



Identifying Socio-Technical Barriers And Drivers To The Large-Scale Diffusion Of Off-Grid Solar Pv In Rural Areas In Nigeria

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Abstract

Despite the enormous potential of Nigeria to generate electricity from photovoltaic solar systems, the diffusion of this technology still remains low. The present multi-disciplinary study, which aims to span a period of nine (9) months through a combination of multi-actor, multi-domain, and multi-level approaches, seeks to identify and investigate the barriers and drivers to solar PV electricity systems in rural areas in Nigeria. Firstly, after literature review, interviewing the experts and thematic analysis, transition barriers (categorized under social, economic, political, institutional, and technical) will be identified, and MAXQDA software will be used for data analysis based on the Fuzzy Delphi technique. In the second phase, interviews with experts and the use of the Strategic Options Development and Analysis (SODA) method will be used to indicate the impact of the identified barriers on the functions of resource allocation, legitimization, and system orientation. Finally, some mechanisms will be proposed to overcome these obstacles.

Keywords: Solar PV, Rural Areas, Electrification, Nigeria, Renewable energy



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1.0 INTRODUCTION

Electrification, as a source of energy, is very significant in enhancing living standards. Be it rural or urban, the availability of electricity is essential for the social, economic, and psychological needs of man. In the last three decades, efforts have been made to ensure that rural settlements have access to electricity. As a result of the deregulation and fractionalisation of electricity providers into various geographical coverages, it is expected of the service providers to ensure that electricity should be provided irrespective of the settlement status. In recent decades, it is obvious that efforts have been made by the government to ensure that rural electrification is incorporated into its overall regional electrification master plan. This is further necessary as it has been observed that non-availability of electricity supply in many rural areas of Nigeria seems to be responsible for the rural-urban migration syndrome. Despite such efforts, rural electrification has continued to remain a huge challenge for the Nigerian government.

Understanding the barriers that inhibit the deployment of solar PV electricity technology to achieve energy security in rural areas is paramount to Nigeria. Although there are some improvements towards solar energy uptake, the share of this technology in the energy mix in Nigerian rural settlements is still very minimal. It is evident that significant policy barriers to renewable energy still exist at the national level, which has reduced the effectiveness of a concerted national effort to deploy renewables. In this study, a review of potential challenges and the main problems for the deployment of solar PV energy is presented. Data on barriers to solar PV development are collected, then analyzed at several levels before recommending measures to overcome the barriers. Through interviews and questionnaires with a focus group of key personnel, the barriers and challenges facing the implementation of solar energy deployment will be clarified. The current policy landscape, which benefits from fossil fuel imports, the lack of technical know-how and the lack of research and development in the renewable energy space will be among the key barriers to be considered. The research has outlined the key policy frameworks, regulatory environment, and lack of incentives, which encompass the renewable



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energy sector and present a critical analysis of the barriers faced by the industry. A mitigation framework will be proposed to bridge the gap in solar energy (renewable energy) deployment.

The objectives of the research include the following:

- Identification of the barriers/drivers to the penetration of solar PV electricity energy in rural areas.
- Categorization of the barriers/drivers into social, political, institutional, economic, and technical categories
- Prioritization of the barriers/drivers in accordance with their relevance to solar PV penetration
- Recommendation of effective reforms and strategies for a sustainable solution to solar PV development.

2.0 LITERATURE REVIEW

Despite the technological advances and cost reduction of renewable energy technologies (RETs), it is obvious that there are persistent barriers preventing the large-scale development of RETs in developing countries. Painuly (2001) analysed the key barriers to the diffusion of RETs from a stakeholder perspective. The analytical framework uses a stakeholder-based approach to analyse barriers to the adoption of renewable energy. The study identified the RET barriers under six categories: economic and financial-institution, technical, market failure, market distortions, and social-cultural-behavioral. Many other similar studies on the barriers to RET diffusion have been conducted by researchers and are highlighted in Table 1 below.



S/No	Reference	Case study area	Methodology	Stakeholders	Barriers	Driver
1.	Painuly (2001)		Stakeholder-based approach/ Stakeholder perspective		Economic and financial institutions, technical, market failure, market distortions, and social-cultural-behavioural	
2.	Ahlborg and Hammar (2014)	Mozambique and Tanzania	Qualitative methodology/ analytical framework/ semi-structured interviews	Government officials, international donors, technical consultants, and the civil society organization	Weak institutions and organizations, economy and finance, social dimensions, technical system and local management, technology diffusion and adaption, and rural infrastructure, lack of access to human capital, difficulties	Political priority



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					in planning and donor dependency, low rural markets and little interest from private sector, difficulties with installing electric equipment intraditional buildings”	
3.	Barry, et al., (2009a, 2009b)				Technology factors, site selection factors, economic/financial factors, and achievability by performing organization	
4.	Barry, Steyn, and Brent (2011)	Rwanda, Tanzania and Malawi	Stakeholder interview/gathering secondary data	Implementing agencies and end users	Technology factors, site selection factors, economic/financial factors, and achievability by performing organization, government support and environmental benefits	



