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AFFORDABILITY AND EFFECTIVENESS OF SOLAR PHOTOVOLTAIC SYSTEM'S AS A PANACEA FOR CLIMATE CHANGE MITIGATION AND SUSTAINABLE DEVELOPMENT IN KANO METROPOLIS

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ABSTRACT

The study assessed affordability and effectiveness of solar photovoltaic (PV) energy technologies for electricity generation in Kano Metropolis. Three local government areas were selected purposively namely Tarauni, Nassarawa and Ungogo. Household and Small-Scale Business users of solar PV energy and technicians were selected using snowball sampling, while marketers of the PV facilities were selected purposively. Data was analysed using SPSS software version 23 by IBM. The findings revealed that most of the users of solar PV systems considered the prices that was mostly within the range of $487-$973 for households and $292-$487 for small-scale businesses as affordable. Almost all users adjudged their systems as being efficient, durable and enhanced their profit in the investments. A significant number of users, technicians and sellers of the facilities were optimistic that there is widespread use of PV system consequently reduce the use of generator sets and therefore the greenhouse gases emitted by generator will also be reduce. However, high initial investment cost, improper installation, lack of awareness, sub-standard products, lack of government support were the major factors militating against the utilization of the solar PV energy around Kano Metropolis. Governments, International NGOs and Banks should provide low interest loans and grants to solar products producers, importers and users in the country. Subsidy and tax incentives to solar equipment producers, importers and users should be provided.

Keywords: Electricity, energy, greenhouse gases, photo voltaic, clean energy

INTRODUCTION

Access to clean, reliable, affordable and modern energy for all by 2030 is one of the sustainable development goals developed to bridge the challenges of low access and use of dirty energy sources across the world especially in sub-Saharan Africa. It is no longer news that electricity is indispensable towards economic development and stability of nations. The more the production of electricity, the better the quality of life, level of industrialization and creation of wealth (Gbadebo & Okonkwo, 2009). Global demand for, and dependence on electricity is increasing and, as environmental concerns become more pressing, so does the focus on the reduction of greenhouse gas emissions which disrupt the ozone layer leading global warming (Energy World, 2015). This is resulting in a move towards a decarbonised electricity system based on a large volume of variable renewables generation, predominantly delivered by wind and solar photovoltaic (PV). This current situation has created a dilemma in terms of energy security and climate protection. The use of renewable energy technologies, energy efficiency, and energy conservation practices have been identified as solutions to this problem (Harmsen *et al.*, 2014). Research into alternate sources of energy dates back to the late 90s when the world started receiving a shock from oil producers in terms of price hiking (Abbasi *et al*., 2011). It is evident in literature that replacing fossil fuel-based energy sources with renewable energy sources, which includes: bioenergy, direct solar energy, geothermal energy, hydropower, wind, and ocean energy, would gradually help the world achieve the idea of sustainability.

The current energy use pattern in Nigeria is less sustainable, and hence there is the need to adopt renewable energy sources especially solar to supplement the persistent electricity crisis and climate change mitigation in the country. International Energy Agency (IEA, 2019) has projected that the global renewable energy output will expand by 50% between 2019 and 2024 with solar photovoltaic taking the lead. Across urban areas around the world, transition to clean energy is undermined by behavioral, technological, and institutional locks-in (Urge- Vorsatz-urge *et al*., 2018). Sub-Saharan African Countries therefore, cannot be an exception, therefore household headship by gender, level of education and income determine the adoption of solar technology (Guta, 2018). Most literatures highlighted initial investment cost as the main challenge/obstacle militating against deeper penetration of the solar PV systems in Nigeria (Umoh and Lugga, 2016; Kabir *et al*., 2017). For these reasons it becomes imperative to assess the affordability of solar PV energy technologies in a region bedeviled with the twin challenges of poverty and in sufficient energy supply. These was achieved through exploring the experiences of households and small-scale businesses with respect to affordability, efficiency and effectiveness of the new technology which will help in mitigating the GHGs emission.

