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Not There Yet: Mapping Inhibitions to Solar Energy Utilisation by Households in African Informal Urban Neighbourhoods

Aliyu Salisu Barau [1,*], Aliyu Haidar Abubakar [2] and Abdul-Hakim Ibrahim Kiyawa [3]

1 Department of Urban and Regional Planning, Bayero University Kano, Kano 700241, Nigeria
2 Department of Environmental Management, Bayero University Kano, Kano 700241, Nigeria; ahabubakar.em@buk.edu.ng
3 Tianjin Key Laboratory of Indoor Air Environmental Quality, Tianjin University, Tianjin 300072, China; aikiyawa@tju.edu.cn
* Correspondence: asbarau.urp@buk.edu.ng

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Abstract: The average household access to electricity in Nigeria is estimated at four hours per day. This paradoxical energy crisis in a top oil and gas exporting country makes an interesting case for local and global players in the sustainable energy agenda. The current study showcases experiences of households that installed and use solar photovoltaic (PV) technologies in urban Africa. It identifies the key sociotechnical transition issues that shape the households' solar energy adoption strategies. To get a clear picture of the situation, the study focuses on the Kano urban agglomeration—a densely populated city with high economic activities. To answer the research question, the sampled respondents shared their experiences via questionnaire and interviews. Similarly, field observations guided the research team to identify patterns of household solar energy use, and how urban planning, building, and roofing types inhibit solar energy utilisation. From the results of the study, it appeared that households use solar energy for lighting, energising rechargeable appliances, and cooling of houses. Nevertheless, none of the respondents use solar photovoltaics (PVs) for cooking—the biggest consumer of fuelwood in Nigeria. Finally, this study is optimistic that despite the challenges identified, the transition to clean energy security in Africa is achievable through coordinated efforts of people, industry, and governments. The transition to renewables by households promises significant changes that can lever the mainstreaming of the UN Sustainable Development Goals-SDG no. 7.

Keywords: energy; SDGs; urban planning; sustainability; transition; socio-technical

1. Introduction

Affordable and clean energy is one of the Sustainable Development Goals (SDGs-Goal no. 7) designed to tackle the challenges of dirty energy and low access to energy by communities around the world. Indeed, one of the strategies to combat climate change and other development challenges is investment in renewable energy. This strategy can improve poor households' access to energy in developing countries. Since the launch of the SDGs in 2015, some progress has been made in their implementation. A forecast by the IEA (International Energy Agency) [1] has suggested that the global renewable energy output will expand by 50% between 2019 and 2024 with solar photovoltaic (PV) taking the lead. It is evident from some studies that sub-Saharan Africa has in recent years made some progress in off-grid connections particularly in the solar energy sector [2]. Although, there is an irony associated with Africa's renewable energy development, on the one hand, the quest for economic development supports it, and on the other population growth impedes it [3]. Some critical scholars have decried the rate at which large scale renewable energy projects fail in sub-Saharan Africa [4]. It is important to add that one can only create a big picture of energy crises in Africa by reflecting on the level of inequality in energy access within the region [5].

Considering the challenges outlined above, many studies have stressed the importance of transitions to clean energy in Africa. Studies have also shown the extent of energy poverty among African households. For instance, only about 40% of households of Africa's most populous country—Nigeria—have access to electricity [6]. While this situation remains, the potentials of renewables and especially for businesses is shown to be high in richer Nigerian urban areas [7]. Therefore, it becomes important to explore the experiences of households with respect to access to renewable energy and to understand challenges and opportunities for improving access and sustainable development of the renewables sector.

Indeed, there are plenty of studies that focus on households and renewables from across the globe. For instance, studies from technologically advanced countries have focused on households and renewables in contexts of financing and payment mechanisms for systems that work or are efficient [8–10]. Nevertheless, in developed countries the renewables range from mixed, hydrogen, solar photovoltaic and others. Thus, issues investigated by researchers in those countries range from participation, governance, investment, consumption patterns and user perceptions. On the other hand, in spite of the potentials of cleaner energy sources such as solar energy across Africa, the number of households using solar energy remains insignificant [11]. However, the fact that urbanization is growing ever faster in Africa suggests that renewable energy and in particular solar photovoltaic (PV) technologies are an indispensable option for the urban poor and middle-income population.

Whilst there are other options and potentials for renewables, many of them are at rudimentary stages of research and development. For example, heat energy transfers within urban informal settlements could have a high potential of energy generation and emission reduction [12]. Currently, this technology requires investments and perhaps long-term planning and financing mechanisms. The most cost-effective risk mitigation strategy is to gradually replace large-scale electricity exports with domestic solar energy which is abundant in Africa. Solar energy is no doubt one of the easiest short cuts for attaining universal access to clean energy in Africa. For African countries, solar energy is the cheapest and it enhances national energy sovereignty, is climate friendly, and it erodes regional generation and transmission dependencies [13]. Given this, it is apparent that households will potentially be one of the major beneficiaries of solar technology development.