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5.	Ohunakin et al. (2014)	Nigeria			Technological barriers, financial barriers, and institutional barriers (i.e. inadequate government policy and incentives, etc.)	
6.	De Jongh et al. (2014)	Gauteng, South Africa	Structured questionnaires/ interviews	Investment companies	Political, economic, social, and technological factors, financial viability and return on investment, public-private partnerships (PPPs)	
7.	Reddy and Painuly (2004)	Maharashtra State, India	Stakeholder-based approach/ survey/ stakeholder discussion work groups	Households, industry and commercial establishments, policy experts	Awareness and information, financial and economic, technical, market, institutional and regulatory, and behavioural	
8.	Lidula et al. (2007)	Association of Southeast Asian Nations (ASEAN)			Funding/financing difficulties, lack of awareness, lack of institutional and financial structures, limited policy framework, lack of	Amendment of renewable energy related policies and regulations at both



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					government support, lack of research and trained personnel, to economic barriers	national and regional levels
9.	Eleftheriadis and Anagnostopoulou (2015)	Greece			Inadequate financial resources, low grid capacity, delays in the issuance of building permits, opposition from local communities, and the lack of a stable institutional framework	Policy intervention
10.	McCormick and Kåberger (2007)	Europe (Sweden, Finland, Austria, Poland, Italy, and the UK)	Stakeholder interviews	Industry, research workshops	Economic conditions, know-how, and supply chain coordination	



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11.	Byrnes et al. (2013)	Australia			Policy landscape at regime level, low investment risk at regime level, lack of support for RETs, lack of skilled human capital	
12.	Sovacool (2009)	US	Semi-structured interviews with stakeholders	Public utility commissioners, utility managers, system operators, manufacturers, researchers, business owners, and ordinary consumers	Economic, political, and behavioural impediments	
13.	Trotter et al., (2017)	Sub-Saharan African countries	Peer-review of relevant journal articles		Institutional and financial	Adequate policy and institutional design, sufficient finance, and



						favourable political conditions
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Table 1: Summary of existing literature on the barriers/drivers for renewable energy development

This study focuses on identifying barriers and drivers to the deployment of large-scale solar power in rural areas in Nigeria as opposed to most of the previously discussed literature, which investigates generic barriers to REs without stating technology-specific barriers (e.g. barriers to large-scale solar power can be different from barriers to large-scale hydropower) and without stating the targeted scale of installations (e.g. small-scale vs large-scale) and the target beneficiaries (rural vs urban).

3.0 RESEARCH METHODOLOGY

This research has attempted to identify the key barriers and drivers to the diffusion of solar photovoltaic power in Nigerian rural areas from a stakeholder perspective. The study also aims to analyze barriers/drivers to the penetration of solar PV and to organize them under certain categories. Our study will use a stakeholder-based approach to analyse barriers and drivers to the penetration of solar PV energy and conduct a systematic classification thereof. Our study will use a qualitative methodology for the analysis based on the Fuzzy Delphi technique. The study is expected to be conducted during the nine months of fieldwork in Nigeria. The study will conduct a literature survey to gather data on potential opportunities and barriers for solar electricity energy in Nigeria. The survey is designed to determine the major barriers and to specify the major factors that need to be addressed from a policy perspective (e.g., suggestions for barriers' removal). The study will use semi-structured questionnaires during interviewing representatives (who make or contribute to energy projects' investment decisions) from various stakeholders in Nigeria.



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One hundred and fifty (150) semi-structured interviews will be conducted by interviewing different stakeholders, from implementing agencies to end users of solar energy systems in Nigeria. Data is collected based on stakeholders' interviews, which will include government officials, international donors, technical consultants, and civil society organizations, as well as stakeholders in industry, research workshops across the country. Through the qualitative methodology, data was collected through interviews with stakeholders. The interviews addressed six themes: (1) the current state of the electricity infrastructure in rural areas; (2) institutional and socioeconomic drivers and barriers to solar PV energy; (3) productive uses of electricity; (4) potential for off-grid and renewable electricity systems; (5) local participation in electrification processes; and (6) the impact of electricity on people's lives. In addition, the study will also gather secondary data in the form of project reports and other documentation. The data will be collected through a survey administered to households, personnel belonging to industry and commercial establishments, and policy experts. The stakeholders' perceptions were collected through answering surveys and participating in stakeholder discussion work groups.

The interviews were recorded (under normal circumstances) as sound files. The interviews will be semi-structured, i.e., asking open-ended questions, using an interview guide, and considering the professional experience of the respondent. The respondents are selected based on their influence on and experience of RET systems. Some interviews can be with two or three respondents at a time. The study will present the findings from 150 proposed interviews (from at least fifty communities) that will be carried out with the stakeholders. Our analytical strategy is based on theoretical propositions (Yin, 2009) and the concepts of "drivers" and "barriers", which are commonly found in the management literature, but are also commonly used by stakeholders in the field to signify factors that enhance or hinder the desired development.

