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Solar Photovoltaic System: A Case Study of Akure, Nigeria

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ABSTRACT

Erratic supply of electricity to residential buildings has led many occupants/owners to source for alternative sources to complement the epileptic supply from the National Grid. The sun produces energy expense-free, which is being untapped in this part of the country and thus the energy of the sun is being wasted. This energy can easily be converted to electric power for use in both in residential areas and industrial sectors through solar photovoltaic (PV) system. This paper assessed the level of awareness, adoption and barriers as related to solar PV system in Akure by assessing one hundred and fifty (150) residential buildings randomly with a structured questionnaire administered to the occupants/owners. The findings revealed that; a large percentage of the residential buildings make use of diesel/petrol generating set as an alternative to the National grid, that the level of awareness of solar PV is significantly low, the willingness to adopt is high but it's hindered by cost implication of the system. The study's findings contribute to the growing literature in the adoption of renewable energy for electricity generation, highlighted the major barriers hindering this for effective solutions to be proffer. It also provides a prospective market for those interested in the solar energy market.

Keywords: Energy generation, Solar Photovoltaic (PV), Residential buildings, Akure (Ondo State), National Grid

1. INTRODUCTION

Electricity is one of the main drivers of development; it has a major impact on every aspect of our socioeconomic life. It is used in residential buildings, commercial buildings, and industrial buildings. The source of electricity in most Nigeria residential buildings is through the National Grid. According to statistics, in Nigeria, less than 40% of the country is connected to the national grid and less than 60% of the energy demand by this group is generated and distributed (Akinboro, Adejunobi & Makinde, 2012). An emerging means of generating electricity is through the solar photovoltaic cells installation, not much research and development have been carried out on it and associated devices (Adeyemo, 2013).

Solar panels are a form of photoelectric or thermoelectric processes of conversion of solar energy directly to electrical energy. In Nigeria, the use of solar panels in power generation in residential architecture has not been too encouraging. This may be due to the cost, technology or awareness (Aminu, 2011). A sizeable number of Nigerians are unaware that the solar PV can power a whole building and not limited to street light with which they are conversant. The erratic and epileptic nature of the power supply from the National Grid has led to many emerging alternatives of power supply to the residential buildings; the most common is the diesel generator, inverter with batteries and recently Solar PV (which is being used by a very low percentage of the populace). The use of standalone solar PV installations does not require transformer, high or low-tension wiring, equipment and logistics involved in the distribution of electricity, which means the solar PV (panels) can easily be carried, deployed and installed on individual establishment and premises in any part of the country at low cost within a very short period (Akinboro *et al*., 2012).

Akinboro *et al*. (2012) in a review of solar energy system in Nigeria highlighted some problems confronting solar installations as affordability, the present level of research and development, lack of awareness, the technology of equipment and fabrication, government policy, the cost of generation among others. This was corroborated by Adeyemo (2013) in a study of solar energy powered projects in Lagos state, analysing the failed projects and understanding the reasons for the failure of the projects. He opined that security risks, poor understanding of the consumption rate/local need, maintenance, technical problems, price and economic sustainability, little awareness, communication challenges are the challenges facing solar energy projects in Nigeria.

In the view of Ohunakin *et al* (2013), variability and intermittency of radiation, lack of awareness and information, high initial investment cost, grid unreliability, operation & maintenance cost, government policy & incentives, ineffective quality control of products, insecurity of solar plant infrastructure and competition with land use are some of the challenges facing the utilization of solar energy system in Nigeria. Awogbemi and Komolafe (2011) evaluated solar energy, hydropower and wind energy which are the major renewable energy sources in Nigeria and opined that major constraints to the expansion of solar utilisation in Nigeria are cost, unfriendly government policy, solar technologies are not manufactured locally. Low level of public awareness, financial constraint, the high cost of energy infrastructure and technological incapability were listed by Akinbami (2001) in a study of renewable energy resources and technologies in Nigeria.

