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An Economic Based Analysis of Fossil Fuel Powered Generator and Solar Photovoltaic System as Complementary Electricity Source for a University Student's Room

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Abstract

Notwithstanding the reported hazardous effect of combustion of fossil fuel on humans and the environment, and the established viability of renewable energy source (in this case solar) as alternative sources of electricity in Nigeria; there seems to be increasing subscription to fossil fuel powered generators amongst regular university students living off campus. Beyond functionality and safety, the economic implication of acquiring and running an energy generating source seems to contribute significantly in the decision to adopt same. Similarly, student's propensity to choose an alternative electricity supply source is supposedly affected by this factor. There is therefore need for economic based analysis of the alternative sources. The results of an online based survey among the students and a mini experiment served as basis for and input data in the analysis. The cost implications as at the time of this research were obtained from local vendors, classified and used in the analysis. Net present worth, net annual worth, benefit-cost ratio and return on investment were measures employed in the analysis, and decision making was based on the set criteria. The result of the analysis shows that the challenger (solar photovoltaic system) could be more economical than the defender (fossil fuel powered generators) for the 5 years' study period, if the current electricity load of the selected student's room is optimized.

Keywords: Solar energy, Renewable Energy, Economic analysis, Fossil fuel

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1. Introduction

Availability of adequate supply of energy is germane to development of any nation [1,2,3]. Similarly, electricity is important in various sphere of human endeavor [4,5,6]. The effect of electrification in schools in enhancing literacy level and associated improvement in quality of education has also been reported [7,8,9]. According to Skelton et al. [10], extremely poor electricity infrastructure affects the performance of teachers and pupils negatively. The electricity situation in Nigeria with respect to:

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System Average Interruption Duration Index (SAIDI1) [11,12,13] and inaccessibility of supply by greater percentage of households in the country for over a century [14]; is incredible and disturbing.

Several attempts by the Nigerian government to have sustainable electricity for all have not yielded the expected result [15]. Chinwuko et al. [16] posit that the nation's electricity distribution infrastructure could be responsible for inadequate supply of electricity in the country. But for Sambo [17], Ajao et al. [18] and Gujba et al. [19], the electricity challenge in the country could be as a result of inadequate generation. The interest of the masses is no longer on who or what is responsible for the problem as many of the nation's populace have resorted to use of fossil powered generators of various capacities to augment supply from the national grid.

In order to have reliable electricity supply in Nigeria, residents as well as other category of users of electricity, usually have one or more alternative electricity supply sources. As at the time of this study, the average daily hours of power supply from the energy Distribution Companies (DISCOS) is less than eight (8) hours around the study area (Nnamdi Azikiwe University Awka campus and environs), and some days go by without power supply from the DISCOS. This indeed affects the productivity of the students.

Although, a sizable fraction of the students living off campus have ameliorated this inadequate electricity supply through the use of fossil fuel powered generators, the use of fossil fuel powered generators has been reported to pose serious threat to the environment, and there is call for switch to renewable energy sources [20,21].

Solar energy, one of the renewable energy sources, is described as clean energy source with no emission of harmful gases [22]. It is also characterized by zero noise pollution and low maintenance cost. Nigeria is located in the solar belt with an average sunshine of up to 9 hours per day, equivalent to 5.5 $kWhm^{-2}$ $days^{-1}$ degrees of solar radiation are seen almost throughout the year [23]. According to Blacshke et al. [24], solar energy possesses the potential to adequately fulfil the global energy need. About 4×10^6 EJ of solar energy reaches the earth annually, and 5×10^4 EJ of these could be harnessed [22], and could be used via photovoltaic technology and solar thermal technology [25]. According to Mohanty et al. [26], solar photovoltaic system has enjoyed more acceptability in Africa than other Renewable Energy (RE) sources like Wind, Biomass, Geo-thermal and Wave.

Interestingly, Nigeria's solar radiation distribution favors the use of solar energy [27,23]; Yet a preliminary survey shows that the subscription rate amongst students living off campus in Nnamdi Azikiwe University, Awka campus is surprisingly very low (3.7% of the 400 respondents). Aliyu et al [23] reported similar situation concerning the energy mix in Nigeria as a whole. According to Ohunakin et al [28], major subscription to the use solar-PV plants for electricity generation across the country has been among learning and research institutions, government and international agencies.

Several policies have been made to enhance the adaptability of solar energy: The 2003 national energy policy [29, 30, 28]; The electric power sector reform Act of 2005 – aimed at tackling the historic energy crisis in Nigeria, through liberalization of the electricity generation industry [31, 32]. Shaaban et al [33] noted that beyond the broad objectives of the policy, other objectives of the policy include the development of the country's solar utilization capabilities.