The interviews will be recorded and then analyzed using MAXQDA software for qualitative data analysis. Each interview is thoroughly read through and studied, and then all meaning units (quotations) are sorted into categories (e.g. "barriers for RE") and subcategories (e.g. "communication problems"), which are in turn related to the themes. This type of analysis combines a deductive



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analysis (categories are based on the themes of interest) with inductive analysis (subcategories emerge from the material) in an iterative process (Mikkelsen, 2005). The software then allows for analysis of e.g. specific categories, subcategories and Boolean queries. The result is a cross-sector mapping allowing for comparison between various perspectives, organizations, and communities.

However, some observations can be made concerning the weaknesses and shortcomings in the methodological approach that we intend to adopt. First, the analysis is limited in scope in terms of both the number of respondents and the allocated time in each interview. The respondents in general have vast knowledge in their area, and much more can be learnt from each stakeholder. For practical reasons, only one interview will be held with each respondent, implying that the analysis reflects what stakeholders found relevant at a specific point in time. However, the format of semi-structured interviews allows for respondents to reflect on their own answers and bring up additional aspects even if they are not asked for. Second, there is always a risk of misunderstandings due to a lack of language skills. Interviews will be held in English and translated by a local interpreter where and when necessary. Further, information given must be assessed critically as respondents may lack knowledge or hold subjective perceptions that are inaccurate in some areas. Such weaknesses are addressed through triangulation of findings. It also matters if there are sensitive issues on which respondents are unwilling to answer. The question of biases in interviews, the concepts of reliability and validity (from quantitative science) are discussed at length in the literature. In this study, the trustworthiness of results is sought for inconsistencies and by comparing findings to existing literature.

4.0 RESULT AND DISCUSSION

4.1 FINAL ROUND CODING AND REPORT

The data obtained from the interview was in the form of verbal statements by the interview participants. The recorded interviews were later transcribed. Thereafter, the textual data was read several times in order to make meaning out of the data. Subsequently, initial



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precoding was conducted in order to highlight the significant words and short phrases that occurred in the data. This was done by circling, highlighting, bolding, underlining, or colouring rich or significant participants' quotes as recommended by (Saldana, 2013). Upon completion of the precoding, the actual coding process was undertaken to identify themes and sub-themes (nodes) that emerged from the data. The coding process was conducted in multiple stages that included attribute coding, descriptive coding, and pattern coding as shown in **Table 2**. The attribute coding was used to identify the demographic characteristics of the interview participants. The descriptive coding was used to break down the original chunks of interview transcripts into smaller, more manageable words or phrases that can be used in subsequent analytical work, as recommended by Miles and Huberman (1994). Lastly, pattern coding was used to identify the emergent themes or nodes in the underlying interview data.

Table 2: Coding process

S/N	Coding approach	Purpose
1	Attribute coding	To identify the demography of the participants
2	Descriptive coding	To summarise the interview data into smaller and manageable units
3	Pattern coding	To identify the underlying themes in the interview data

Finally, a Computer Assisted Qualitative Data Analysis Software (CAQDAS), Nvivo 10, was used to organise the emergent themes into broader but manageable categories that contained the participants' realities on the issue being investigated.

FACTORS INFLUENCING DECISIONS ON THE ADOPTION OF SOLAR PV SYSTEMS

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Figure 1 shows the nodes that emerged from the interviews on the theme "factors influencing the decision to purchase a PV solar system". The result shows that factors such as lack of finance, erratic supply from the national grid, system reliability, level of awareness, and others play a major role in influencing people’s decisions to invest in solar PV systems.

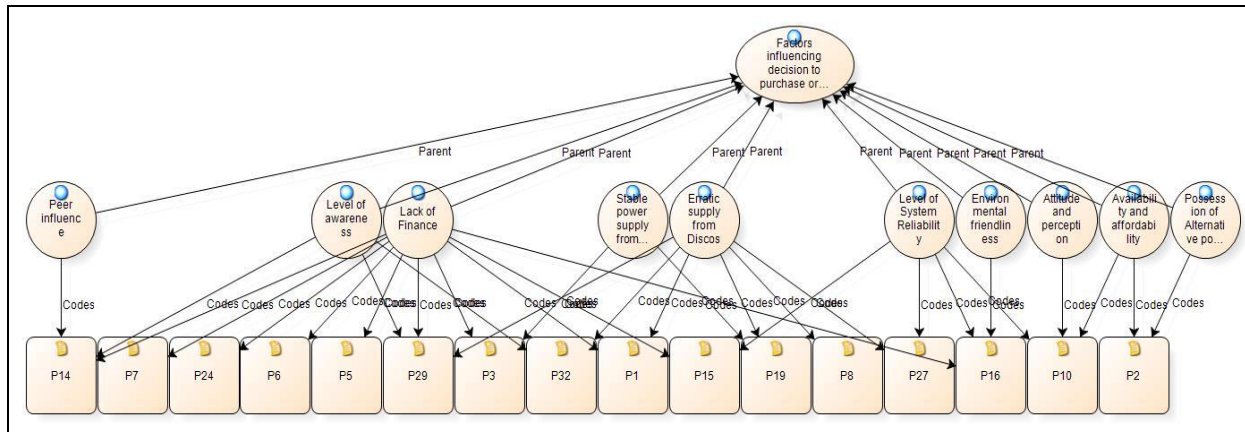


Figure 1: Factors influencing decision to install solar PV system

LACK OF FINANCE

Lack of sufficient finance among people is considered one of the most important factors that shapes an individual’s decision to invest in a PV solar system. The interviewees affirmed that the high cost of PV solar systems coupled with the unfavourable economic status of people resulted in low access to PV solar systems. The following are some excerpts of the verbatim expressions of the participants:



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"...not to purchase for now, basically is funding. Because when you find out you make finding you discover that to have a complete power pack that will power your house, you will need about 700k and 1 million naira. That's a huge sum, and you need budgeting to that. And that kind of money is not available, and that's the reason why I am holding back. " Participant 1

Nevertheless people are keen and desirous to obtain pv solar system lack of sufficient money prevents them from achieving their goals. This is evidenced in the submission of Participant 14 and Participant 15 who narrated that:

"Everybody wants to have light, so everybody wants to get something convenient for himself. But the issue there is money. If you don't have money, you can go for it. The main problem is getting your money to get all the materials. " Participant 14

And;

“Because of high cost of installation. And I called last time to come and install it for me they say...they charge me over...almost 1.8 million naira before I can get it...so even if I sourced money I refuse to go” Participant 15

ERRATIC POWER SUPPLY BY DISCOS

The interview results further revealed that the incessant failure of the Electricity Distribution Companies (DISCOS) across the country to supply regular electricity to the consumers is one of the most important driving factors that drive people into the adoption of PV solar systems. The position was captured in the responses as sampled below:

"The state of electricity in Nigeria is so poor that you cannot rely on the NEPA you cannot rely on power holding, is it power holding distribution company or Port Harcourt electricity distribution company PHEDC, you cannot rely on them for the supply of electricity



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absolutely, absolutely you have to look for alternative... But you see the state of electricity in Nigeria, I think everybody needs solar so that you don't rely absolutely on the government and the power distribution companies. You can do something alternatively for yourself, so I think everybody needs solar. " Participant 1

"The reason is that people want to get uninterrupted power. As you can see, the electricity is not enough for people, so for people like me, now in my own area, I hardly have power for two hours a day, so I need that PV solar panel to power to give me enough power. Like when I reach home in the night overnight I will have power. " Participant 8.

"People are adopting solar systems because of the failure of power from our national grid. Our national grid, I must tell you, is a failure. Because you cannot assume when the power will be available and when it will not be available. So solar is an option as long as the earth exists and there is sunlight... Of course definitely, if you are looking at an environment where you can stay for one week or one month without any power supply from the national grid, you have to look for alternatives, so those things affect people's decisions. " Participant 32

LEVEL OF SYSTEM RELIABILITY

Another important factor influencing people's decision to adopt or not to adopt a PV solar system is the level of system reliability. The interviewees hinted that deciding on whether to invest or not to invest in a PV solar system depends on how effective and efficient the system works. Their narrated opinions suggest that positive recommendations from people using the system can influence their decision to invest in it. Sample opinions from the interviewees are:



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“Of course by the promises that the...by the assurances that the manufacturers or people that you know have used solar over the years, overtime, have given to our people and many people have tested, you know I have come to believe that well, it could be a remedy to be a way out of our present predicament as far as power is concerned.” Participant 27

“I guess one of the important issue is the quality of the product. The quality of solar panels and the related accessories available for installation the quality I think should be the major concern.” Participant 16

On the other hand, negative feelings about the PV solar system occasioned by negative recommendations from other users and poor service experience on the part of the technician installing the system can lead people to not be attracted to the PV solar system. This scenario is vividly captured in the following narrations:

“...for some people that have tried this and par adventure the people that did the work for them did not give them the actual specification that they brought to the table when they came for agreement on the contract agreement, so those people will feel discouraged that this is not worth it.” Participant 10

“...one problem I have with solar energy was sometimes...the breaking down because of how they will not have energy to carry on.” Participant 15.

LEVEL OF AWARENESS

The level of how people are knowledgeable and aware of PV systems, their workings, and advantages is expected to influence their decision to install or purchase it or otherwise. A high level of awareness is expected to potentially result in high adoption and vice



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versa. Some of the research participants alluded to this proposition. For instance, participant 14 and participant 32 statements connote this proposition.

“One of the factors just like I mention before is the knowledge of it, the awareness of how solar works. The benefits of it that is one.” Participant 32

“The main factor that cause major role in peoples’ decision is that if you have been aware and civilized with it (solar system) you definitely invest in it.” Participant 14

AVAILABILITY AND AFFORDABILITY

Evidence from the interviews shows that another factor that will likely influence people’s decisions to invest in solar systems is to make it available and affordably so that it is easily accessible to the majority of the populace, especially the rural areas dwellers. It is believed that making the PV solar components available at an affordable price can attract people to adopt it as an alternative source of power.