It has been revealed that in Africa, many factors determine the adoption of solar technology by households; and these factors range from household headship by gender, levels of education and income [14]. Such neighbourhood-based findings have left some issues relating to urban planning situations, households' behavioural disposition in relation to use of solar energy and also a number of technological challenges such as repairs for gadgets. Such are important gaps that need to be filled in order to understand the challenges of transitions to solar energy adaption in African countries. More so, it is important to note that most low and middle-income households in African countries live in informal settlements characterised by poor urban planning. In effect, it is estimated that 60–70% of African urban population live in slums and informal neighbourhoods [15].

Theoretically speaking, household transitions to clean energy are in three main domains: adoption of solar photovoltaics (PVs), the residential heating system (RHS), and alternative fuel vehicles (AFVs) [16]. Considering the level of economic and technological underdevelopment in Africa, more attention is needed on solar PVs and how households interact with this technology. Recently, some scholars have critiqued the theoretical basis of African urban households' clean energy transitions. In the opinion of [17] and [18], it is imperative for academic and policymakers to consider engagement of end users in co-production of solutions to the energy crisis.

Often, socio-technical transition scholars underscore the complexities of clean energy transitions in relation to interactions of science, engineering, policy, people and how these reshape the future [19]. However, such notions are more correct in the context of developed economies where planned transitions may follow normative and linear pathways. In the case of sub-Saharan Africa, households may be open to too little choices among others due to urban planning and constraints of informality. Across urban areas around the world, transition to clean energy is undermined by behavioural, technological, and institutional lock-ins [20]. Therefore, this is hardly not true for sub-Saharan African countries.

The main research question driving this study is the following: What is the nature of solar energy adoption and utilisation in African cities? The current study showcases households' experiences of utilising and living with solar energy from solar photovoltaic (PV) technology. The study also identified the key sociotechnical transition issues that shape households' solar energy adoption patterns. To get a clear picture of the situation, the study focuses on the Kano urban agglomeration—a densely populated city with preponderance of economic activities. However, this major urban area has a dominance of informal economy and informal settlements adjoining it. Therefore, it justifies its selection as a focus for understanding solar PV in informal neighbourhoods—a settlement type—that represents the situation of over 60 of Africa's urban areas as demonstrated by [14]. This article is subdivided into four sections with an introduction setting the scene of the research and its main goal. The introductory part of the paper also sheds light on Nigeria's energy crises and the need for faster transition to clean energy as one of the vehicles for socio-economic transformation and implementation of the SDGs. The methods section outlines the study design processes and details of the study area appear in the second section. The findings are given in third section where the results and their implications are discussed. Key recommendations and the overall meaning of the study and its connections to the global sustainable energy agenda are given in the concluding section.

An Overview of Nigeria's Energy Crisis and Potentials for Transition to Renewables

The body of literature has explained much on the state of the energy crisis in sub-Saharan Africa. Although, the current study largely explores the situation of urban households, it is important to understand that the success or failure of renewable energy largely depends on the resource base and the policy climate of a given country. For instance, based on its geographical location, Nigeria receives an average daily solar intensity of 20.1 MJ/m^2/day; the wind speed ranges from 1.5 to 4.1 ms^{-1}; with vast potentials of biomass, geothermal and water [21]. The authors maintain that the current 7566.2 MW produced in Nigeria is seriously inadequate for its projected population of 300 million by 2050. Currently, hydropower has the best renewable energy potential, which amounts to 10,000 MW for large hydropower and 734 MW for small hydropower [22].

Since of all the renewables, solar energy technology is seemingly the most accessible by poorer households, it is critical to understand its distributional situation in Nigeria. Ozoegwu et al. [23] revealed that previously and even currently Nigeria has lacked experience of grid-connected solar power integration although the future may be promising. Apparently, this implies that the potentials lie more with households and businesses to own and maintain solar PV technologies. Regardless of their situation now, energy policies and the decision-making process will play an important role in determining the success or failure of the adoption process of solar PVs and other renewables by households in Nigeria.

It could be said that some of the barriers to attaining sustainable energy in Nigeria cannot be separated from governance and policy issues. For instance, [24] identified cost and pricing barriers; market performance barriers, and legal and regulatory barriers as impediments of sustainable energy development in Nigeria. As such, building on the above premise, it is strongly recommended that the policy-making processes should fast track provision of energy infrastructure through: granting access to data; regulations; and issuance of licenses [25]. The authors cautioned that by failing to do so, the Nigerian government will end up financing corruption in the energy sector; injecting economic delusion; and having uncontrolled growth in export-based energy demand [21].