Aside the satisfaction of the functionality quest in any design, the economic implication is the next important factor considered by users or customers. According to Bamiro and Ogunjobi [34], the prices of fuel types significantly affect choice of the fuel. Actually, the first (Purchasing and installation) cost of solar photovoltaic system is higher than that of the corresponding fossil fuel powered generators; thus, it is adjudged as being more expensive than the fossil fuel powered generators. Most of the interviewed students have not done a comparative economic analysis of the two alternatives, and 92.1% of the respondents wish to know the outcome of such analysis. Therefore, there is need for detailed economic analysis of the challenger (solar system) and the defender (fossil fuel powered generators) in an attempt to provide the students an economic basis (aside the environmental factor) for making informed decision.

The claims that electricity generation from solar energy with respect to Nigerian contest is cheap, stable, reliable and environmentally friendly [35], and several efforts made to reduce the first cost [36, 37], poses this thought provoking question: “why is there poor adoption level in the use of solar photovoltaic system for meeting electricity need, especially among students as shown by the result of the preliminary research amongst students”? Poor perception, orientation and understanding especially with respect to total cost of owning and using this system as compared to the predominantly used fossil fuel powered generators, seem to be the challenge.

2. Materials and Methods

2.1. Research Design

The observed significant effect of cost in choosing from alternative electricity sources, especially among Nigerian students, necessitated this study. The use of observed data and deductive reasoning was adopted in the analysis. The study was conducted via the following procedure:

a. Preliminary survey on electricity supply and consumption; use of alternative electricity generation source; and the application of economic techniques in choice of alternative sources amongst students was carried out, using Computer-Assisted Personal Interviewing (CAPI) system. A total of 431 students were interviewed.

b. A mini experiment was designed and carried out, to determine the fuel consumption rate for various generators’ capacities and load. This output served as input parameter in computing the total fuel consumption for the five years’ study period.

c. The total electricity load of a selected student room was calculated, and an appropriate solar photovoltaic system was designed for the room. The cost implication of installing and using the system was also computed. The cost implication of running a fossil fuel powered generator (most frequently used capacity – 0.95Kva) was computed for same electricity load. The two cost implications were compared economically based on 5 years’ study period and 15% minimum return on investment. Present Worth Analysis (PWA), Annual Worth Analysis (AWA), Benefit – Cost ratio (BCR), and Return on Investment (ROI) were used to decide on the preferred alternative.

d. The electricity load of the room was optimized by using energy saving appliances, and the corresponding design of the enhanced solar photovoltaic system was then compared economically against the fossil fuel powered generator.

2.2. Study Area

The study was conducted among Nnamdi Azikiwe University Awka students living off campus but around the university – Ifite-Awka, Okpuno, Amansea and Agu-Awka. The university is situated in Awka, in Awka- South local government area of Anambra state, in Nigeria.

2.3. Data Collection

Data was obtained using Computer-Assisted Personal Interviewing (CAPI) system in form of Google form, to ascertain: the electricity need (in hours) of an average student, and perception of students with respect to use of fossil powered generators and solar photovoltaic system. The fuel consumption rate under various load level was obtained via experiment. The power rating of a typical student room was obtained using observational guide administered by the research team. The cost of components of the solar photovoltaic system, the fossil fuel, and the generator were obtained from open market. Maintenance details for the generator and the components of the solar photovoltaic system were obtained from experts and online sources.

2.4. Method of Data Analysis

Descriptive statistics was employed in analysing the responses from the students and the result of the experiment. The cost implication of the two alternatives were computed for the study period of 5 years, which is the highest minimum student’s study period in Awka campus for regular students. Present worth Analysis (PWA), Benefit – Cost ratio (BCR), Return on Investment (ROI) were employed in analysis of the alternatives.

2.5. Design of Solar PV system

Figure 1 shows the block diagram of the solar PV system for electricity generation. From the figure 1, energy from the sun falls on the solar PV module which converts the solar energy to electrical energy in the form of direct current (dc). This electrical energy then charges the battery. The charge controller is used to regulate the rate of charging so as to protect the battery. It also boosts the rate of charging for Maximum Power Point Tracking (MPPT) charge controllers. The battery is then used to drive any dc load connected to it. This dc load can be dc bulb, TV, dc pumping machine, etc. On the other hand, if the load is alternating current (ac), the battery voltage then has to be converted to ac using an inverter. The inverter converts dc to ac and the resultant ac is used to drive ac load.

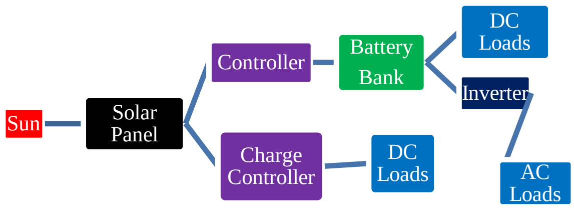

Figure 1. Block diagram of solar energy system for electricity generation.

In the design of the solar PV System, the power consumption (demands) of the facility were determined, and used to compute the appropriate size of PV modules, and subsequently for selection of inverter, battery size and appropriate solar charge controller.