Ismail, Ajide and Akingbesote (2012) embarked on performance assessment of installed solar PV system in Oke agunla, Akure LG area of Ondo state in Nigeria, it was concluded that the PV systems were inefficient as a result of poor maintenance, lack of technical know-how

and inability of the project contractors or managers to take these factors into consideration while embarking on the solar PV installations.

Melodi and Famakin (2011), in a study to determine the adequacy of solar electricity potential (SEP) for meeting the domestic demand of Akure, concluded that SEP in Akure is appreciable and sufficient as an alternative energy source for domestic needs. Offiong (2003) revealed that solar systems are the most economically viable compared to diesel generator which is the most common alternative source.

This study embarked on a random survey of residential buildings in Akure, Ondo State, Nigeria with the aim of determining the percentage of household with alternative power supply, the type of alternative power supply, the percentage willing to adopt solar PV as an alternative source and the reason for their decision. Thus, it assessed the level of adoption of solar PV and barriers in Akure, Ondo State.

2. ELECTRICITY CONSUMPTION IN RESIDENTIAL BUILDINGS

Electricity is one of the frontiers of any nation's development. Electricity supply in this country has been erratic and epileptic thus resulting in frequent power outages that have impaired economic growth and development. The residential, commercial and industrial electricity consumption accounted respectively for 51.3, 26.7 and 22 percent of total electricity consumption (Nwachukwu, Ezedinma, & Jiburum 2014). The supply of electricity to the residential sector and other sector at large is getting declined; this can be attributed to the increase in population and drastic decrease in electricity generation. Most residential building buildings owners have resorted to the use of diesel generator and of recent, the use of solar photovoltaic installations and inverter system as an alternative/ backup to the epileptic power supply. The industries are moving out of the country to neighboring countries with a more reliable power supply, this has led to high cost of goods and services in this country (Adenikinju, 2003). Nwachukwu *et al.* (2014) determined the electricity consumption pattern in south-south geopolitical region of Nigeria. The results showed that there were significant differences in electricity consumption pattern amongst the six states that constitute the geopolitical region. River state had the highest mean consumption rate, followed in descending order by Delta, Edo, Akwa Ibom, Bayelsa and Cross River states. He recommended for strategic and systematic distribution of electricity to ensure adequate supply in south-south geopolitical region. Arimah (1993) discovered that that there was spatial variation in electricity consumption in Nigeria. This, he attributed to variation in socio-physical variables among various regions. These variables are the price of electricity, urbanization, income, population, number of residential houses, land area, commercial activities, industrial activities and distance of each state to Kanji Dam. Donatos and Mergos (1991) examined the determinants of residential consumption in Greece over the period 1961 – 86. The result showed that: first, the residential demand for electricity was price inelastic but income elastic. Second, there was high substitutability between electricity and liquefied natural gas. Third, during the examined period, the number of consumers played a very important role in the expansion of electricity consumption in Greece. Fourth, there was no regional variation in residential electricity demand. Similarly, Tserkezos (1992) studied household electricity consumption in Greece. The results showed that personal disposable income, prevailing temperature and price of electricity used by the household played an

important role in the demand for electricity. Tiwani (2000) determined the short run residential demand for electricity using household survey data for Bombay (Mumbai), India. Holtedahl and Joutz (2004) showed that residential demand for electricity in Taiwan was a function of household disposable income, population growth, the price of electricity and the degree of urbanization. In the long-run, the income was inelastic and the own-price effect was negative and also inelastic (Kennedy-Darling, Hoyt, Murao, & Ross, 2008). Due to the lack of reliable electricity, many people and companies supplement the electricity provided by the grid system with their own generators. In fact, most everyone who can afford a generator owns one. According to one approximation, well over 90% businesses have generators. Kennedy-Darling *et al* (2008) opined that the electricity from private generators is more expensive than that from the national power grid, thus raising the price of domestic goods. Efforts to alleviate this strain are met with opposition from the companies who import generators, as they have created an extremely lucrative industry. There is suspicion that some of the grid system sabotage is from members of this industry