Energy imbalance and inequality between cities and industrial areas on one hand, and rural areas and places of the poor is alarmingly disproportionate. The nature of energy disenfranchising in Nigeria is high to the extent that 60% to 70% of the population lacks access to electricity [26]. This apparent energy insecurity has implications on environmental sustainability, where for instance, over 80% of the population rely on fuelwood, charcoal and other biomass energy sources for cooking [27]. Despite this, fuelwood is yet to be prioritised and wholly recognised in the context of current renewable energy transition discourses in respect of Nigerian urban centres [28]. Another aspect to the challenge is that low and middle-income households that cannot cope with raising prices of kerosene and cooking gas shift to firewood [29]. This situation will particularly increase pressure on woody plant species within and around urban agglomerations.

2. Materials and Methods

2.1. Study Area

Urban Kano is located on the central plains of Northern Nigeria also called Kao Plains. The area bestrides latitude 11,059′59.57–12,002′39.570 N and longitudes 8033′19.69–8031′59.690 E. It lies in the northern part of Nigeria and is located some 840 km away from the edge of the Sahara Desert and 1140 km from the Atlantic Ocean [30]. Urban Kano constitutes the old city, Fagge and the metropolitan areas which together serve as the capital city of Kano State. The Kano Urban area covers 137 sq km and comprises eight Local Government Areas (LGAs)—Kano Municipal, Fagge, Dala, Gwale, Tarauni, Nassarawa, Kumbotso and Ungogo [31]. The population of the study is estimated to be approximately 4.5 million making it the second largest metropolitan area in Nigeria [32]. Solarimeter readings of solar radiation in urban Kano using a modified Fluke datalogger revealed that within a period of one year, the city receives 1367 W m^{-2} [33]. However, a recent computer-driven study determined the optimum slope angle for solar radiation collectors in Kano [34]. The findings suggested that for maximum solar collection, the optimum angle of each month should be set to the seasonal tilt angles—horizontal from April to September—and then set to Kano's latitude plus 15° for the other months. Thus, the sloping of the solar collector to the monthly optimum tilt angle brings radiation gain throughout the year and up to 28.6% and 24.8% in December and January. Given this, it is critical to investigate the current state of solar adoption in an area that is characterised by high consumption of fuelwood and where its energy transitions have also attracted the attention of many researchers [26,27,34].

2.2. Sampling of Solar PV Users

Recent studies have argued that households give a clearer picture of true energy access and dynamics of transition to renewables [35,36]. The population of Kano metropolis (and its agglomeration) is projected to be between 5 to 6 million people [37]. The challenge of access to energy for this population is clear. According to the Nigerian Data Portal (2017), only 0.3 percent (18,000 people) of residents of Kano metropolis use solar energy technology. Thus, following [38], the sample size for the PV users (target population) 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 (http://www.raosoft.com/samplesize.html). With such insignificant number of solar energy users in the study area and more with an unspecified population, focussing on urban households helped the study to answer its research question. Studies rely on this model to determine the minimum sample size for social and health related research [39]. The population of solar users (18,000) was inputted and the software suggested a sample of 377 respondents in Kano metropolis and a five percent margin error of 377 (17) was added making a total of 394 which was rounded up to 400.

2.3. Sampling of the Study Sites

For the purpose of sampling the study locations, two diagonal lines crossing each other were drawn on the map of Kano Metropolis, thereby dividing the map into four parts. Consequently, five (5) points representing major neighbourhoods were chosen at random from each of the four segments, thereby making a total of twenty (20) neighbourhoods. Afterwards, ten (10) respondents (Solar PV adopters) were selected from each locality, thus giving a total of 200 respondents. This number was appropriate for this kind of study because a recent review paper suggested that the average sample size for lighting (energy) publications is 40 [40]. For most studies on energy, the selected respondents answered questions on behalf of the sampled participating households/houses identified. The study was supported by two field assistants with many years of fieldwork experiences in Kano city and perhaps this helped in achieving 100% response within the two years of the study (2017–2019). Some 64% of the respondents were male household heads, an additional 33% of the respondents were educated adult male members of the selected households, while only 3% of the solar energy using households were headed by females. For the questions asked please see the supplementary list. The selected sites include: Hotoron Arewa, Kundila, Yar Akwa, Kuntau, Tudun Yola, Gadon Kaya, Fagge, Rimin Gata, Kofar Wambai, Yola, Unguwar Gini, Sharada, Alfindiki, Sheka, Bakin Zuwo, Chedi, Bompai, Durumin Iya, Dakata and Gandun Albasa. See Figure 1 for location of the study sites.