The total Watt-peak rating needed for PV panels (TWPR) is computed using equation 1.

$$\mathrm{TWPRpvp} = \frac{1.3}{\mathrm{PGF}} * \sum_{i=1}^{n} W_i h_i \qquad (1)$$

Where:
W_i is the power rating of appliance i in watts, h_i is the number of hours' appliance i is to be powered by the solar photovoltaic system, n represents the total number of electricity powered appliances. Also, 1.3 was used as the factor of safety to accommodate for energy losses in the system. The PGF is a function of the climate of the region. According to Liu and Brandon [38] and Adewale et al [39], the panel generation factor (PGF) for Nigeria is approximately 3.41.

The minimum number of PV panels to be used is obtained by dividing the TWPR_{pvp} by the rated output Watt-peak of the selected PV modules, and rounded up to a whole number. The more the PV modules installed, the better the system performance and battery life. The battery size is selected using equation 2

$$\text{Battery Capacity (Ah)} = \frac{\mathrm{TWHPD_{APP}} * \mathrm{D_a}}{(0.85 \text{ x } 0.6 \text{ x NPV})} \qquad (2)$$

Where,

NPV = nominal battery voltage
$\mathrm{TWHPD_{APP}}$ = total watt-hours per day needed by the appliances
D_a = days of autonomy

The constant terms 0.85 and 0.6 are standards for taking care of battery loss and depth of discharge respectively. The days of autonomy are the number of days the system will have to operate without power supply from the PV panels. Based on rule of the thumb, for non MPPT charge controller, the sizing of solar charge controller is taken as 1.3 times the short circuit current (I_{sc}) of the PV array.

2.6. Economic Analysis of the Alternatives

The economic analysis is based on the net present worth, net annual worth, return on investment of the alternatives and benefit-cost ratio. In the case of net present worth and net annual worth, the alternative with higher net value becomes the preferred alternative. The interest rate adopted for the study was 15%, which is a little above the Central Bank of Nigeria (CBN) current interest rate for commercial bank (11.5%) as reported in Alonso [40].

For the benefit-cost ratio and the return on investment, the elimination of the defender's (fossil fuel powered generators) cost implication is taken as the benefit (or return), while the cost of using the challenger (solar photovoltaic system) becomes the cost (or the investment). If the ratio is positive, then the challenger is economically fit to replace the defender, else, replacement is not justified economically.

The double declining balance depreciation method was used in getting the salvage value of components whose life is specified. These components include: solar panel, battery, inverter and the generators. Equations 3 a – b were used in the computation Salvage value (book value) for period n (BV_t).

$$BV_t = BV_{t-1}(1 - 2 * r) \qquad 3a$$

$$r = (1/n) * 100 \qquad 3b$$

Where, r is the rate of depreciation; n is the useful life of component; and BV_t is the book value of the component at time t.

The net present worth and net annual worth of the alternatives were computed using the appropriate formulae based on the cash flow diagram. In the case of benefit- cost ratio, the net present worth of the cost implication of using fossil fuel powered generators was used as the benefit, while the net present worth of the cost implication of using the solar photovoltaic system served as the cost.

$$\mathrm{B/C} = \frac{\mathrm{NPW_{ffpg}}}{\mathrm{NPW_{spvs}}} \qquad (4a)$$

The value of the return on investment presents the extent of impact of an investment on the system. It measures this impact (savings, profit, interest or dividend) against the investment that lead to the impact. Here, the net present worth of the cost implication of using fossil fuel powered generators is the return, while the net present worth of the cost implication of using the solar photovoltaic system was used as the investment.

Actually,

$$\mathrm{ROI} = \frac{\mathrm{V_f - V_i}}{\mathrm{V_i}} * 100 \qquad (4b)$$

Where, V_f is the final value of investment, which includes dividend and interest; and V_i is the initial value of investment. The dividend and interest on the investment (use of solar photovoltaic system) is the savings made by replacing the defender with the challenger, which is 'net cost of running the defender – net cost of running the challenger' or 'net income from challenger – net income from defender'. But in this case where only the cost component is involved in the analysis, 'net cost of running the defender – net cost of running the challenger' was adopted.

V_f= initial value of investment + Dividend and /or interest = net cost of running the challenger + (net cost of running the defender – net cost of running the challenger)

= net cost of running the defender

Then, $V_f – V_i$ = net cost of running the defender – net cost of running the challenger

Therefore, based on equation 4b, the ROI for the case considered becomes:

$$\mathrm{ROI} = \frac{\mathrm{NPW_{ffpg} - NPW_{spvs}}}{\mathrm{NPW_{spvs}}} * 100 \qquad (4c)$$

2.7. The Student Room Sample Problem

The following appliances were found in the selected student's room, and the total load was computed using equation 1. The hours of use per day on alternative electricity source was obtained from a simple interview of the occupants (2 undergraduate students) of the room.