3. SOLAR ENERGY

The utilization of solar energy depends on its availability and appropriate technology (Nasir, 2001). The idea of using the sun's power has held scientist in its grips for centuries (Bradley, 1995). Also, for most of its evolution, mankind relied for its sources of energy on constantly replenished materials. When the use of fire was discovered for the provision of heat and for the processing of food, the additional demand for energy was met by constantly renewed sources. Later still when water and wind powers were harnessed to the service of mankind, the new sources were also of a renewable nature. Thus throughout the early phase of human development, the availability of the readily renewable sources of energy was a key constraint and affected the size and distribution of population (Sambo, 2001).

The sun radiates enormous amount of energy. It radiates energy in one year than people have used since the beginning of times (Williams, R & Carl. 1990). It takes millions of years for the energy in the sun's core to make its way to the surface, and then, just a little over eight minutes to travel to the earth. Solar energy travels to earth at the speed of light (Williams *et al*. 1990). Only a small amount of the energy radiated by the sun strikes the surface of the earth; one part in two million. Yet, this amount of energy is enormous. Enough solar energy strikes the earth to supply its energy needs. In 1831, it was discovered that the sun's energy could produce a photovoltaic effect (Webb 1995). In 1878, solar to mechanical conversion was first demonstrated when sunlight was concentrated by focusing a collector on a steam boiler that ran a small printing press. (El-Wakil as cited by Abdulkarim, 2004). In the 1980s, selenium photovoltaic cells were developed that could convert sunlight into electricity with 1-2% efficiency but how the conversion was done was not understood. Solar power therefore remained a curiosity for sometimes. In 1901, larger focusing collector in the form of truncated cone generated steam for a 4.5hp engine. Between 1907 and 1911, solar steam engine of several HP that were used for pumping water were built. Liebowitz and Hanseth (1982) has it that by mid 1950s the efficiency of 45 and later 11% had been achieved with silicon photovoltaic cells. From then, interest in solar power intensified. During the late 1950s and 1960, the space program took active role in the development of photovoltaic. The cells were perfect sources of electric power for satellite because they were rugged, lightweight and could

meet the power requirements reliably. Unfortunately, the cells were not practical on earth due to the high cost of making them efficient and lightweight (Stone, 1993). Consequently, further research was needed.

Climate is the average weather condition of a place over a given period of years. It is determined primarily by distance from the coast and secondarily by elevation. (Bradley, 1995).

Nigeria is entirely between the equator Nigeria's electrical energy consumption in the year 2001 is 15×10^6 kWh and the tropic of cancer (Ojo, 2000 as cited by Ajayi 2009). Its climate varies from tropical to subtropical. There are two main seasons; the dry season lasting from October to March and the rainy season lasting from April to October. In the north, it is hot and dry, rainy season extends between April and September. In the south, it is hot and wet, rainy season extends between March and December. From December to March there is a long dry season. Temperature at the coast rarely rise above 32 °C. The north is drier with temperature range between 32 °C and 42 °C humidity is about 95% (Ajayi, 2009). The sun has been shining for about 4.5 billion years. It has enough hydrogen to burn for about 10 million years (Williams *et al*. 1990). All energy on earth is direct or indirect result of sun's energy. The sun's ultraviolet rays are absorbed by green matter of plant to make them grow.

The plants and trees centuries ago were dead, buried, decayed and turned into coal, oil and gas. Waterpower comes from the sun; water is evaporated from the earth by the sun and this produces rainfall that fills the rivers, lakes, oceans, seas and reservoir. Wind power comes from the sun; unequal heating of the earth worldwide results in kinetic energy (Walters, 1977).

The first concern to the designer of solar energy system is the availability of that solar energy in that region at present and at some other time in the future. The availability of solar energy on earth depends on geographical location and time scale. The sunshine hours and consequently the radiations in different zones differ. The sun's power reaching the earth is typically about $1000W/m^2$ (Hoff *et al*. 2000).

