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ENERGY BALANCE ANALYSIS; CASE STUDY OF RURAL ELECTRIFICATION AGENCY (REA) PROJECT IN UNIVERSITY OF MAIDUGURI

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ABSTRACT

University of Maiduguri has been faced with power supply challenges due to insurgency that negatively affects the north eastern part of Nigeria. Being a research institution, increases in the costs of power and instability of on-grid power supply have jetlagged almost comatose research and academic activates. Government through the Rural Electrification Agency (REA) has provided the University with solar powered streetlights to curb energy consumption and to improve security. This study performed comparative energy cost analysis between solar photovoltaics streetlights executed by REA and public powered streetlights to evaluate energy costs. The objective of this study is to analyse the cost benefits of using solar photovoltaics streetlights, against public powered streetlight. The analyses showed 58% savings in energy costs as against 7.99% rise for public powered streetlights in 2019. The usage of solar photovoltaic streetlights has saved the University of Maiduguri close to 14.8 million Naira from year 2017 to 2019 using 134 solar streetlights poles with 77.22% fil factor.

Keywords: Energy Balance, solar photovoltaic streetlight, public powered streetlight

INTRODUCTION

Energy study is the perfect statistical method of energy accounting that provides micro insights to institutions, companies and economies. Energy study permits consumers to know the total amount of energy collected from the environment, traded, transformed, and used by consumers. Energy Study brings a perfect vision of energy state of a nation in a firm format, like the energy usage of the entire economy and of specific sectors (European Commission, 2019).

Bogmans *et al*. (2020) stated that energy is a vital part of economic systems as a lot of durable goods (electronic devices like washers, refrigerators, air conditioners, television, etc) need energy to function. Growth in energy usage is linked to rise in durable goods usage. As a nation arrives higher incomes, the edge between manufacturers and users of durable goods services can arrive at a satiation point. That means income level can cause satisfaction in energy demands. International Monetary Fund (IMF) 2022 report emphasize the need to carry out an estimation of the coefficient on energy efficiency. Comprehensively in line with their prior studies a 10% rise in energy efficiency is related to 8.8% reduction in CO_2 emissions.

According to a 2019 joint report from International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nation Statistics Division (UNSD), World Bank (WB), World Health Organization (WHO), which indicated that renewable electricity usage increased by 8% in 2016; its share value grew by 1% point to arrive at 24% which represents a rapid percentage rise since 1990 and more than twice of the increase in 2015. Also, the active involvement of United Nation Development Program (UNDP) has progressively aided countries to involve energy in planning to achieve sustainable development goals (UNDP 2021). Chanchangi *et al.* (2022) suggested the problem of energy in Nigeria affects both rural and urban populations with negative impacts to rural areas where most of the population do not have access to national grid while in urban locations most Nigerians use fossil-fuel powered generator leading to rise in greenhouse emissions. IRENA 2022 report showed that the global percentage of electricity from commissioned utility-solar photovoltaic projects dropped by 85% from 2010 to 2020. However, it projects solar power to surpass 5200 gigawatts by 2030.

Bello (2021), noted the need for Nigerian government to invest in renewable energy as it is the first action that needs to be taken in accomplishing an energy transition from fossil-based fuels to present day environmentally friendly alternatives. Achieving this will encourage other methods of energy generation and decentralized energy suppliers to emerge. Laudable energy technologies should be backed by political will as it will strengthen decentralized small scale energy markets to evolves as it has been practiced in United States where department of Energy (DOE) has obligated Environmental Pollution Control Authority (EPCA) to carry out periodical research that will bring more technological breakthroughs leading to a more noticeable energy savings. In India, mini-grids systems and national grid are used as partners in the success of achieving access to dependable electricity for the nation. This tells of the rapid development of renewable off-grid sources of energy like the solar photovoltaic (Herbert, 2022).

In Nigeria the Federal Executive Council of Nigeria in 2016 implemented the National Renewable Energy Action Plan in line with ECOWAS Renewable Energy Policy (ERRP) to strategize roadmaps for implementation of renewable energy in Nigeria (Daudu & Idehen, 2021). Under this act Rural Electrification Agency (REA) embarked on providing 37 Federal Universities and & University Teaching Hospitals with independent solar power plants. Currently, Rural Electrification Agency (REA) under Energizing Education Project (EEP) has connected 9 (nine) federal universities and one university teaching hospital with a combine 28.5MW of solar hybrid/gas-fired captive power plant (REA, 2023).