Table 1. Computation of Total Load for a Selected Student's Room

S/No	Appliance	Number of such appliance	Wattage per appliance (watts)	Hours of Use Per Day on alternative electricity source	Total Load (Kwh)
1	Lightning points	4	25	4	0.4
2	Laptop chargers	2	45	4	0.36
3	Phone chargers	4	5	1.5	0.03
4	Ceiling fan	1	80	4	0.32
5 5	Total power need of the appliances		290	Total load per day (Kwh/day)	1.11 Kwh/day
6	$\sum^{n}_{i=1} W_i h_i$= {(1.3/3.41)* TWPRpvp}				424 watt/day

The components of the solar photovoltaic system were then designed for the total Watt-peak rating in Table 1. The nominal battery voltage is 12 V, and the design is for 3 days of autonomy.

Table 2. Computation of Total Load for a Selected Student's Room

S/No	Parameter computed	Formular	Input parameter source	Value	Units
1	Number of PV panels needed	(Total Wp of PV)/110	table 1, s/no 6, column 6	3.86 ≃ 4	modules
2	Minimum inverter capacity	1.3* total wattage of appliances	table 1, s/no 5, column 4	377	watts
3	battery capacity (12v, 3 days of autonomy)	equation 2	table 1, s/no 5, column 6	544≃ 600	Ah
4	Solar charge controller capacity	1.3 * Number of PV panels * the Isc rating	table 2, s/no 1, column 5	39 ≃ 40	A

Hence, the system is expected to be powered by at least 4 modules of 110 Wp PV modules**.** The solar charge controller should be rated 40 A at 12 V or greater. The available PV module in the market has the following specification:

i. Pm = 110Wp
ii. Vm = 16.7Vdc
iii. Im = 6.6A
iv. Voc = 20.7A
v. Isc = 7.5A

Where, P_m, V_m, I_m are the power rating, permissible voltage and current for the module. V_{oc} and I_{sc} are the permissible voltage and current for the open circuit and short circuit respectively.

Result and Analysis of the Preliminary study

From the summary of the responses obtained from the respondents, it is gathered that 97% of the respondents are students of Nnamdi Azikiwe University, which translate to a total of 391 students. A sizeable number (64.8% of the respondents) live off campus and are directly responsible for meeting the shortfall in electricity supply from national grid, unlike what is obtainable in the university owned apartments. Most of the students (84.6% of the respondents) face power supply challenges and more than half of these students own a generator, most of which is 0.95 KVA.

Although, most of the respondents are not aware of the four economic analysis tools presented, 65.5% of the respondent feels that the solar photovoltaic system is more economical than the predominantly used fossil fuel powered generator, and only 3.7% of them subscribed to this renewable energy source. A further probe indicated that the first cost, which is usually very high, scares the prospective subscribers (students) away from this technology. Since 80.9% of the respondents live in self-contained room, the student sample problem was designed for a student living in such room.

The most interesting aspect of this preliminary study is the interest of the respondents in having economic basis for informed decision on which of these alternative electricity supply sources to subscribe to. Actually, 92.1% of the respondents wish to know the outcome of an economic analysis between the two alternatives, in order to enable them decide on which of them to adopt.

Table 3. Summary of Responses from the Administered Questionnaire

S/No	Questions	Responses
1	Are you a student of NnamdiAzikiwe University?	YES = 97% NO = 3%
2	Do you live on campus?	YES = 35.2% NO = 64.8%
3	What kind of apartment do you live in?	self-contained room = 80.9% 1Bedroom Apartment = 10.2% 2 Bedroom Apartment = 2.2% Flat = 6.7%
4	Are you facing power supply	YES = 84.6% NO = 11.2%

	challenges?	NOT SURE =4.2%
5	How many hours per day do you receive power supply on an average from EEDC?	0hrs/day =6.3% 1-3hrs /day = 35.7% 4-7hrs /day = 41.4% ≥ 8hrs /day = 16.6%
6	How many more hours do you wish you could receive this power supply?	1hrs/day =1.5% 2-4hrs /day = 0.5% 5-7hrs /day = 15.1% All day = 82.9%
7	Are there days you don't have power supply from EEDC?	YES = 96% NO = 4%
8	Do you own an electricity generating set?	YES = 59.1% NO = 40.9%
9	What is the size of your generator?	0.95KVA = 41.9% 1.1 KVA = 10.9% 2.5 KVA = 14.4% 3 KVA = 8.2% 4 KVA = NIL N/A = 18.4%
10	What is the average quantity of fuel(in litres) you consume per day?	1 Litre = 11.2% 2 Litres = 20.1% 3 Litres = 16.2% N/A = 44.5% >= 4 Litres = 8%
11	Do you have a photo voltaic system (solar panel) installed for your room?	YES = 3.7% NO = 96.3%
12	Which do you think is more economical?	Fossil Powered Fuel Generators = 27.8% Solar Photovoltaic System = 65.5% Not Sure = 6.7%
13	Have you done economic analysis on the two options?	YES = 24.3% NO = 65.3% NOT SURE = 10.4%
14	Do you know about present worth analysis?	YES = 15.9% NO = 67% NOT SURE = 17.1%
15	Do you know about return on investment?	YES = 43.4% NO = 44.7% NOT SURE = 11.9%
16	Do you know about annual worth analysis?	YES = 22.6% NO = 61.3% NOT SURE = 16.1%
17	Have you heard of replacement analysis?	YES = 18.6% NO = 69.7% NOT SURE = 11.7%
18	Would like to know the outcome of an economic analysis between this two to enable you decide on which to adopt?	YES = 92.1% NO = 7.9%