“If solar is coming in to take the place of...side by side with PHEDC we should try as much as possible to make it much more available. We try as much as possible to see how we can work the price to make it much more pocket-friendly such that anybody that is interested could just deep his hand or her hand in the pocket and acquire.” Participant 2



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POSSESSION OF ALTERNATIVE POWER SOURCE

Despite the fact that electricity supply from the national grid is considered to be erratic and insufficient, yet access to other alternative sources of power may hinder some people to invest in PV solar systems. For instance, possession of a generator has been identified as one of the reasons that may prevent some individuals to contemplate on investing in a PV solar system, such as that portrayed by Participant 2.

“Because I have a generator. That is the backup plan for PHEDC. Apart from that apart from the generator I have this other rechargeable bulbs that when you have light you charge in case the generator or PHDC doesn’t come up when you need it you on that light you have light in your own way...you have 3 or 4 lighting point.” Participant 2.

This suggests that people holding this notion are adamant about the long-run cost of running a generating set and the issue of green gas emissions.

ENVIRONMENTAL FRIENDLINESS

One of the main advantages of the PV solar system is its environmental friendliness. Environmentally conscious people are likely to choose cleaner sources of energy whenever making a choice. Thus, all things being equal, the PV solar system, being an environmentally friendly source of energy, has a higher potential of being used compared to other sources of energy. This assertion is supported by the view expressed by Participant 16, who mentioned that:



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“One other factor will be the environmental friendliness of solar as a source of power compared to generators for instance electric generators where pollution resulting from burning of fuels and all of that so environmental concerns will favour solar as alternative source.” Participant 16

PEER INFLUENCE

Man, as a social creature, is always being influenced by his environment. Sometimes people’s decisions are influenced by the actions and behaviours of their peers, family, or other social actors. In the same vein, the decision to use or not to use PV solar power can be influenced by these referents. Hence, peer influence is found to be among the factors that may likely influence one's decision to invest in PV solar power or not. This positioning was highlighted in Participant 14's submission. Here he hinted that:

“The main factor that cause major role in peoples’ decision is that if you have been familiar with it and or you have a friend or colleague using these modern technics of generating electricity or see a friend or anybody you too will be eager to get this for your conveniences, for your family... Everybody want to use this system for his convenience.”

Participant 14

STABLE POWER SUPPLY FROM DISCOS

One of the major reasons for having alternative sources of electricity supply is to make up for the gap created by insufficient power supply from the national grid. Therefore, the availability of constant supply via the national grid may likely influence the desire to invest in other alternative sources. This preposition is affirmed as revealed by the interview result. Participant 3 argued that he did not need a PV solar system because he has access to a constant electricity supply from the national grid in the area he lives in.



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“one of the reasons why I don’t have one of it which is where I leave we have constant power supply. That is one of the reasons probably may be because if I have money I would have love to do that in case there is no power supply.”

Participant 3

Similarly, another participant shared the same view in the following excerpt:

“Severally people have recommended, but then need, since I am not really in need of extra power source for now I don’t consider it (pv solar system).” Participant 19

ATTITUDE AND PERCEPTION

Analysis of the interview data further revealed that people’s attitudes and perceptions may also play a role in influencing their decision to purchase or not to purchase a PV solar system. Evidence from the participants’ verbatim narrations points to this revelation. For instance, participant 10 opined that people's general attitude toward accepting new technologies could affect their decision to accept PV solar systems.

“...you know when a new technology is involved, some people don’t really believe it, yeah. So now see some people are still doubting if solar can be able to carry even to charge their phones...laugh...so people so many of them have not even believed because before you do something you must first of all accept and believe that.” Participant 10

This suggests that lack of sufficient knowledge about PV solar systems, especially in rural areas, may lead to a negative perception of the system, which can affect its level of acceptance and subsequent use.



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Similarly, a wrong perception about the PV solar system, which arises from a lack of information about how it works and its advantages over other alternative energy sources, is likely to affect the level of people's acceptance and use. This is evident considering the response of Participant 2 who stated that:

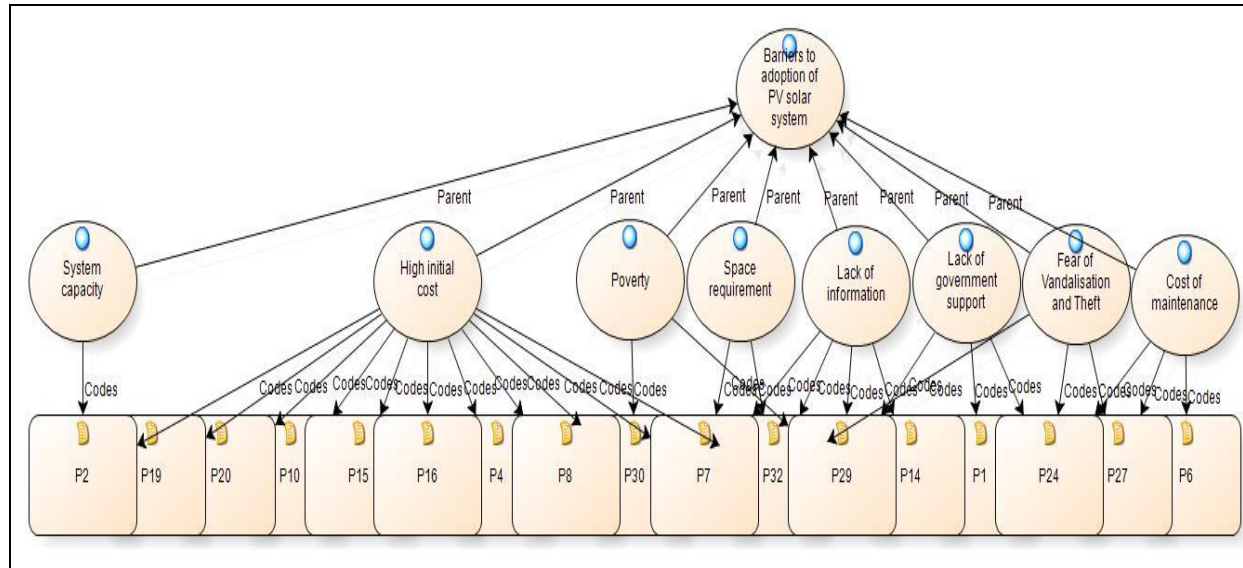
“To install it acquisition...it's a barrier even though fuel is 200 naira a litre a lot of people will still prefer to power ‘I pass my neighbour’ generator to do what they want than a solar panel in somebody's house and irrespective of all the advantages that the solar panel have.”

The above statement shows that lack of knowledge about the long-term cost-saving advantage coupled with the high initial cost of the PV solar system can negatively influence the decision of individuals to adopt it as an alternative power source.

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4.2 BARRIERS TO WIDER DIFFUSION OF PV SOLAR SYSTEM

Analysis of the theme ‘the potential barriers/challenges to wider adoption of solar PV system in rural areas’ identified some factors as key barriers. Figure xx shows the emergent nodes on the theme as captured in the expressed opinions of the research participants.

**Figure 2: Barriers to diffusion of solar PV system**

(Source: Nvivo output)

INITIAL COST OF INSTALLATION

As depicted in the figure majority of the participants identified ‘high initial cost of installation’ as one of the important barriers or challenges to the adoption of PV solar system in the rural areas. Participants expressed their lived experience concerning this reality as thus:



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“The barrier is majorly the cost. The initial investment cost is high and for many homes, especially the rural areas to be able to afford the solar set up you know, large enough to power their needs may come to monetary cost that is outside their reach.” Participant 16

“The cost of installation especially the batteries and co. the cost, the budget. Its more capital intensive, yes. Basically that’s the major factor” Participant 4

“Uhhmm one I feel that the cost is still a major problem because most people can’t really afford it that’s one. We have good weather I don’t think that will be a big challenge, cost is one.” Participant7

Despite the fact that a solar PV system might be regarded as an efficient alternative power source, the issue of its initial cost of installation can hinder its wider adoption. This reality was captured in Participant 2 submission:

“The simple barrier is ehhn it will be in the high side, it’s expensive. The cost, that’s what is no matter how efficient or useful as an alternative or backup to the power source but the cost is not friendly.” Participant 2

Although the initial installation cost is seen as a major barrier to wider adoption of PV solar systems, especially in rural areas, it has been identified as a cost-saving alternative in the long run. This understanding was captured in the opinion of Participant 20, where he stated that:

“...one of the key issues in solar is always the initial cost of getting the installation. Solar system comes with high cost, like I said initial cost and that most time scares people away. But however, in the long run it could be cost saving because all you need to do is to get on there get ...inaudible... and that’s all you need. So the initial cost could scare a



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lot of people but if you can gather enough fund to get that done, that wouldn't be a problem so that initial cost of getting it fixed is the factor making people not to invest in it." Participant 20

The above submission suggests that people consider solar PV systems as a cost-effective alternative energy source despite the fact that they consider the initial installation cost to be prohibitively high.

Furthermore, high installation costs have been identified as a factor that not only deters people from getting a PV solar system installed but also limits the system capacity needed to fulfill an individual's energy needs. This reality was vividly captured in the response of Participant 8, where he lamented:

"What I can say about that is that it's too expensive and it's very difficult to get solar panel large enough to provide ones power need. For instance, I need more than twelve panels but due to situation in Nigeria and other issues with money I can only have 4 panels. Like I said earlier the advantage is I can be able to get my own power any time any day I can easily get my own power so that's the advantage." Participant 8

Corroboratively, Participant 32 also lamented this fact where he mentioned that:

"The biggest challenge in solar is the finance. It is capital intensive for you to build a solar that will give you power in the home you need to spend a reasonable amount for you to get that." Participant 32.