This study aims to provide insights on energy balance in the University of Maiduguri from 2017 to 2019 using energy balance analyses between solar photovoltaic and public powered streetlights to determine operational costs and to detemine evaluate the performance solar photovoltaic street poles.

MATERIALS AND METHOD

Materials

The following are the materials that were used:

i. Microsoft-Excel
ii. Solar photovoltaic efficiency formulae
iii. Solar photovoltaic cell fill factor formula

Method

This research is focused on the cost benefit analysis and performance of photovoltaic standalone streetlight in University of Maiduguri using statistical method and data analysis software.

Method of Data Collection

Major data for the study were collected through physical interview with Engineers in the procurement unit of University of Maiduguri. The Engineers answered key questions concerning the solar photovoltaic streetlight within in the institution, questions concerning number of recently installed standalone streetlight, capacity of batteries, wattage of the LED bulb and type of photovoltaic panels deployed. Additionally, secondary data were gotten from published and unpublished articles, information on energy cost per kilowatt were gotten from Nigerian Electricity Regulatory Commission homepage.

Area of Study

The area of study is University of Maiduguri, established by the Federal Government of Nigeria in 1975 and located in Borno State, in the North Eastern part of Nigeria with an estimate of 20,000 enrolled students (UNIMAID, 2020).

Method of Data Analysis

Data analyses were performed to evaluate three parameters:

i. Energy costs of solar photovoltaic streetlight per kwh and energy cost of sodium vapor public power dependent streetlight per kwh
ii. The benefits of the photovoltaic panel over public power supply base on energy costs analysis
iii. The solar panel efficiency and fill factor.

Energy Consumption Rate

Table 1 shows the features of the solar photovoltaic (poly-crystalline) streetlight and the public power streetlight within University of Maiduguri.

Table 1: Data of the Streetlights in University of Maiduguri

	Features	Solar Streetlight	Public Powered Streetlight
1.	No. of poles	134	134
2.	Power rating (W)	160	250
3.	Duration of operation (hrs)	12	12

Table 2 shows the global average cost of solar photovoltaic power which was used to calculate the energy consumption of the solar photovoltaic streetlight.

Table 2: Global Average Cost of Solar Photovoltaic Power (IRENA, 2019)

	Global Average Cost of Solar Photovoltaic Power ($/kwh)		
Year	2017	2018	2019
$/kwh	0.10	0.085	0.048

Table 3 shows the cost of electricity tariff in Nigeria with various classes. Class A3 was used to calculate the energy consumption of the public powered streetlight.

Table 3: Yola Distribution Tariff (Nigerian Electricity Regulatory Commission, 2020)

Class/year	2017 (₦/kwh)	2018 (₦/kwh)	2019 (₦/kwh)
A3	49.01	50.49	53.00

Class A3 is the electricity tariff class designated for educational establishments, water boards, religious houses, government and teaching hospitals.

Energy Consumption

The energy consumed by the streetlights was calculated in naira per kilowatts-hour using (Equation 1)

$$₦/kwh = \frac{w \times time}{1000} \times ₦ \quad (1)$$

Where w is the streetlights wattage and ₦ is Naira (NERC, 2020).

Fill Factor

The fill factor (FF) defined as the ratio of the maximum power to the product of open circuit voltage and short circuit current estimates the quality of a solar cell. It is computed using equation 2. Vidyanandan (2017) indicated above 70% fill factor is acceptable.

$$\text{Fill-Factor} = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{sc}} \quad (2)$$

Where, V_{max} is the maximum voltage, I_{max} is the maximum current, V_{oc} is the open circuit voltage, I_{sc} is the short circuit current.

Solar Cell Efficiency

Solar cell efficiency is the ratio of electrical output power (in Watt) to the incident energy which is in the form of sunlight as shown in Equation 3 (RF wireless, 2023).

$$\eta_{max} = \frac{Pmax}{E \times A_c} \times 100\% \quad (3)$$

Where; P_{max} = maximum power output (W), E = incident radiation flux (W/m^2), A_C = Area of collector (m^2)

RESULTS AND DISCUSSION

With the data collected, the energy consumption of the solar photovoltaic streetlight was analysed with the fill factor and the efficiency of the photovoltaic calculated.

Energy Consumption Costs

In 2017, there was 127.8% decrease in energy consumption cost in solar photovoltaic streetlights than public powered streetlights which correspond to a money saving of 4.4 Million naira in savings for the university. Likewise, the university saved 4.8 Million naira in 2018 due to adoption of solar panels as seen in Figure 2. The savings in energy costs

is due to rising costs of public power. Similarly, in 2019 the university recorded a 90.2% savings in energy costs. This corresponds to 5.6 Million naira savings. Again, the rise is due to high prices of public power (Figure 3).