3. Results & Discussion

3.1 Result and Analysis of the Mini Experiment Conducted

A mini experiment was designed for the three most subscribed generators capacities (0.95, 1.1, and 2.5 KVA), to ascertain the rate of consumption of the fossil fuel (petrol) by these generators. The result is presented in table 4. It could be deduced from table 2 and table 4 that the capacity of the generator is much greater than the electrical load of the student's room, hence the electricity generating capacity of the generator is grossly underutilized. In industrial engineering, this is regarded as waste, and occurs because the generator is not designed based on the student's electricity need.

The 1.1 KVA generators consumed approximately same fuel per hour per watt as the 0.95 KVA. This is shown in the computed value of the fuel consumption in litre per hour per watt. Surprisingly, based on the result of the experiment, the generators with higher load consumed a little less fuel than their counterpart of same capacity with fewer loads.

Table 4. Result of the Experiment on Fuel Consumption by selected Generators

Generator type	Capacity (KVA)	Load (Watts)	Duration per litre (hours)	Fuel consumption (litre/hour)	Fuel consumption (litre/hour/watts)
Tiger	0.95	265	2.417	0.414	0.0016
Tiger	0.95	315	2.583	0.387	0.0012
Sumac firman	1.1	275	2.833	0.353	0.0013
Sumac firman	1.1	245	2.533	0.395	0.0016
Sumac firman	2.5	1166	1.1	0.909	0.0008
Sumac firman	2.5	465	2.117	0.472	0.001

The efficiency of the generator which is dependent on the age and level of maintenance was suspected. Nevertheless, the difference is not much. The 0.95KVA generator was adopted for the economic analysis, because most of the students that responded to our questionnaire (41.9%) use this capacity of generator. Actually, 51.36% of those who use generator use 0.95KVA generators. Most of the respondents run generator for 1 to 3 hours and 4 to 7 hours, 4 hours was chosen for the economic analysis.

3.2 Economic Analysis of Alternatives

The cost implication of installing and using the solar photovoltaic system is presented in Table 5. The values were obtained from a vendor who is also an expert in solar energy.

The total cost computed in Table 5 is the first cost, which comprises the procurement cost of the solar system components, installation materials and installation cost. There is no maintenance or operating cost. The only future cost/ income component is the salvage values for the three components with life (Inverter, Battery, Solar panel). It was computed using the double declining balance depreciation method, as shown in the equations 3a–b.

Table 5. Cost component of the solar photovoltaic systems

S/No	Components	Quantity needed (unit)	Unit cost ' 000 (#)	Total cost ' 000 (#)	Life (year)
1	Inverter (12v 900VA, pure sine wave)	1	55	55	5-10
2	Battery (deep cycle 12V-100Ah)	6	50	300	5-6
3	Charge controller(40A)	1	20	20	N/A
4	Solar panel(12v 150w)	4	30	120	20
5	6mm wire (10yards)	10	0.6	6	N/A
6	Change over	1	1.5	1.5	N/A
7	Aluminium rail, bolt and nut	N/A	4	4	N/A
8	Nail	N/A	0.5	0.5	N/A
9	Clips	N/A	0.5	0.5	N/A
10	1.5mm cable	1 yard	1.05	1.05	N/A
11	Installation fee	1	10	10	N/A
	Total		**518, 550**		

The cash flow diagram is presented in Figure 2.

The net present value for the Solar Photovoltaic System was computed based on the cash flow diagram in Figure 2:

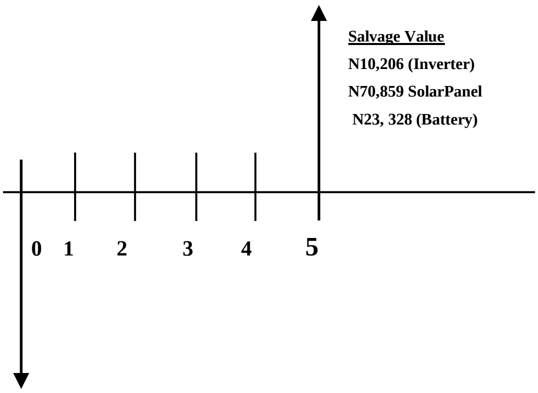

Figure 2. Cash Flow Diagram for the Solar Photovoltaic System

$$\mathrm{NPV_{spvs}} = -\mathrm{P} + F * (P/F\,, i\%\,, n) \quad (5a)$$

$$\begin{aligned}\mathrm{NPV_{spvs}} &= -518{,}550 + (10{,}206 + 70{,}859 + 23{,}328) * (P/F\,, 15\%\,, 5years)\\ &= -518{,}550 + (104{,}393) * (0.4972)\\ &= \mathbf{-N466{,}646.00}\end{aligned}$$