Utilization of solar PV technology have a potential to shape a clean, reliable, scalable and affordable electricity system for the future (Tyagi *et al*., 2013). Considering this fact, all over the world, governments are encouraging the development and deployment of solar PV technology. Nigeria located on the equator is within a high sunshine belt where radiation is potentially well distributed, especially over the Northern part of the country, therefore, about 3.7% of Nigeria's landed area is required to gather an amount of solar power equal to the country's conventional energy reserves (Okoye and Taylan, 2017). The annual solar energy value of Nigeria is about 27 times the country's total fossil energy resources and is over 115,000 times the electrical power produced (Augustine and Nnabuchi, 2009). It was reported that Nigeria possess an estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar power potentials falling on its 923,768 km^2 land area (Ohunakin, *et al*., 2014). It was estimated that the annual daily average of total solar radiation varies from about 12.6 Mega

Joules per metre square per day ($MJ/m^2/day$) (3.5 $kWh/m^2/day$) in the coastal region to about 25.2 $MJ/m^2/day$ (7.0 $kWh/m^2/day$) in the far north (Ohunakin *et al*., 2014), thus making Nigeria possess an estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar power falling on its 923,768 km^2 land area, Energy Commission of Nigeria (ECN, 2013); ECN-United Nations Development Programme (UNDP, 2013). Consequently, these solar power potentials were not inadequately harnessed. Adoption of renewable sources of energy will help Nigeria achieve its apportioned target towards reduction in GHG emissions pledged at 2015 Paris Agreement and achieve the Sustainable Development Goal 7 (SDG 7) of ensuring access to clean, affordable, reliable and modern energy for all by 2030.

Overview of Nigeria's energy crisis and GHG emission

Nigeria has 25 power plants with 12.5GW of installed capacity, but due to maintenance and repair issues, only 21 plants are available, with 7.1GW of capacity, Advisory Power Team (APT, 2015). On top of this, power generation is constrained due to gas availability, water availability, and transmission constraints, among others. This results in only 3.8GW of capacity being operational at any given time, or 31% of the installed capacity (APT, 2015).

The Nigeria Power Baseline Report shows that all plants are running sub-optimally, with seven operating at less than 10% of their installed capacity (APT, 2015). Around 2GW of this under-utilization is due to natural gas constraints, including insufficient gas-processing and pipeline infrastructure and poor economics for gas investment (APT, 2015). Though Nigeria has one of the world's largest natural gas reserves, its low domestic prices have led producers to simplyflare it off during oil extraction rather than bothering to capture it (2016). Overall, less than 10% of the natural gas Nigeria produces goes towards its power sector, compared to 41% going to exports (APT, 2015). On top of this, long-term under-investment and delays in the delivery of planned gas infrastructure have resulted in a shortage of gas-processing and pipeline infrastructure requiring major upgrades and investment to meet even current available generation capacity. A clear example of the system's gas constraints happened in 2018 when a fire incident in a pipeline system shut down six power plants and led to a collapse of the Nigerian grid and widespread blackout (Nnodim, 2018). System collapses were not just due to natural gas supply issues; the Transmission Company of Nigeria (TCN) states that "the prevailing situation in Nigeria is characterised by overloaded lines and transformers, poor quality of supply and insufficient reliability of supply thus, causing frequent outages" (Fichtner, 2018). These collapses are a result of a lack of investment from both the TCN and the private distribution companies managing the grid (Soleye, 2014). Although the transmission capacity is currently higher than the average operational generation capacity, it will certainly need to increase if the TCN hopes to handle the full installed generation capacity, much less new generation growth (APT, 2015). These outages and supply issues led the Spectator Index to name Nigeria the country with the second-worst electricity supply for 2017 (Bungane, 2018).

In response to these chronic reliability concerns, Nigerians have turned to alternate sources to supply their power, from simple candles to fuels like diesel and petroleum (Muoh, 2016). For those who can afford it, expensive diesel generators are a popular solution with Nigerians spending over twice as much on self-generation than on grid-based power (Advisory Power Team, 2015). In 2009, an estimated 60 million Nigerians owned their electricity-producing generator sets (Nwachukwu, 2010). By 2016, this number rose to 100 million (Odutola, 2017). Over 50 million homes spent a minimum of N30, 000 a month ($83/month) on fuel for their generators, and even the offices of the President and Vice President spent N32.9 million ($91,400) to run their generators in 2016 (Odutola, 2017). However, government ministries spent approximately N55.4 billion ($154 million) on fuel, the majority of the N5.5 trillion ($15.2 billion) spent in the year 2016 came from the residential and private sectors (Odutola, 2017).