LACK OF INFORMATION

Another major potential barrier to widespread adoption of solar PV systems, particularly in rural areas, has been linked to the majority of rural dwellers' lack of adequate information about the system. For instance, as Participant 7 complained, lack of access to



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information about the reliability and efficiency of the solar PV system as well as how it works influenced the rate at which people adopted the system as an alternative source of power. This was captured in the following text:

“Then sometimes we don’t even have enough information about which one is good which one is not good, which one is reliable *mtchww* it’s not an information that is readily available...” Participant 7

From the technical perspective, people’s lack of information or awareness on how to use PV solar systems efficiently was also identified as a barrier to the large-scale diffusion of the PV solar system. Such lack of awareness is linked to negative feelings towards the system. This was captured in the submission of one of the participants, who complained that:

“One of the problems is awareness. Some people are not aware technically they don’t understand how the solar works. When we are here and see people coming and the kind of questions they ask it shows me that these people are not aware they are ignorant of how solar work. So first and foremost what I do if they come is to explain the technical background, the technical aspect to be able to get little bit of understanding before we move further...” Participant 32

People’s inability to understand that the long run advantage of the pv solar system in comparison to other alternative energy sources, such as generator, also resulted to low adoption, especially in the rural areas. It has been identified that failure to compare the cost-in-use of solar PV with that of other sources have led to people opting for those alternative sources, which seems to be cheaper than pv solar system when only the initial cost is considered. This fact was evidenced in the following statement:

“...a solar system that can cost you N500,000 a normal person who doesn’t think the return on investment that after two years...will tell you ‘I can buy generator for N200,000 I will still have reserve of N300,000.’ But the person



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doesn't think about you fueling that generator N5000 naira every day. Fuel of N5000 naira every day in a year you are looking of spending over N600,000 which is almost what it will cost you to build the solar. So some people don't understand the economic part of it." Participant 32

LACK OF GOVERNMENT SUPPORT

Being a cost-intensive investment, having a PV solar system requires a huge investment commitment. As seen from the majority of the participants, the initial cost of installation of a PV solar system was identified as a major barrier that plays a role in its adoption and/or diffusion. Hence, people desire some kind of support for them to adopt it. Lack of government support has been identified as another barrier to the wider diffusion of PV solar systems. A sample of responses from the research participants points to this reality.

"Number one government policy. Government should make a policy that will enhance that and also the local or communal local government policy. If the policy can support these people I believe it will help these people."
Participant 29

Participant 29 opined that government at all tiers should design policies that will encourage people, especially in the rural areas to have pv solar system installed. However, people have negative feelings and reservations about the effort of government towards ensuring that pv solar system is made available to a wider section of the populace; For instance, Participant 24 lamented that:

"You know because... even the so called solar government is not actually investing in it and individuals are so poor they can't also invest in it." Participant 24



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This assertion was further confirmed by participant 1 where he narrated that:

“...the will-power in the part of the politicians to do these things for the rural people. The only time rural people becomes important in Nigeria is when election is approaching after election they abandon them until next election...these rural people they don't have representation at the federal level or state where decisions are made most times they don't...” Participant 1

MAINTENANCE COST

In addition to the initial cost of installation of PV solar system, the maintenance cost was also identified as a potential barrier to its wider diffusion in the rural areas. Participant captured this reality as presented in the following extracts:

“I don't know personally I observed that even the solar in the long run it might become costly as well. Because the solar batteries does not last forever, you know. And I have seen a couple of ...friends who have invested so much in the solar power who are no more using them today. Because it only last for some time and before you know it also collapsed. And if you don't have money to fix the whole system again it's still costly you know...but I don't know at what level it could be economical.” Participant 24

And;

“While...I don't know personally I observed that even the solar in the long run it might become costly as well. Because the solar batteries does not last forever, you know...” Participant 27



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The above excerpt demonstrates how some people feel about the PV solar system. Even though it is considered as a cost-saving alternative energy source, this kind of understanding is still obtainable among people and is capable of influencing their decision to adopt PV solar as an alternative source of energy.

FEAR OF VANDALISM AND THEFT

Results from the interviews further revealed that fear of vandalism and theft were also identified among the barriers to the wider diffusion of the PV solar system. Being a cost-intensive investment, losing PV solar components to vandals and thieves will have a huge effect on the individual involved. The fact that cases of stolen solar components abound, especially in rural areas where the news of theft or vandalism of solar installations of rural water projects has been reported, makes people sceptical about investing in PV solar systems for their personal use. This fear is expressed by participant 32 and participant 27 in the following lines:

“The third one I can say is theft. Because some people they may install solar some are even scared how would I build a solar system of close to N200,000, N500,000 what about if I keep it there and somebody go and steal it. So those are the challenges.” Participant 32

“I don’t know the guarantees that are there especially in the rural areas. Because the existing power infrastructure have been vandalized you know...armored cables have been stolen and nobody seems to be doing anything about it you know. And then if you put solar in the rural areas there is no guarantee that those things will not be stolen over the night?” Participant 27