The net Annual value for the Solar Photovoltaic System was computed based on the cash flow diagram in Figure 2:

$$\mathrm{NAV_{spvs}} = -\mathrm{P} * (A/P\,, i\%\,, n) + F * (A/F\,, i\%\,, n) \quad (5b)$$

$$\begin{aligned}\mathrm{NAV_{spvs}} &= -518{,}550 * (A/P\,, 15\%\,, 5years) + (10{,}206 + 70{,}859 + 23{,}328) * (A/F\,, 15\%\,, 5years)\\ &= -518{,}550 * (0.2983) + (104{,}393) * (0.1483)\\ &= \mathbf{-N139{,}208.00}\end{aligned}$$

The cost implication for the use of fossil fuel generator is shown in Table 6. The amount of fuel required per year to run the generator was computed for: four (4) hours per day consumption (based on response from student living in the selected room - see Table 3); 25 days per month, excluding 5 days per month for absenteeism; 4 months per semester – based on regular school calendar; and2 semesters per year. The fuel consumption for the 0.95kva on full load was computed based on the result from Table 2. Hence, the total amount of fuel required per year is:

0.4 litres/hour *4 hours/ day * 25 days/ month * 4 months/ semester * 2 semester/ year = 320 liters/year.

Table 6. Cost of Running the fossil fuel powered generator

S/No	Components	Quantity needed	Unit cost ' 000 (#)	Total cost ' 000 (#)	Life	Type of cost
1	Generator (0.95kva)	1	45	45	5-10	First cost
2	Installation fee	1	3	3	n/a	First cost
3	Clips	n/a	0.5	0.5	n/a	First cost
4	Nails	n/a	0.5	0.5	n/a	First cost
5	1.5mm wire	3	0.34	1.02	n/a	First cost
6	Change over	1	1.5	1.5	n/a	First cost
	Total First Cost			**51,520**		
1	Plug	2	0.15	0.3	n/a	Annual cost
2	Maintenance	8	1	8	n/a	Annual cost
3	Fuel	320	0.17	54.4	n/a	Annual cost
4	Oil	320	0.1	32	n/a	Annual cost
	Total Annual Cost			**94,700**		

Each litre of fuel consumed is usually mixed with a measure of engine oil, which is purchase at #100 per measure. The plug is replaced after every session (approximately 1 year) and there is recommended monthly routine maintenance, which cost #1000 per maintenance. The associated costs were aggregated per year.

The salvage value of the generator was computed at the end of year 5, using equation 3 a - b. The cash flow diagram for the generator is presented in Figure 3.

The net present value for the Fossil Fuel Powered Generator (0.95KVA) was computed based on the cash flow diagram in Figure 3

$$\mathrm{NPV_{ffpg}} = -\mathrm{P} - A * (P/A\,, i\%\,, n) + F * (P/F\,, i\%\,, n) \quad (6a)$$

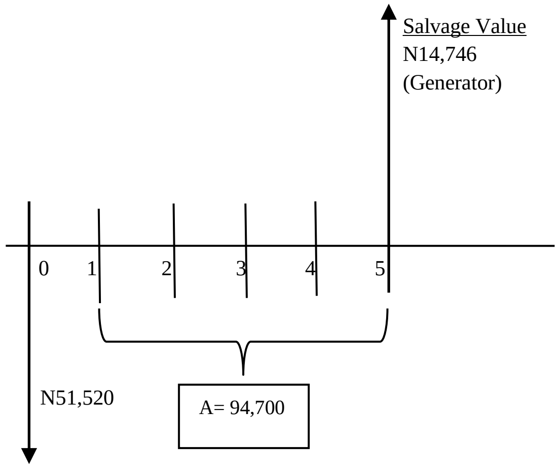

Figure 3. Cash Flow Diagram for the Fossil fuel powered generator

$$\mathrm{NPV_{ffpg}} = -51{,}520 - (94{,}700) * (P/A\,, 15\%\,, 5years) + (14{,}746) * (P/F\,, 15\%\,, 5years)$$
$$= -51{,}520 - (94700 * 3.3522) + (14{,}746 * 0.4972)$$
$$= \mathbf{-N361{,}642.00}$$

The net Annual worth/ value for the Fossil Fuel Powered Generator (0.95KVA) was computed based on the cash flow diagram in Figure 3.