According to the Manufacturing Association of Nigeria (MAN), the "electricity crisis is the most important infrastructure bottleneck in Nigeria and all types of firms experience power outages and 85% of them own two or more generators as an alternative source of power generation" (Odutola, 2017). On average, these diesel generators meet 70% of business power needs, Beacon Power Services (BPS, 2017). These standby generators are referred to as captive generation capacity, which is estimated to be as high as 14 to 20GW, Renewable Energy Cooperation Programme (RECP, 2017). With this captive generation capacity now exceeding the power sector's installed capacity, it is clear that Nigeria's electricity sector is in crisis. Citizens turn to diesel to meet needs, but this comes at a price of constant exposure to toxic fumes and noise pollution (Solynta, 2018). In addition, diesel engines are a source of GHGs emissions, and hence the widespread use of this fuel is a concern not only for Nigerians but communities outside of Nigeria as well (Jakhrani *et al.,* 2012). In addition to GHG emissions in the form of carbon dioxide (CO_2), diesel combustion is also associated with carbon monoxide (CO), nitrous oxides (NOx), sulfur dioxide (SO_2), and particulate matter emissions, including black carbon (World Bank, 2014). In Lagos, a study showed that the CO emissions from diesel generators were around 143mg/m^3, over 14 times the European Union (EU) air quality standard of 10mg/m^3 (Babayemi *et al.,* 2017).

In 2014, a report by the World Bank estimated the emissions of CO_2, SO_2, NOx, and black carbon from diesel generators in various sectors to be 160,000 tons of CO_2, 154 tons of SO_2, 4,069 tons of NOx, and 114 tons of black carbon (World Bank, 2014). These concentrations are a concern for both human and environmental health and lowering these emissions require reducing the use of diesel generating sets (Babayemi *et al.,* 2017). The objectives of the study are to assess the cost of the installed solar PV systems, its efficiency, durability and installed system investment and climate change mitigation of PV.

MATERIALS AND METHODS

Description of the Study Area

Kano Metropolis is located between latitudes 11˚ 57' 0'' N to 12˚ 2' 0'' N and Longitude 8˚ 29' 0'' E to 8˚ 33' 0'' E (Figure 1) on the Central Plains of Northern Nigeria and covers 137Km^2. The area received maximum of 6.39kWh/m^2 of solar radiation around April to the lowest of 5.56kWh/m^2 in August with an average of 6.003kWh/m^2 (Emodi and Boo, 2015). The National grid electricity supply from Kano Electricity Distribution Company (KEDCO) is far from adequate. KEDCO had reported that the average supply for the entire region it serves (Kano, Jigawa, and Katsina) is 200MW, with the highest supply of 340 MW and as low as 45MW, while the demand is around 600MW (Nigerian Energy Hub, 2017). Population increase and urbanization have caused a simultaneous rise in energy demand. This is evident in the proliferation of more filling stations for petroleum products, and the emergence of more gas refill outlets (Kiyawa, 2016).