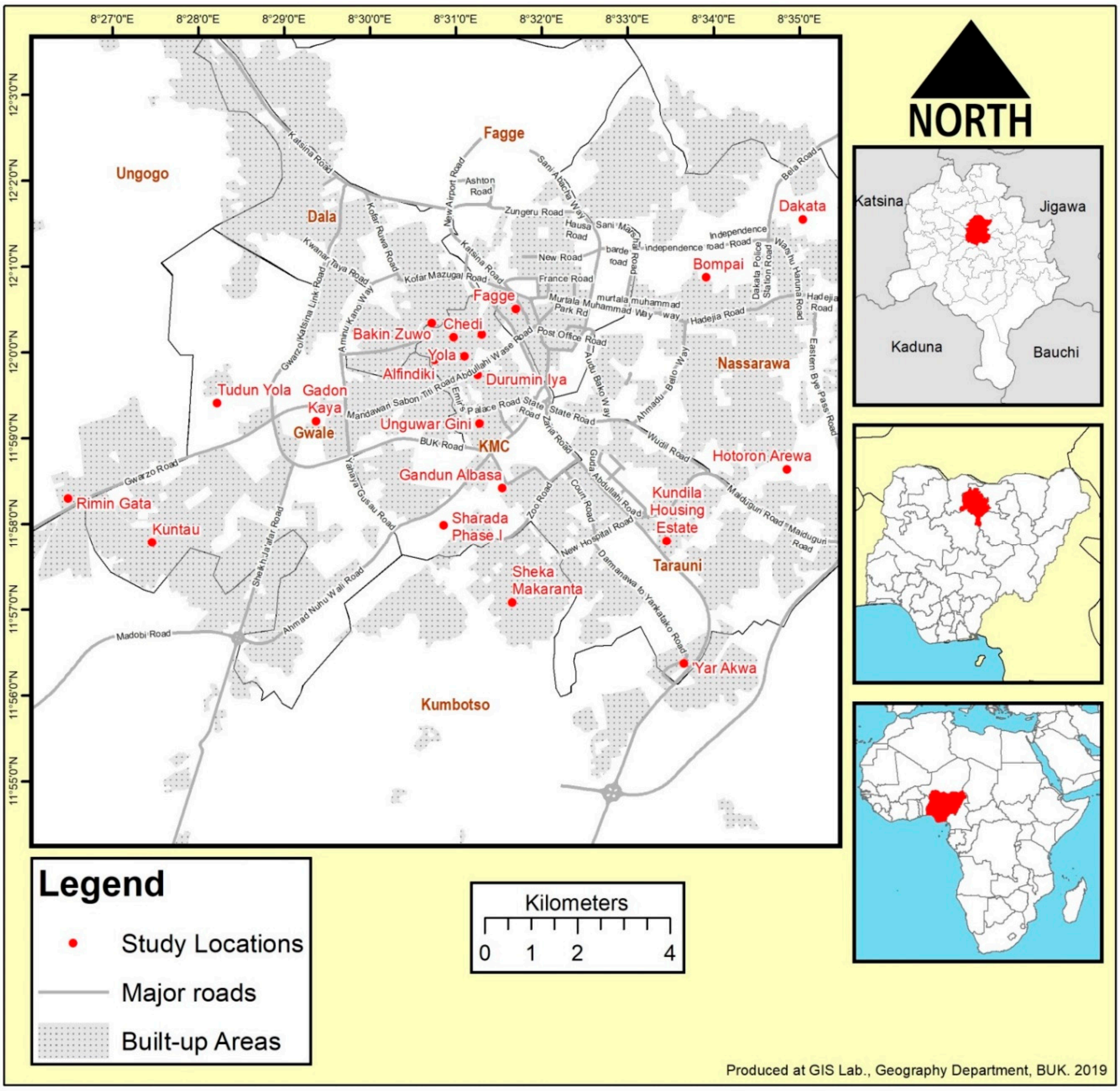

Figure 1. Locations of the 20 study sites in urban Kano.

2.4. Procedure for Data Collection and Analysis

A semi-structured questionnaire was designed comprising both open-ended and closed-ended questions so as to avoid bias, ambiguity, or uncertainty in the answers provided. The questionnaire was divided into sections that sought demographic, socio-economic and technical information from the respondents. Options were given for closed-ended questions, while the Likert scale was used for questions with options ranging from 1–5 signifying various levels of agreement or disagreement with the pre-determined answers. The questions also elicited responses on problems encountered and level of adoption by households. Similarly, a fieldwork was carried out between 2017 and 2019 to ascertain some sociotechnical related issues that could be impediments to adoption of solar PVs by households. The issues covered include the appropriateness of siting PVs in houses located in the study area. Descriptive statistics were used to compute means, standard deviation percentages and frequencies of data such as problems of adoption and level of adoption. All data were presented in tables and charts containing frequencies, mean, and standard deviation while percentages were calculated in Microsoft Excel 2010 and SPSS software version 16.0. Where necessary, quotations of respondents were presented to stress important points or patterns. The summary of the research design is diagrammatically given in Figure 2:

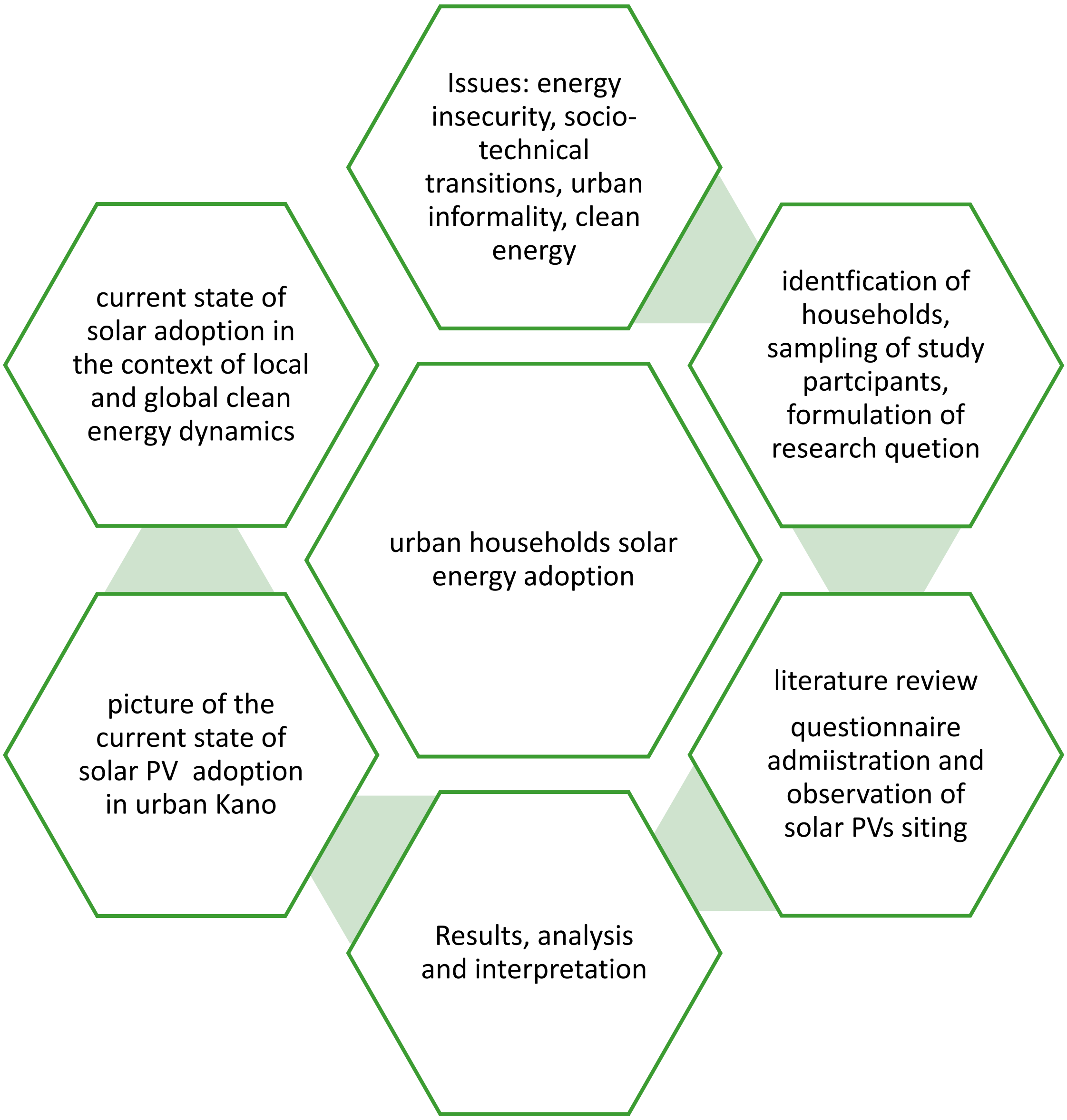

Figure 2. Research design process followed in the study.

3. Results and Discussion

3.1. Analysis of How Households Use Their Solar PVs

The analysis of the study variables is presented in Table 1 which shows that households use their PVs mainly for lighting. Less than half of the respondents use solar energy for charging of appliances such as phones, rechargeable lamps and other rechargeable appliances. However, utilisation of solar for water pumping (powering boreholes) has the lowest percentage as less than one-tenth of the households used it for pumping of water. Therefore, in this case, it is clear that only a few households have a high number of panels that can generate sufficient energy for water pumping.

Table 1. A descriptive analysis of how households use solar energy.

Variables	Sum	Mean	Std. Deviation
Usage of Solar PVs			
Lighting	158	0.79	0.41
Charging Appliances	87	0.435	0.50
Cooling and Heating	31	0.155	0.36
Pumping	16	0.08	0.27
Television and Radio	68	0.34	0.47
Night versus daytime Usage			
Morning Usage	333	1.665	0.47
Afternoon Usage	349	1.745	0.44
Night Usage	244	1.22	0.42
Hours of Solar Usage			
1–6 h	57		
7–12 h	62		
13–18 h	33		
19–24 h	48		

Based on the responses drawn from this study, solar energy is mostly used for house lighting. This is likely to occur because most households light up their houses even if they have no other electric appliances. This is in line with findings by [39] where it was revealed that lighting and ventilation had the highest annual consumption of electricity in Nigerian states. On the other hand, the daily average duration of solar energy consumption was found to be highest among households that used it between 7 to 12 h, accounting for almost one-third of the solar users. The general pattern of duration of usage may be insufficient but is still better than the average national grid supply of four hours experienced in Nigeria [41].