4. AREA OF STUDY

The study location, Akure, is the capital city of Ondo State, South-West Nigeria. The city lies within Latitudes 7°15'0" N and 7°28' N and Longitudes 5°6' E and 5°21" E (Akure, 2016).

The climate is tropical. The State is nicknamed "sunshine state" because it experiences plenty of Sunshine (See Figure 1) for a good part of the year. There are two principal seasons, namely, the rainy season, which starts in April and peaks in June through September, and the dry season, which begins in November and lasts until April (Holladay as cited by Melodi & Fanakin, 2011, Aribigbola, 2009).

The climate and energy needs of the study location are typical for the south of Nigeria. This location suffers a crisis of crippling electricity deficit. Because of its equatorial location and the climatic condition, solar radiation is appreciable for a good part of the year. A statistical mean daily sunshine hour was estimated at 5.21 hours and reveals average highest amplitude of 7.29 hours per day in November and 2.9 hours in August (Adewumi, 2011).

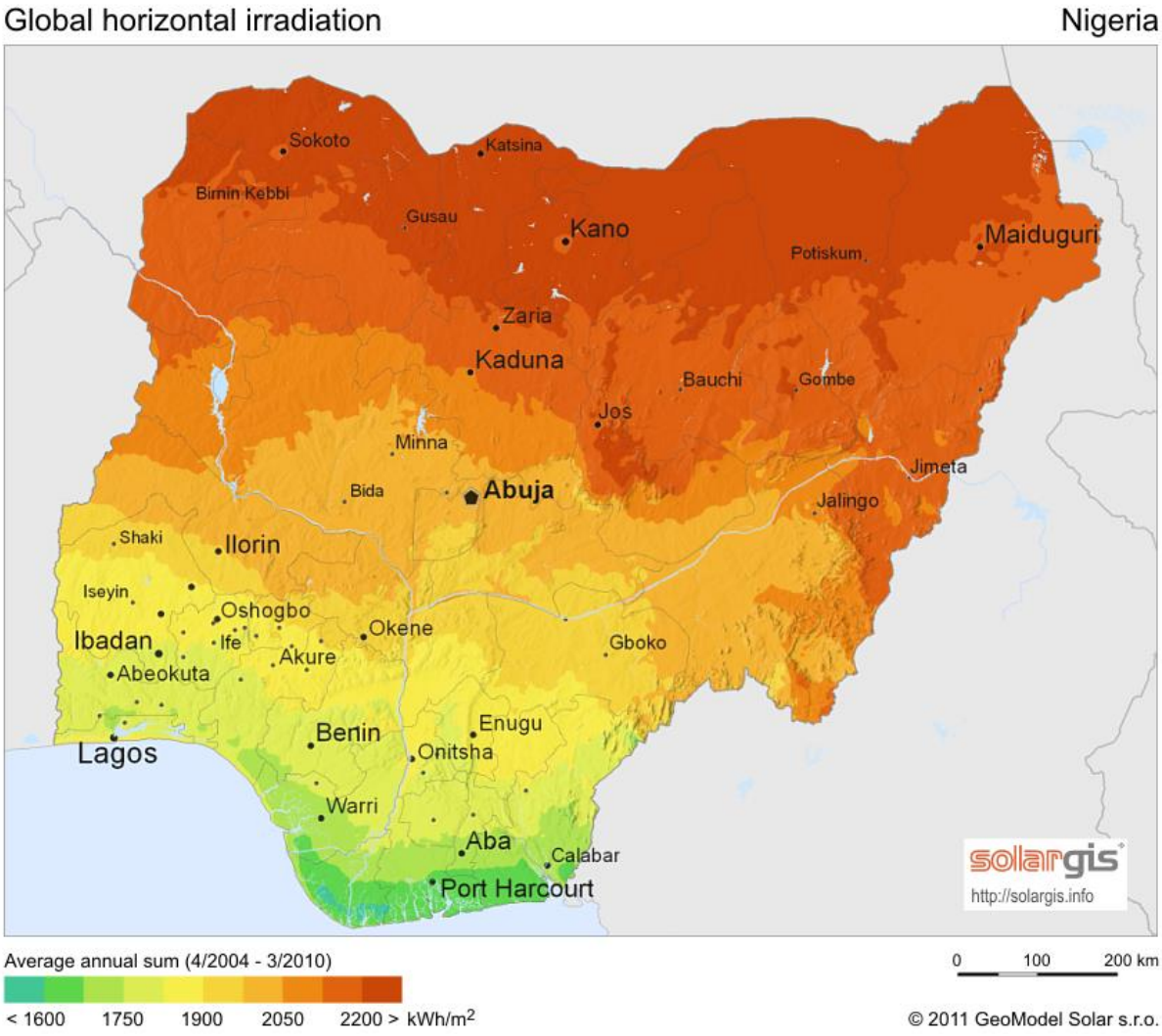

Figure 1. Irradiation in Nigeria
Source (solargis.info)

5. SOLAR PV INSTALLATION

The stand-alone photovoltaic system is a collection of interconnected electrical components, which can generate electricity from sunlight and satisfy our daily energy requirement without worrying about any interval when the sunlight may not be available. According to Guda and Aliu (2015), Ishaq, Ibrahim and Abubakar (2013) and Pal, Das and Raju (2015) the components (see Figure 2) of such a system are:

a) Solar PV array

This is commonly refers to as solar panel. It is responsible for trapping of the solar energy as it is placed outside under the sun. They are arranged in series and parallel to meet desired output.

b) Charge Controller

The charge controller is use in controlling the charge (from the word charge control) in the batteries, either to prevent overcharging or discharging.

c) Inverter

This is used in converting DC to AC as power from solar PV arrays is in DC form.

d) Battery

These are used to store power for usage during the non-sunshine hour. The recommended batteries that should be used in stand-alone photovoltaic power system are deep-cycle lead-acid batteries because of their high performance (Abu-Jasser, 2010).

e) Balance of System Components

Components such as protective devices, blocking & bypass diodes, lightning-protection system and cable wiring constitute what is known as balance of system components (Abu-Jasser, 2010). Such components are necessary to keep the PV power system safe and reliable. In particular, selecting the correct size and type of cable will enhance the performance of the system while selecting inadequate cable size will cause voltage drop from the source to the load. In low voltage systems, such voltage drops will lead to inefficiencies.