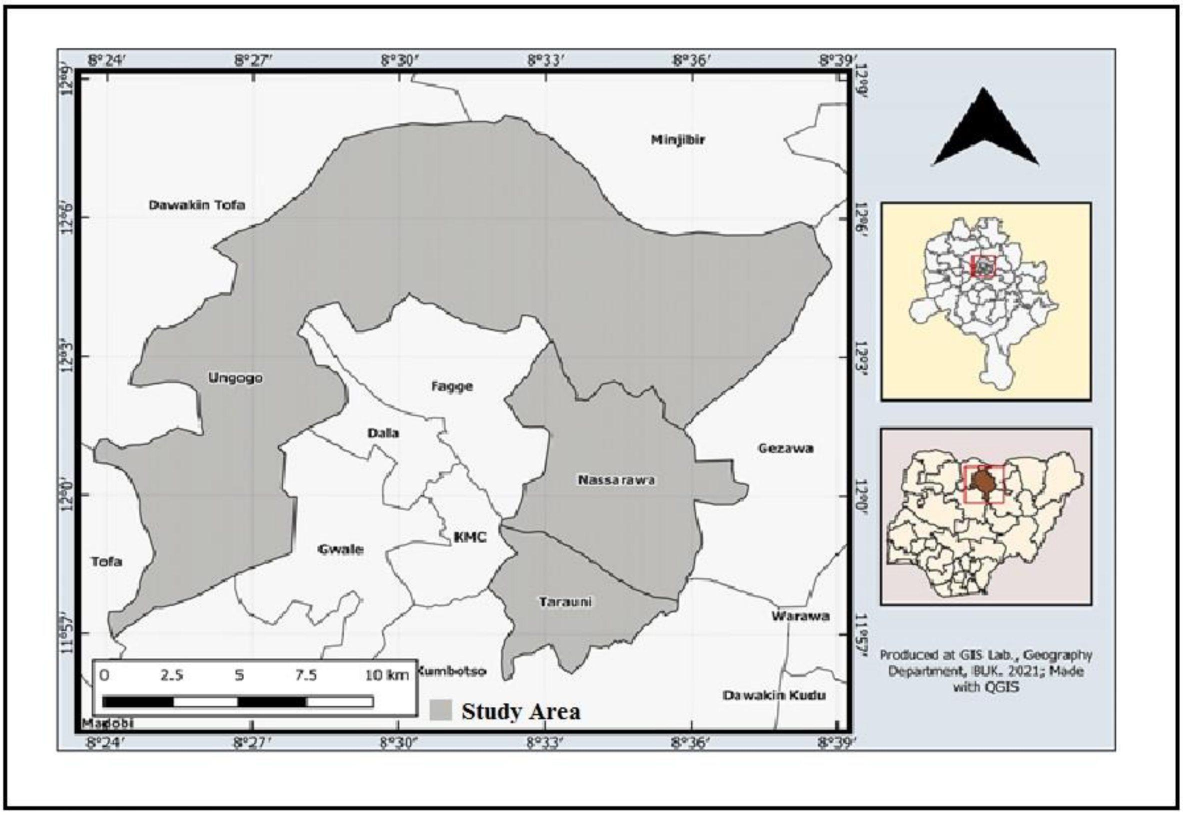

Figure 1: Study area

Sampling Techniques

The sample size for this research was calculated using the Raosoft online sample size calculator, this is an online sampling size calculator that suggests an ideal sample size for a given population. The 2016 population estimates of Kano Metropolis (3,931,300) was inputted and the software suggested a sample of 385 respondents in Kano metropolis and a 5 per cent margin error of 385, 19 was added making 404 which was projected to 415 for convenience. Ten Solar Marketers and Technicians were selected for a face to face interview for the study. Three local government areas (LGAs) were selected purposively whereby four major wards were chosen in each LGA. Twenty Five household were identified from each ward making a total of one hundred respondents from each local government and three hundred in the three LGAs. One hundred and fifteen respondents from solar PV facilities marketers and technicians were identified from the three local government area for interviewed.

Data collection

Two types of questionnaires were administered for households and small-scale business using likert scale option. The information obtained include cost of the solar PV facilities system, cost consideration by the respondents, the efficiency, durability and return on investment of the system installed. It is important to note that out of the 415 copies of questionnaire administered only 293 were returned, 215 for households and 78 for small-scale businesses.

Data analysis and presentation

Data collected was analysed using descriptive statistics computed using Microsoft Excel 2013 and SPSS version 23 by IBM. Relationships between variables were analysed using chi-square test of independence and cross-tabulations in Microsoft Excel 2013 and SPSS software version 23. The results were presented in frequencies and percentages.