The variation between night and daytime usage of solar energy shows that the majority (78%) of the households use solar energy during the nightfall. This is because there is need to illuminate the houses, coupled with the fact that most people are at home and need to watch television and cool their surrounding using fans and low energy air conditioners. On the other hand, only one-third of the solar users makes use of it in the morning, while one-quarter uses it in the afternoon.

This study found that about 60% of the solar energy adopters in the study area installed their system between 2015 and 2016 while the remainder had acquired them before. This reveals an increase in the adoption of renewables by the Kano urban households in recent years (see Figure 3).

Figure 4 shows the challenges encountered by households that have embraced solar PV technology. The major challenge identified by the respondents is associated with the reduced duration of charge retention by the batteries. About 40 percent of the respondents pointed at this problem while others complained of poor charging, inverter malfunction and solar panel problem. Technical and maintenance problems have been identified by [42–44] as the major problems of solar adoption. In the interview conducted, some of the households noted that inadequacy of technically skilled manpower, coupled with low quality products in the market make the lifespan of the system shorter. In this regard, it has been observed that component failure occurs when a fully installed operational device such as home device becomes un-operational shortly after installation [45]. Since the adoption of solar energy is relatively new in Africa, users are discouraged when the performance is below their expectations.

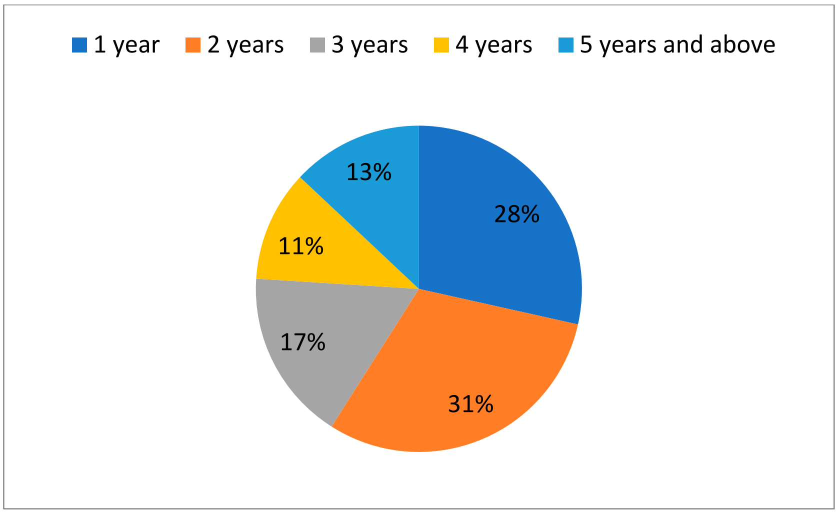

Figure 3. Years since installation of solar PVs as at the time of the study in 2017/2019.

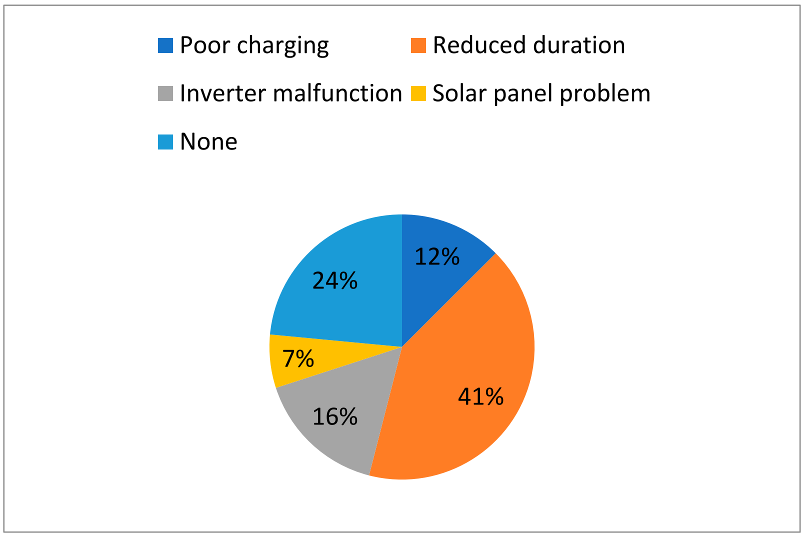

Figure 4. Technical challenges encountered by solar photovoltaic (PV) adopters.

The result also revealed that about 60% of households reported they replaced their batteries at least once. This is so because batteries have lifespans and need to be replaced after some time. However, as at the time of this study only 40% of the respondents were yet to replace their batteries. Battery problems are mostly encountered due to some factors such as poor maintenance as a result of inadequate technical know-how or sales of substandard products [46]. Out of those who changed batteries, which represents about three in every five, about one quarter replaced batteries at least once since installation, while one fifth changed batteries at least once a year, and over one-tenth replaced batteries at least once in two years. It is known that batteries have a lifespan, and all solar PVs require batteries to store the energy. It is for that reason that battery lifespan is very important to adopters, the longer the lifespan the better.