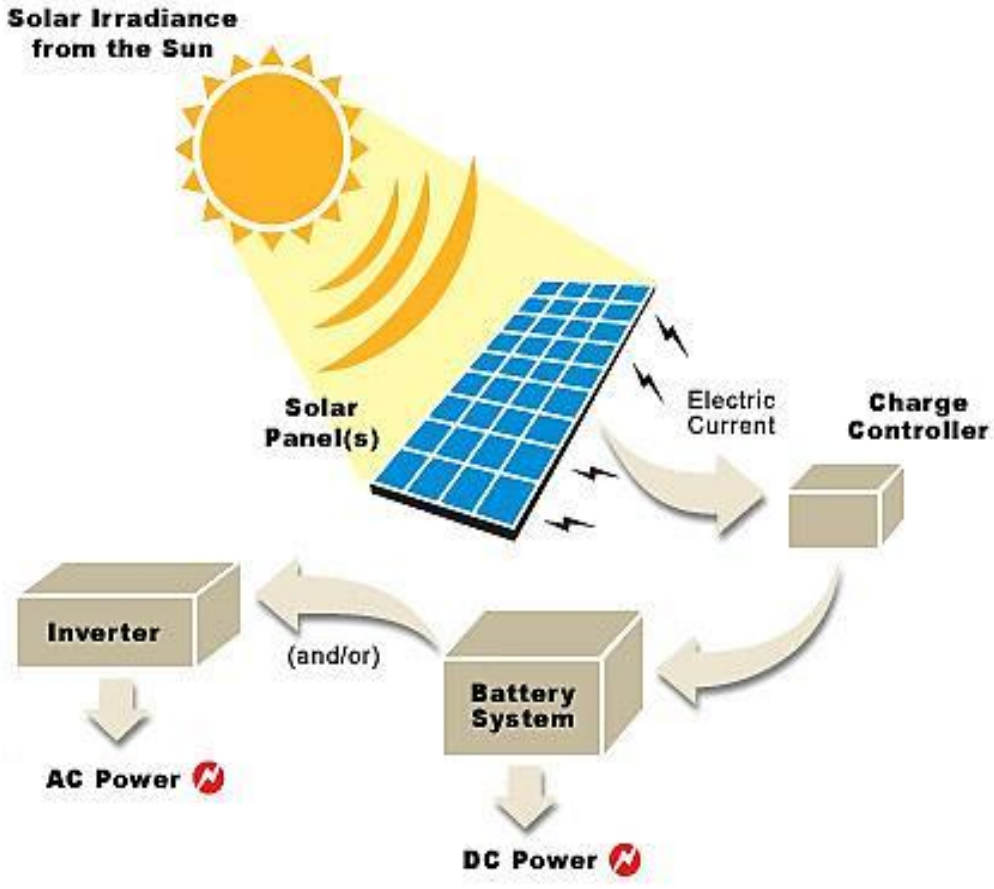

Figure 2. Pictorial representation of Solar PV system
Source: Musekaite, Kevelaitis, Obialo and Raudius (2008)

6. RESEARCH METHODOLOGY

A random survey was carried out on one hundred and fifty (150) residential buildings (One hundred and fifty residential buildings were selected because of the time and cost involved in assessing more buildings) in Akure, Ondo State, Nigeria. The residential building occupants/owners were then administered a structured questionnaire.

6. 1. DATA ANALYSIS

The Table 1 shows the distribution of the houses assessed, with three bedroom flat having 28.7% which is equivalent to 43 houses out of the 150 houses, two bedroom accounted for 23.3%, four bedroom flat is 26.7% and 5 bedroom flat for 21.3 % which are equivalent to 35, 40 and 32 houses respectively.

Table 1. Distribution of apartment

Apartment	Frequency	Percentage (%)
2- Bedroom Flat	35	23.3
3- Bedroom Flat	43	28.7
4- Bedroom Flat	40	26.7
5- Bedroom Flat	32	21.3
Total	150	100.0

Source: Field survey, 2016

6. 1. 1. ALTERNATIVE SOURCES OF POWER SUPPLY

From the structured questionnaire, question was asked from the respondents on whether they have another source(s) of power supply apart from the National grid; their responses were recorded in the Table 2. From Table 2, 75.3% of the residential buildings have other sources of power supply which accounted for 113 out of the 150 houses. The rest 24.7% of the residential buildings do not possess any other sources of power supply, which accounted for 37 of the houses.

Table 2. Residential buildings with alternative sources

Option	Frequency	Percent
Yes	113	75.3
No	37	24.7
Total	150	100.0

Source: Field survey, 2016

6. 1. 2. THE VARIOUS ALTERNATIVE SOURCES TO THE NATIONAL GRID

The 75.3% which responded in affirmative has having another source(s) of power supply were probed further as to the alternatives which they use. The Table 3 shows the responses, 102 of the houses which accounted for 68.00% are using generator while 7.3% are using inverter as an alternative to the national grid. Thus, 90.2% of residential buildings with other sources of power supply are using generator, while 9.73 accounts for those using inverter as an alternative. It is noteworthy that none of the 150 houses assessed is using solar PV.

Table 3. Other sources of power supply.