RESULTS AND DISCUSSIONS

Cost of the Installed Solar PV System

The average cost of the solar PV system used by households stood at N591, 159.00 ($1,438.3). This clearly shows that the initial cost of installing a Solar PV System is high, however, most respondents use a PV system within a cost range of N200, 000 to N400, 000 ($487-$973) which represents about 27% of the total Households. This cost range will enable a user to have lighting, recharge phones, use fans, and to some extent use one refrigerator or an inverter air conditioner. Moreover, household electricity use is mostly for the above-mentioned functions that indicates that this Solar PV system provides households with efficient services. A solar PV system that falls within the cost range of N1, 000,000 to N4, 000,000 ($2,433-$9,732) accounted for 17% of the total households with the highest investment being N4, 670, 000.00 ($11, 362.5). These categories of users need energy for other purposes such as small-scale sachet water business or the household sizes are big containing many rooms and hence need more cooling, lighting and perhaps the use of refrigerators and air conditioners. The lowest installed Solar PV system price stood at N26, 000.00 ($63.00) only to provide lighting and recharging of phones.

The average cost of the installed solar PV system used by a small-scale business owner was found to be N238, 600.00 ($580), thus displaying the small-scale nature of the businesses. The majority of the small-scale businesses use solar PV systems that falls within the cost range of N120, 000 to N200, 000.00 ($292-$487) representing about 42% of the total small-scale businesses. This was because most of these businesses have small capital, and energy supply constitute the largest running cost for these businesses. The highest investment within the small-scale businesses was the Medical Diagnosis and Laboratory Business where N2, 000,000.00 ($4, 866) was invested to power the business. This was because the user needs an uninterrupted supply of electricity during business hours and the erratic and unreliable supply from the national grid will not provide the business energy needs and the cost of running a generator set is huge. The Agro-Allied Business with an investment of N1, 200,000, followed this ($2,920) while the lowest investment by a small-scale business owner was for N20, 000 ($48.66) only, just to provide lighting for his business premises. It should be noted that some users bought already-used (second-hand) solar PV equipment such as solar panels, batteries, charge controllers and inverters available in the market at cheap prices.

Cost Consideration by Solar PV Users

The majority of the households considered the cost of their Solar PV system as being average. This was because if the cost is compared with the cost of running petrol or a diesel-powered generator set, the cost is minimal, mostly the initial investment cost will be at par with the cost of running a generator in one or two years. The same applies to their small-scale business counterparts and these represent about 58% and 63% of the total households and small-scale businesses respectively (Fig. 2). However, 39% and 32% of both households and small-scale businesses said the cost is high. This was because the cost of buying and installing the solar PV system has taken a large chunk of their income and they felt it should be cheaper than that.

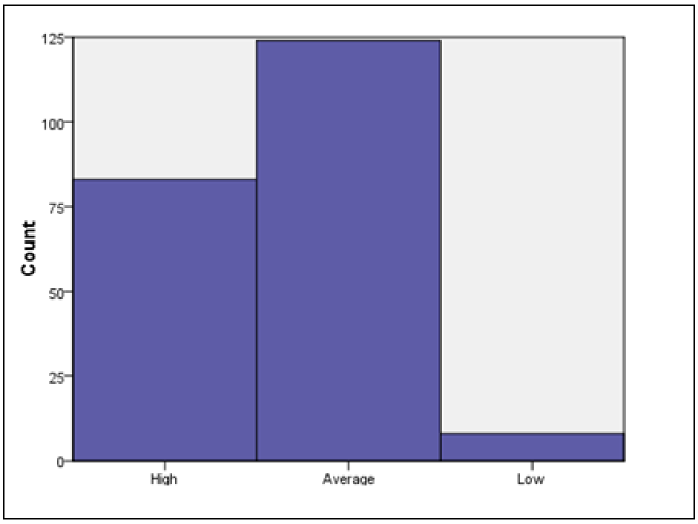

Figure 2: Household cost of PV system

Nevertheless, only about 4% and 5% of both households and small-scale businesses considered the cost as being low due to their experiences and their ability to compare the cost of running a diesel/petrol generator and using a solar PV System (Figure 3).