3.2. Challenges to Effective Transition to Solar PV Energy

Besides the use-related challenges identified by households, there are several other challenges that may arise from the nature of placement of the solar PV panels on buildings, the location within urban planning typology and the type of building or roofing style. It is crucial to pay attention to these factors in order to understand renewable energy transition dynamics of African households. Other issues relate to discipline and the decision-making process in the use of electrical appliances plugged into the household solar energy system. Out of the 200 houses within the 20 neighbourhoods observed 139 (69.5%) of them are located in unplanned parts of the city. This suggest the predominance of solar energy adoption in informal settlements as is common with a typical African urban area [14]. This may at the same time imply that formally planned areas receive more electricity supply. On the other hand, 42.5% of the buildings are duplex compared to 29.5% duplex type and 28% that are a mix of the two. An interpretation of this situation could be that individuals that own duplex houses or occupy them by renting have higher economic status.

In relation to type of building and planning area, the study found that the neighbouring houses' type of building significantly affects the quality of solar energy that households can enjoy. This has to do with for instance a situation whereby a neighbouring duplex house can block sunrays for a neighbouring bungalow building that has installed solar PV panels. Similarly, types of roofing vary in both planned and unplanned neighbourhoods of urban Kano. As such, the study found that 51% of the households have hip type of roofing whereas 21% have gable roofs while 28% have gable roofing style.

The type of roofing affects the adoption of solar energy in two ways: first it affects the solar radiation to the next building; and second, it affects the solar radiation for the panels mounted on the roof. The angle of inclination of the roof affects the solar radiation if the angle of movement of the sun is not in consonance with the roof tilt angle. This has an effect on the energy output because according to [47], at any location on the earth, solar output is affected by its tilt and azimuth angles. These angles play an important role in the efficiency of the solar photovoltaic panel (see Figure 5; Figure 6).

Figure 5. Solar PV panels mounted over a hip roof.

Figure 6. Solar panels mounted on the roof top of a bungalow house with a duplex house blocking the early morning sunrays from the east.

The majority of the solar PV panels were placed on roofs, only about 20% of the respondents had their panels placed on the fence and open space within the perimeters of their buildings. Although the roof-top may not be the most suitable space for siting the panels due to unavailability of space, they have no option but to use the roof. According to a respondent:

> "If we have enough space, we would have mounted the panels on stake to serve as car shade, but due to lack of space, we had to mount it on the roof, yet the roof was not enough, so we had to mount some of the panels on the adjacent building,"

3.3. Decision-Making Issues in the Management of Solar PV by Households

The sustainability of clean energy produced at household level will certainly depend on the decision-making system that can determine how households use energy and maintain the installed system. Decision-making may also entail what kind of appliances household members use or their energy efficiency labelling. For instance, 67% of the respondents indicated that by using solar PV they developed the culture of switching off appliances when not in use. However, households with many PV panels that generate energy for up to 18–24 h per day exhibited indifference to switching off their appliances. As a whole, adopters have to monitor their usage in order to maximize their back up time as well as maintain a healthy lifespan of the solar component. In this regard, one of the respondents argued that as a household: "we monitor our energy consumption, and once the battery backup remains 20%, we switch it off until the battery is charged again."

The nature of decisions taken by households to achieve efficient use of solar PVs is outlined in Table 2. The timing of solar energy consumption appeared to be the leading strategy that households employ to tackle inefficient use by their members.

Table 2. Measures for addressing inefficient usage.

Measures	Frequency	Percent
Timed usage	81	40.5
System upgrade	19	9.5
Sensitisation	22	11
Light off	40	20
None	38	19
Total	200	100.0

Nevertheless, some users combine two measures to ensure maximum efficiency. The majority of the users prepared a timing for using the solar energy system. However, this is dictated by understanding and negotiating the use of the solar energy by the family members. For instance, a respondent observed that they had to "disconnect electric cooker from the distribution box, and now we rely gas cooker due to its lower cost and energy demand."

In this study, it was difficult to genuinely establish the efficiency of electric appliances in Nigeria. This is due to poor standardisation, quality control lapses, and flooding of markets with imported counterfeit products. To overcome this, this study asked the respondents to categorise their home appliances that they plug in to solar energy. The breakdown of appliances is given in Table 3.

Table 3. Use of energy efficient appliances.

Perceived Energy Efficiency	Frequency	Percent
Poor	41	20.5
Moderate	76	38
Good	83	41.5
Total	**200**	**100.0**

Despite the challenges of energy efficiency labelling in Nigeria [48], the majority of the observed households claimed to use appliances with good energy star labelling. They believed that their appliances consume less energy. As a whole, appliances with low energy consumption tend to elongate the backup time as against appliances with high energy demand.