Source	Frequency	Percent
Generator	102	68.0
Inverter	11	7.3
None	37	24.7
Total	150	100.0

Source Field survey, 2016

6. 1. 3. ADOPTION OF SOLAR PV AS AN ALTERNATIVE

Building occupants/owners were asked if they can adopt solar PV installations as an alternative to the National grid. The Table 4 shows the distribution of their responses, 62.7% of the residential buildings replied with affirmative, while 37.3% replied negatively. Thus, 94 residential buildings are willing to adopt solar PV installation as an alternative to National grid, and 56 residential buildings are not willing to adopt solar PV as an alternative to the National grid.

Table 4. Adoption of solar PV as an alternative

Option	Frequency	Percent
Yes	94	62.7
No	56	37.3
Total	150	100.0

Source: Field survey, 2016

6. 1. 4. BARRIERS TO ADOPTION OF SOLAR

The respondents were asked further as to the reason for their responses; the table shows the distribution of their responses. Out of the 56 residential buildings, 39 responded with

affordability factor as the main barrier to the adoption of solar PV, 15 responded with Lack of awareness as the main barrier, while 2 responded with others (Lack of technical know-how, environmental problem among others). Affordability accounts for 26% (69.64% of 56 NO) of the responses of those that are unwilling to adopt solar PV as an alternative, while 10% (26.79% of 56 NO) of the responses accounts for Lack of awareness and other barriers accounts for 1.3% (3.57% of NO).

Table 5. Barriers to adoption of solar PV

Barriers	Frequency	Percent
Cost	39	26.0
Lack of awareness	15	10.0
Others	2	1.3
None	94	62.7
Total	150	100.0

Source: Field survey, 2016

7. DISCUSSION OF FINDINGS

It was crystal clear from the findings that a large percentage of the population have an alternative source of electricity supply to their buildings, which is in tandem with the findings of Iwayemi (2008), Odularu and Okonkwo (2009). This is due to the epileptic nature of the power supply from the National Grid, vandalism of transmission equipment among other challenges. Most of the residential buildings are using diesel and petrol generator as a backup and as supporting source for the National grid, this alternative resulted in the pollution of the environment by the emission of CO and noise pollution to the environment (Patrick and Babatope, 2013).

This is supported by findings of Azodo (2014), who assessed sources of electric power supply, utilisation features and effects of electricity deficits in Obantoko residents in Abeokuta, Ogun state. Also, it corroborated Olaleye and Akinbode (2011)'s analysis of household's demand for alternative power supply in Lagos state, Nigeria.

The use of an inverter is gaining ground in residential buildings, this involved the use of deep cycle batteries; which are always fully charged when there is a supply of electricity from the National grid and then put in use during power outage. It is noteworthy that none of the randomly surveyed building was making use of solar PV system as an alternative to the grid, this shows that the level of adoption of solar PV is very low which is in agreement with Eronini (2014), Akinboro et al, (2012) and Aminu (2011).

From the data analysis, most of the residential building owners/occupants are willing to adopt solar PV as an alternative and back up for the electricity supply from the grid, as a

result of more stable supply that can be benefitted from the system. It also revealed that Cost of solar PV system and lack of awareness top the chart of reason for those that are not willing to adopt solar PV, which is agreement with the study of Adeyemo (2013), Ajayi (2009), Okoro and Madueme (2004), Eronini (2014) and that of Ohunakin *et al*. (2013)

8. CONCLUSION

The assessment which was carried out on randomly selected one hundred and fifty(150) residential buildings revealed that the level of adoption of solar PV system in Akure is very low presently, as most residential buildings make use of diesel/petrol generating sets as alternative/backup for the epileptic power supply from the National Grid.

The future prospect of solar PV is bright as most of the owners/occupants are willing to adopt it as an alternative; nonetheless, it is hindered by the perceived high cost of solar PV system and lack of awareness.

It is saddening and worm eating that some residential building owners believe that solar PV is only meant to power street lights (which is common in Akure) and cannot power a whole building, this erroneous belief is due to the lack of awareness/solar PV system education among the populace.

The lack of clear government policy on solar energy market also serves as a hindrance to those interested in the market, the government will thus need to help in this regard and also provide incentives for those interested in the market, so as to boost the market.

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