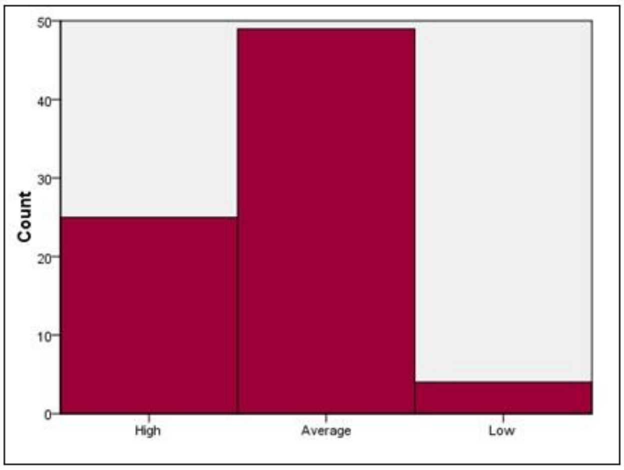

Figure 3: Small-scale business cost of PV

System Efficiency, Durability and Return on Investment

Table 1 presents the views of both households and small-scale businesses concerning efficiency, durability, effectiveness and return on investment of the installed solar PV system. Just like in cost consideration, the majority (61%) of the households said their solar PV system is of average efficiency, a good portion (39%) considered the system as being highly efficient. This was because good products were bought, proper installation was done and the system was well maintained. However, only a negligible portion (1%) of the households said their system's efficiency is low and this was due to either purchase of sub-standard products, improper installation, or poor maintenance, lack of energy audit before installation and purchase of second-hand products. A large segment of the small-scale businesses (60%) believed their PV system was averagely efficient, a portion (33%) believed it to be highly efficient while only a small portion (5%) said their PV system's efficiency is low.

Table 1: Efficiency, Durability and Return on Investment

Facility	Household			Small scale businesses		
	Rating	Freq.	Percentage	Rating	Freq.	Percentage
Solar PV System's Efficiency	High	83	38.6	High	26	33.3
	Average	131	60.9	Average	48	61.5
	Low	1	0.5	Low	4	5.1
Solar PV System's Durability	Highly durable	120	55.8	Highly durable	35	44.9
	Averagely durable	92	42.8	Averagely durable	41	52.6
	Less durable	3	1.4	Less durable	2	2.5
Solar PV System's Return on Investment	Yes	164	76.3	Yes	77	98.7
	No	51	23.7	No	1	1.3

The daily hourly usage of solar PV energy by Households as shown on Table 2 was found to be highest between 19-24 hours per day representing about 35% of the total households. This was because most of the households within this category installed solar PV systems that can provide lighting, charging phones, allow fans usage and usage of low energy consuming fridge or Air conditioner for such hours per day.

Table 2: Solar Energy Consumption per day by Households and Small-Scale Businesses

Number of Hours of Service per day	Household		Small-scale Businesses	
	Freq.	Percentage	Freq.	Percentage
1 to 6 hours per day	30	14	15	19.2
7 to 12 hours per day	50	23.3	51	65.4
13 to 18 hours per day	59	27.4	6	7.7
19 to 24 hours per day	76	35.3	6	7.7
Total	215	100	78	100

This was followed by 13-18 hourly usage per day representing about 27% of the total households. About 23% used it for 7-12 hours daily while the lowest usage of 1-6 hours per day was represented by just 14%. The hourly service per day was strongly related to the type of solar PV system and its energy capacity. The higher the energy capacity, the higher the number of service hours provided. It was also related to usage, if high-energy consuming appliances are used, the number of service hours would be low and vice-versa. The scenario was different for small-scale businesses because they use solar energy mostly for 7-12 hours daily especially during the daytime and into the early part of the night, this accounted for about 65% of the total small-scale businesses. Small-scale businesses that use solar energy for 1-6 hours daily constitute about 19%. However, businesses that use solar PV energy for 13-18 hours and 19-24 hours daily represented about 8% of the total respondents each. In terms of solar PV system durability, more than half (56%) of the households considered their system as highly durable, however, about 43% believed it to be averagely durable. This was because good products were bought and are properly maintained. Only a fraction (1%) of the households believed it to be less durable because of either poor maintenance, improper installation, sub-standard products or lack of energy audit before installation. However, the situation was slightly different for the small-scale businesses; about 45% of the small-scale businesses said their system is highly durable, the majority (53%) said it is averagely durable while a small portion (3%) considered the system as less durable.