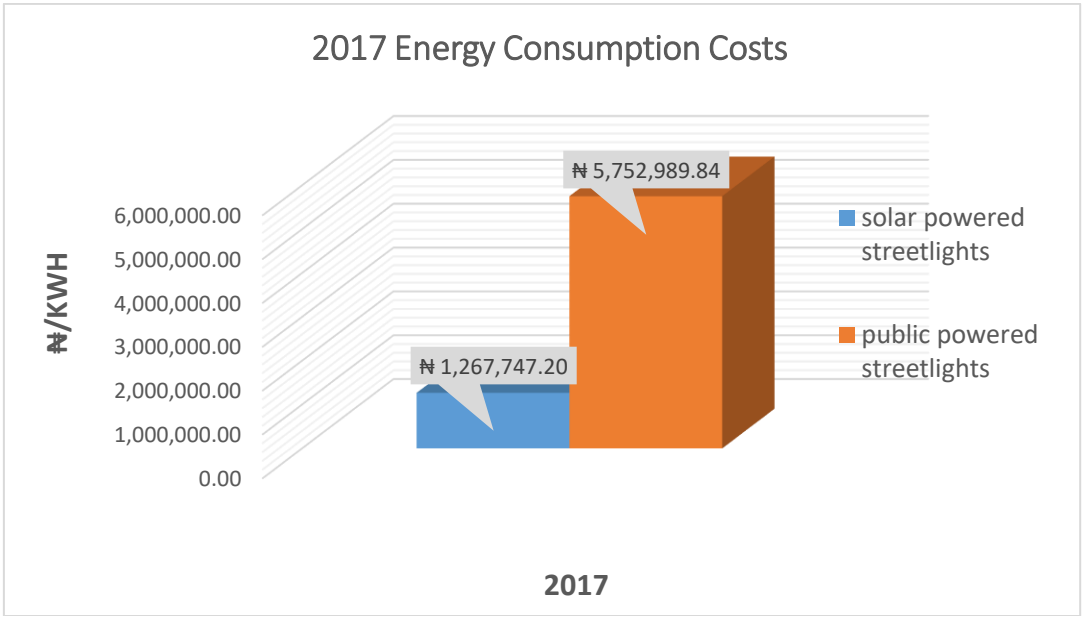

Figure 1: Energy Costs for Public Powered and Solar Streetlights in 2017

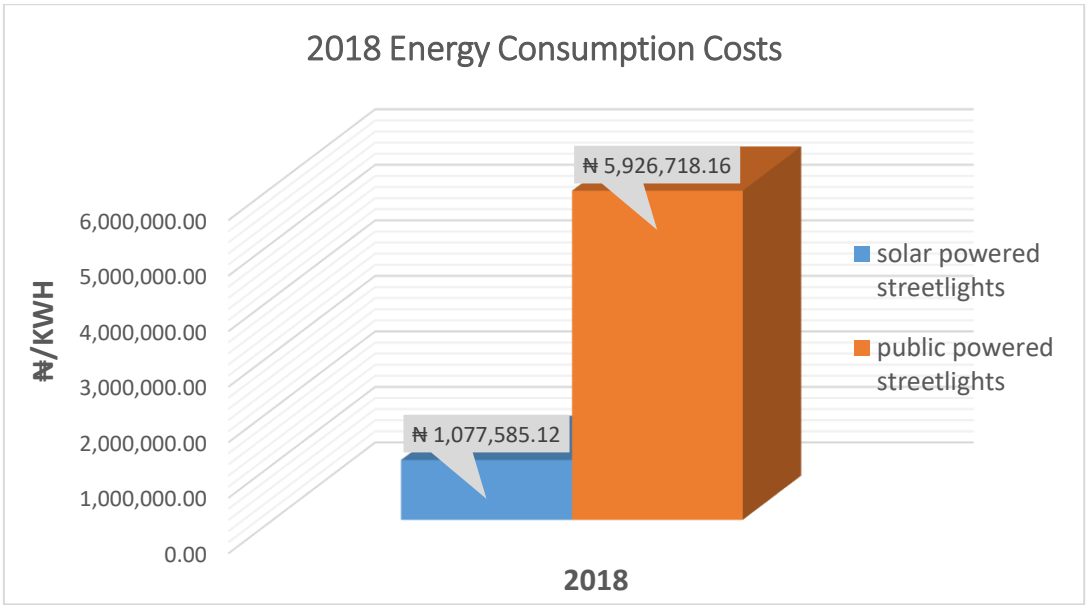

Figure 2: Energy Costs for Public Powered and Solar Streetlights in 2018

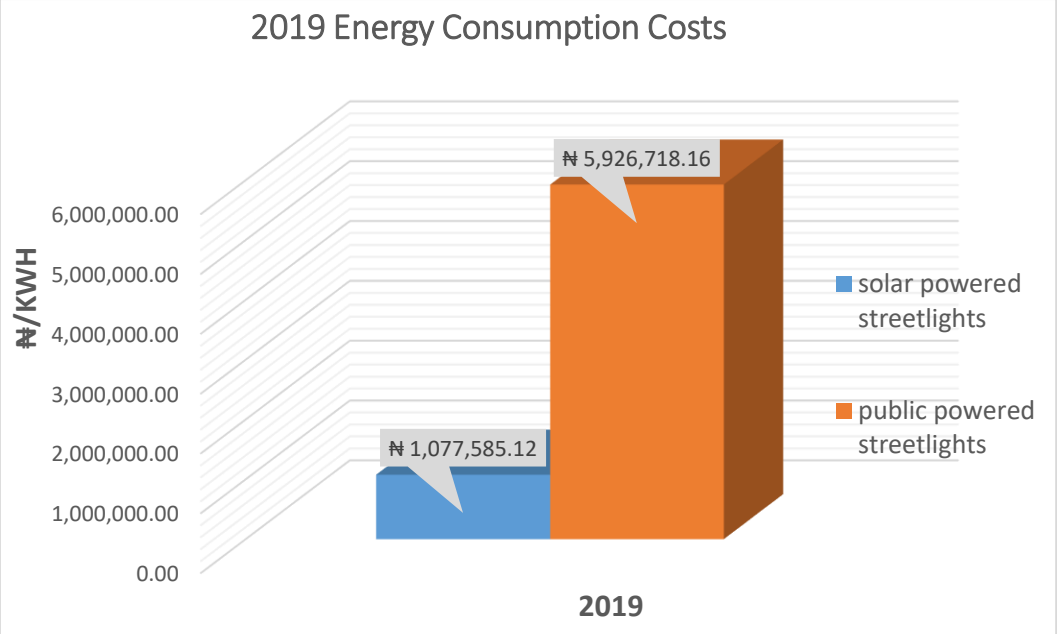

Figure 3: Cost of Energy for Public Powered and Solar Streetlights in 2019

Fill Factor

The fill factor of the solar panel was calculated using the data below:

Fill-Factor = $\frac{V_{max} \times I_{max}}{V_{oc} \times I_{sc}}$

Fill Factor = 77.22%

This value is in agreement with average value stated by Vidyanandan (2017). That signifies the solar panels are of great quality.

Solar Cell Efficiency

The efficiency of the cell was calculated using the data below:

$\eta_{max} = \frac{Pmax}{E \times A_c} \times 100\%$

= 15.69 %

The efficiency of the solar panel is 15.69% which is within the average working efficiency of a solar panel because of the high solar irradiance in Maiduguri (266 W/m^2). This value is in agreement with results of study conducted by Abdulkarim et al, (2020). Additionally, Adeel et al. (2019) illustrated that the efficiency of a poly-crytalline photovoltaic to be within 13-16%. Furthermore, Fu et al. (2021) evalauated the power efficiency of regions with high sun irradiance and reported an avarage of 15.8% of solar panels conversion.

CONCLUSION

The findings of this research clearly establish that solar photovoltaic streetlight has cost benefits advantages over public powered streetlights as it has saved University of Maiduguri almost 14.8 million naira in the space of three years (2017 to 2019). This study highlights the impact of government interventions in public institutions to curb high energy consumption through introduction of energy saving technologies. With a 15.69% efficiency and 77.22% fill factor, the study has shown solar photovoltaic systems as suitable alternatives to anchor clean, affordable and environmentally friendly systems to drive green economy while saving costs.

RECOMMENDATION

With the findings of this research, the following are recommended:

i. The study should be expanded to the university community to provide valuation information towards solar installations within campus.
ii. Nigerian government should increase the capacity of Rural Electrification Agency to provide more decentralized energy technologies to cover all federal universities and rural communities.
iii. The Nigerian government should invest in research and development of solar energy as it is a suitable alternative with low production costs which can boost the economy of the nation.

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