$$\mathrm{NAV_{ffpg}} = -\mathrm{P} * (A/P, i\%\,, n) - A + F * (A/F\,, i\%\,, n) \qquad (6b)$$
$$\mathrm{NAV_{ffpg}} = -51{,}520 * (A/P\,, 15\%\,, 5years) - 94{,}700 + (14{,}746) * (A/F\,, 15\%\,, 5years)$$
$$= -(51{,}520 * 0.2983) - 94700 + (14{,}746 * 0.1483)$$
$$= \mathbf{-N107{,}882.00}$$

The Benefit – cost ratio with respect to the solar photovoltaic system is calculated using equation 4a:

$$\mathrm{B}/_{\mathrm{C}} = -\mathrm{N}361{,}642.00/-\mathrm{N}466{,}646.00$$
$$= \mathbf{0.775}$$

The Return on Investment with respect to the solar photovoltaic system is calculated using equation 4c:

$$\mathrm{ROI} = (-\mathrm{N}361{,}642.00 - (-\mathrm{N}466{,}646.00)/(-\mathrm{N}466{,}646.00))*100$$
$$= \mathbf{-22.5\%}$$

The net present and annual values for the fossil fuel powered generator were higher than that of the corresponding solar photovoltaic system. Hence, fossil fuel powered generator became the preferred alternative. Also the result of the benefit-cost ratio and return on investment confirms that replacement of the fossil fuel powered generator with corresponding solar photovoltaic system is actually not economically beneficial, based on the current electricity load of the room studied.

The electricity load of the student room was then optimized, by using less energy demanding appliances as shown in table 7, which resulted in the redesign of the solar photovoltaic system suitable for the optimized load. The cost components were obtained and economic analysis of the redesigned system was carried out. Since there were no significant changes in the generator's fuel and oil consumption rates. Hence the initial cost implication, NPV and NAV were unchanged.

Table 7. Computation for the optimized Total Load in a Selected Student's Room

S/No	Appliance	Number of appliance	Wattage (watts)	Duration of Use Per Day on SPVS (hours)	Total Load (Kwh)
1	Lightning points	4	5	4	0.08
2	Laptop chargers	2	45	2	0.18
3	Phone chargers	4	5	1.5	0.03
4	Standing fan	1	15	4	0.06
5		Total power need for the room	145	Total load per day (Kwh/day)	0.35 Kwh/day

$$\mathrm{TWPRpvp} = \{(1.3/3.41) * \textstyle\sum_{i=1}^{n} \mathrm{W_i h_i}\} \qquad (7)$$
$$= \left(\frac{1.3}{3.41}\right) * 350\mathrm{watthour}$$
$$= 133.43 \text{ watt/day}$$

The components of the solar photovoltaic system were then redesigned for the load calculated in Table 8. The nominal battery voltage is 12 V, and the design is for 3 days of autonomy.

Table 8. Recomputed values of Total Load for a Selected Student's Room

S/No	Parameter computed	Formular	Input parameter source	Value	Units
1	Number of PV panels needed	(Total Wp of PV) /110	eqaution 7	1.2≃ 2	Units
2	Minimum inverter capacity	1.3* total wattage of appliances	Table 7, s/no 5 Column 4	189	Watts
3	Battery sizing	Equation 2	eqaution 7	223.04 ≃ 300	Ah
4	Solar charge controller capacity	1.3 * Number of PV panels * the I_{sc} rating	Table 8 s/no 2 Column 5	19.5 ≃ 20	A

The selected battery size is for 12V battery and 3 days of autonomy. The system is expected to be powered by at least 4 modules of 110 Wp PV module**.** The available PV module in the market has the following specification:

i. Pm = 110Wp
ii. Vm = 16.7Vdc
iii. Im = 6.6A
iv. Voc = 20.7A
v. Isc = 7.5A

The cost implication of installing and using the solar photovoltaic system for the optimized load is presented in Table 9. The cash flow for the purchase and use of the system is presented in Figure 4.

Optimization of the electricity load in the room through the use of energy saving appliance gave 42.43% reduction in the initial cost of the solar photovoltaic system, and a 30.18% reduction in the salvage value. Optimization of the load did not affect the generator specification (being the lowest obtainable model), nor the fuel and oil consumption. Hence the cost implication is same as shown in Table 6.