Almost all the households and small-scale businesses believed their solar PV systems provided returns on their investments and were satisfied especially when compared with running petrol/diesel generator sets. These represent about 76% and 98% of the household and small-scale businesses respectively. However, about 24% and 1% of households and small-scale businesses felt their solar PV system does not provide returns on their investment respectively, apparently, because sub-standard products were used or because of poor maintenance and lack of energy audit before installation. This means that the system does not provide the services which they hitherto expected it to provide.

Based on the responses from the study as shown on Table 3 most households used their solar PV systems for lighting, phone charging, and use of fans and for TV and Radio systems.

However, more than half of the small-scale businesses used their solar PV systems for lighting, charging phones, and using fans; they represents 57.7% of the total small-scale business respondents. This is somewhat due to the small-scale nature of the businesses. A considerable number of small-scale businesses (24. 4%) used their solar PV system for lighting, charging phones, fans, and the use of TV system (TV with Receiver/DVD/Radio). This may reduce the amount of GHG to be emitted using generator (El-Pateh, 2015).

Table 3: Equipment carried by the Solar PV System

Energy (PV) Utilization	Household		Small-scale businesses	
	Frequency	Percent	Frequency	Percent
Lighting and charging	3	1.4	7	9
Lighting, charging and fans	25	11.6	45	57.7
Lighting, charging, fans & TV system	81	37.7	19	24.4
Lighting, phone charging, Fans, TV System and AC/Fridge	48	22.3	2	2.6
Lighting, B1charging, Fans, TV system, AC/Fridge, and Water Pumping	13	6	3	3.8
Lighting, phone charging, Fans, TV system, AC/Fridge, Water Pumping and other uses	13	6	0	0
Lighting, Phone Charging, Fans, TV system, Fridge/AC and others	26	12.1	1	1.3
Lighting, Phone Charging, Fans, TV system and others	6	2.8	1	1.3
Total	215	100	78	100

Table 4 shows that most households used their solar PV systems all round (24 hours) and these are closely followed by households that used their systems during the night time. This was probably because nighttime usage of electricity is a prominent feature of most developing countries.

Table 4: Period of Solar PV Utilization

Users	Period	Frequency	Percent
Households	Morning	3	1.4
	Night	105	48.8
	All Round	107	49.8
	Total	215	100
Small-scale Businesses	Morning	7	9
	Night	61	78.2
	All Round	10	12.8
Total		78	100

This is somehow different for small-scale businesses, almost all of them (78.2%) utilize their solar PV system during the night-time this is mostly due to the nature of their businesses as most of them are into businesses of barbing saloons, hairdressing, electronic sales and computer business centres. These businesses thrive mostly during the night-time. Daytime users of solar PV systems among the small-scale businesses represent just 9.0% while all-round users accounted for 12.8%. The results obtained contradicted. This shows that conversion from generator to PV system reduce the cost input (fueling and maintenance) and therefore enhance their profit and reduction in GHG emission. This is adduce by Kumar and Kandpal (2007) who reported that us solar energy with reduce the gaseous emission from the combustion fuel used for generators and there reduce the atmospheric pollution.

CONCLUSION

The high initial investment cost needed to procure and install a solar PV system led many users of solar PV technology in the state to use low energy capacity systems. Most Solar PV energy technologies sold in the market are affordable, efficient, durable and provided good returns on investment provided a prospective user do his homework well before procuring and installing the system. Socio-economic challenges and issues such as the need for backup energy sources and improper government policies in the sector were the major factors influencing solar PV energy utilization in the area. However, high initial investment cost, improper installation, lack of awareness, sub-standard products, and inadequate government support, therefore these challenges are surmountable if proper awareness is created and appropriate policies and check-ups are implemented. There is optimism that the transition towards replacing generators with solar PV system that reduce the greenhouse gases and therefore considered to as climate change mitigation strategies. Use of clean energy will be intensified by granting loan and subsidizing the facilities for easy access to all users

CONFLICT OF INTEREST

The authors are hereby declared this manuscript is original research and not send for review and publication and therefore, there is no conflict of interest with regard to this manuscript.

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