years to be 2,125,494 kWh, used to estimate the total emission rate for the duration of 30 years.

Figure 4.1 and 4.2 showed a graphical representation of the two systems with respect to the emission rate. It was deduced that *573,883,380g$CO_{2equivalent}$* would be release to the atmosphere in 30 years, which will add to the existing pollution in the atmosphere causing global warming. According to the world health organization, thousands of people die every year because of this effect (Hajat*et al.*, 2009). Hence, Photovoltaic system is

environmentally friendly (no fuel involved) and is sustainable. Though, carbon dioxide emission released due to using photovoltaic system was a result of indirect emission estimated to be $9\times10^{-3}gCO_2equivalent$ and the emission rate decreases gradually. The emission rate of photovoltaic system was insignificant compared to the diesel generator emission rate.

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