Table 9. Cost component of the solar photovoltaic systems for the optimized load

S/No	Components	Quantity needed (unit)	Unit cost ' 000 (#)	Total cost ' 000 (#)	Life (years)
1	Inverter (12v 900VA)	1	55	55	5-10
2	Battery (deep cycle 12V-100Ah)	3	50	150	5- 6
3	Charge controller (20A)	1	10	10	n/a
4	Solar panel (12v 150w)	2	30	60	20
5	6mm wire (10yards)	10	0.6	6	n/a
6	Change over	1	1.5	1.5	n/a
7	Aluminum rail, bolt and nut	n/a	4	4	n/a
8	Nail	n/a	0.5	0.5	n/a
9	Clips	n/a	0.5	0.5	n/a
10	1.5mm cable	1 yard	1.0 5	1.0 5	n/a
11	Installation fee	1	10	10	n/a
	Total			**298, 550**	

The net present value for the Solar Photovoltaic System is computed based on the cash flow diagram in Figure 4:

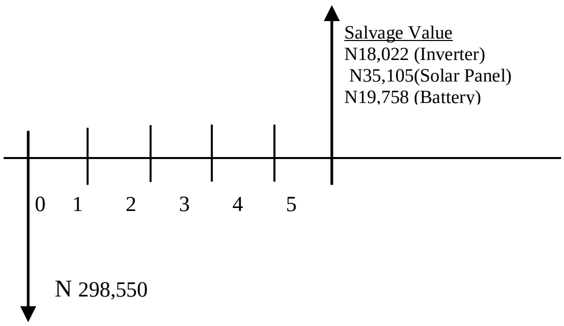

Figure 4. Cash Flow Diagram for the Solar Photovoltaic System

$$\begin{aligned}\mathrm{NPV_{spvs}} &= -298{,}550 \\ &\quad + (18{,}022 + 35{,}105 + 19{,}758) \\ &\quad * (p/f\ , 15\%\ ,5years) \\ &= -298{,}550 + (72{,}885) * (0.4972) \\ &= \mathbf{-N\ 262,\ 312.00}\end{aligned}$$

The net Annual worth/ value for the Solar Photovoltaic System is computed using equation 3.7a:

$$\begin{aligned}\mathrm{NAV_{spvs}} &= -298{,}550 * (A/P\ , 15\%\ ,5years) \\ &\quad + (18{,}022 + 35{,}105 + 19{,}758) \\ &\quad * (A/F\ , 15\%\ ,5years) \\ &= -298{,}5500 * (0.2983) + (72{,}885) * (0.1483) \\ &= \boldsymbol{-N78,248.60}\end{aligned}$$

The new Benefit – cost ratio with respect to the solar photovoltaic system is calculated using equation 3.8a:

$$^{\mathrm{B}}/_{\mathrm{C}} = \frac{-\mathrm{N}361{,}642.00}{-\mathrm{N}262{,}312.00} = \mathbf{1.38}$$

The Return on Investment with respect to the solar photovoltaic system is calculated using equation 3.8c:

$$\mathrm{ROI} = \left(\frac{-\mathrm{N}361{,}642.00 - (-\mathrm{N}262{,}312.00)}{-\mathrm{N}262{,}312.00}\right) * 100 = \mathbf{37.87}\%$$

The computed net present and annual worth of the redesigned solar photovoltaic system were better than that of the fossil fuel powered generator. It is now cheaper to run the solar photovoltaic system. Also the computed benefit-cost ratio was found to be greater than 1, which confirms that replacement of the fossil fuel powered generator with the redesigned solar photovoltaic system is actually beneficial. Finally, a 37.87% return on investment was obtained. It is profitable to invest in the solar photovoltaic system.

From the analysis presented above, it is clear that replacement of the fossil fuel powered generators with the redesigned solar photovoltaic system, based on the optimized electricity load of the room studied, is economical and a profitable venture.

4. **Conclusions**

Sequel to the results obtained from the study, the following conclusions can be drawn:

I. The suitability of using solar energy as a renewable energy source in mitigating the electricity challenges in Nigeria has been widely reported. Albeit, Nnamdi Azikiwe University students that are living off campus in Awka and environ seem to have a bias perception on the viability of solar photovoltaic system as suitable alternative to the predominantly used fossil fuel powered electricity generators. The high acquisition cost of solar photovoltaic system seems to be the reason for such perception.

II. Based on the initial electricity load of the selected student's room, when compared with the predominantly used fossil fuel powered electricity generators (0.95KVA), the use of solar photovoltaic system was found to be less economical for the students living in one room apartment for the 5 years' study period. But, optimization (minimization) of the electricity load by using modern energy saving appliances, reduced the initial acquisition and installation cost for the solar photovoltaic system by 42.43%. Consequently, the result of the economic analysis suggests that the use of solar photovoltaic system to meet the student's electricity need will be more economical than the fossil fuel powered electricity generators.

III. The annual worth of the improved solar photovoltaic system (- #78,248.60), which is less than the annual maintenance and running cost of the fossil fuel powered generator (#94,700.00), could be used as feasible repayment plan for the students. The vendors or manufacturers of the components of the solar photovoltaic system could consider this plan in order to improve subscription to this alternative that was hitherto hindered by very high first cost.

Considering the importance of cost in the choice of design or alternative product, more of such economic studies among alternative energy sources will be germane in such decision making. A good attempt to further reduce the procurement and installation cost will encourage the students to subscribe to this alternative (Solar photovoltaic system), which beyond the established economic benefits, provides environmental and health benefit for the community.

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