Over 50% of the solar PV adopters claimed that they changed their high energy appliances after installing the solar energy system. For instance, some respondents said they had to change all their lighting bulbs to energy saving bulbs. One of the respondents specifically noted that all their bulbs were replaced with 8 watt bulbs and LED lights for indoor lighting points. Overall, the users were satisfied with the performance of their solar energy system, although 10% of the respondents expressed their dissatisfaction with the system. The majority of the respondents stated that they were satisfied because they got some relief from the incessant power outage. According to a female respondent: "my solar energy system is very satisfactory; this may not be unconnected with the high level of maintenance we carry out. It is being checked regularly by skilled personnel, even the liquid in the battery is gauged regularly."

Nigeria depends largely on Indian and Chinese markets for its importation of solar panels, batteries and other accessories. As such, it can be said that Nigeria's transition to solar based renewable energy is foreign dependent. While dependency is not entirely a bad thing, some risks associated with global trade could jeopardise smooth transition to renewables. Currently, over 80% of the users said spare parts and services were readily available through technicians who offer such services on request. At this point, it is important to stress that the solar business and maintenance services are informal and thrive within the broader urban informality. Individuals lacking requisite training and knowledge of electric energy service can enter and join the solar energy business and its related services. One of the respondents related that: "I did my installation myself and have not done any repair, hence I don't know of the availability of services and repairs." This is a serious issue in that professionalism and safety issues are seriously compromised.

4. Conclusions

In this section, we draw many other insights from the results of the current study. Renewable energy offers solutions to the current global energy crisis particularly as it relates to access and climate friendliness which the SDG 7 propagates. This study outlines the stories of the adoption of solar PV technology by households in Nigeria's second largest urban agglomeration Kano. By focussing on this city, the current study has broadened the narratives on the nature of transition to renewables in the informal urban areas in sub-Saharan Africa. As established by the literature, African households have the least access to energy and firewood has remained the main source of energy. Hence, it is critical that all stakeholders drive actions for change and focus on mainstreaming SDG 7 for households as units for measuring success of transitions to renewable energy.

More so, the experiences of households living in informal urban settings are likely to improve our understanding of how poor and middle-income groups react to the energy crisis and the opportunities. In the case of Nigeria—one of the world's leading exporters of crude oil and natural gas—it is paradoxical that access to energy, in particular electricity, is poor. In a country where access to electricity by households is as low as four hours a day, there is a strong probability that energy insecurity could have negative ripple effects on the quality of life of urban households. However, more studies are needed to understand the situation as it affects people of rural areas. Indeed, one of the limitations of the current study is its inability to pay much attention to age and gender dimensions of renewable energy technologies adoption and utilisation. This is definitely the next step to explore in a future study to understand households' renewables utilisation dynamics. Another area of interest for further studies is on the quality and efficiency of solar panels available to households.

From the results of this study, it was revealed that none of the respondents uses solar energy for cooking. On the contrary, the literature has established that more than 70% of Nigerian households rely on fuelwood for cooking. It is clear that most of the households use solar energy for lighting, cooling and other conveniences that support comfortable living. Nonetheless, the limited capacity of the types of solar PVs available in Nigeria makes it impossible for households to use them for cooking.

This technical limitation means solar energy adoption by households can hardly limit emission levels and the deforestation emanating from urban households' massive dependency on fuelwood. This is another issue of interest to global and local players of the SDGs implementation. Therefore, this point is considered critical that engineering and science, policy, development and civil society communities lever their collective actions for mainstreaming renewable energy transitions in developing countries.

Another insight from this study is in respect of the role of urban planning on the effectiveness of solar energy utilisation by households. It is apparent from the current study that siting of solar panels strongly depends on the nature of urban planning associated with neighbourhoods. In other words, the efficiency of the household solar energy system depends on the quality of the existing urban planning systems. In the case of this study, roofing systems and building types significantly affected exposure of solar PV panels to day-long sun rays. By implication, it is imperative for investors and the public sector to create and invest in initiatives to develop solar gardens that can generate electricity for individual urban households. In this way, the identified challenge can be addressed by solar energy sharing and sales to willing urban households.

Our study also highlights the critical role of the decision-making process on how households handle their clean energy sources and facilities. Based on our findings, this is largely a behavioural issue that requires public enlightenment and can be supported by renewable energy associations. Another issue of importance is to do with choices available to households with respect to energy labelling for energy efficient household appliances. Energy regulatory authorities and standards organisations in developing countries need to develop robust strategies to address the importation of counterfeit appliances. Finally, this study is optimistic that despite the challenges identified, the transition to clean energy security in Africa is achievable. At least, the slow and steady running of renewables by households can make significant changes that support the process of implementing SDG 7.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/3/840/s1.

Author Contributions: A.H.A. undertook most aspects of the fieldwork under the guidance of A.S.B. A.-H.I.K. and A.H.A. conducted the analysis and writing of the first draft. A.S.B. rewrote the manuscript and organised it into the current form. All authors have read and agree to the published version of the manuscript.

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