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POVERTY

The socio-economic status of individuals determines their ability to pay for any given service or product. All things being equal, high and middle-income earners are more likely to invest in PV solar systems than low-income earners. Poverty has been mentioned as one of the barriers to the diffusion of PV solar systems in rural areas. For instance, participant 29 and participant 30 narrated that:

“...the barriers in the rural areas to me will just be poverty. Because a lot of people in the rural area can barely feed themselves so I don't think something like investing in alternative energy is their major problem” Participant 30

“Like I said earlier on finance. Money is one of the barriers because when you go to the rural setting they are peasant farmers they don't have the social amenities required.” Participant 29

SPACE REQUIREMENT

Another barrier that emerged from the interviews is the space requirement. Some of the participants showed concern that one needs to have enough space to accommodate a PV solar system. For instance, commenting on the PV solar system that can serve a community, participant 32 hinted as thus:

“If I may say one of the barriers is access to space because solar needs space. If you want to build solar farm as I said you need space. And space individually you may not be able to afford that space where you can have your solar farm to supply to the community.” Participant 32

In addition, Participant 7, while commenting expressed that:



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“Number two may be the, I don’t know how to describe it, the size of the equipment, somehow you have to look for a place in the house to put the batteries and all those things make it somehow if you don’t have such space in your house it’s difficult to install, yeah that’s another way.” Participant 7

The aforementioned statements indicate that the perception of a lack of sufficient space to install PV solar systems for both personal and communal use can hinder wide diffusion of the system, especially in rural areas.

SYSTEM CAPACITY

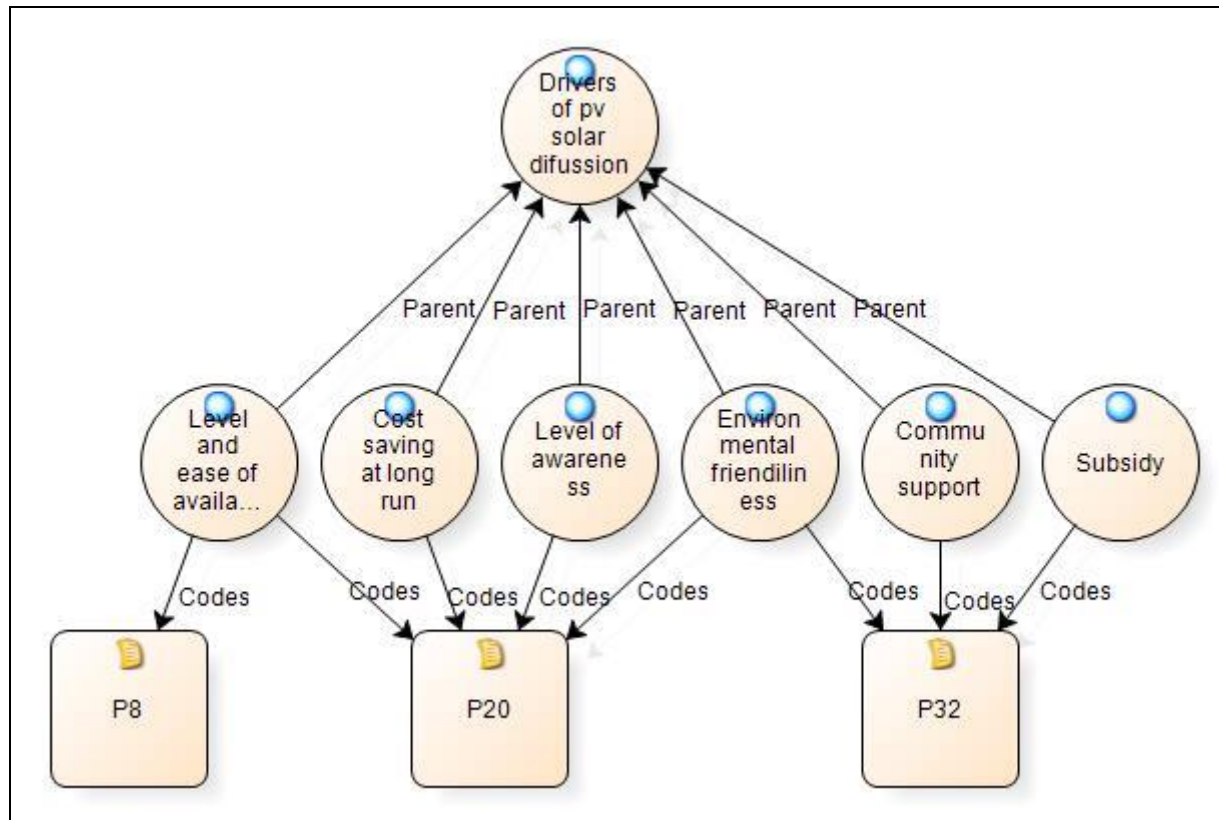
The capacity of the PV solar system is also considered as a potential barrier to its wider adoption. Although PV solar systems are of various capacities, ensuring that the system provides optimal energy that satisfies the energy needs of the user is important. This is vividly captured in the narrative of Participant 2, where he submitted that:as shown in Figure 3.

“I don’t know how this response is going to be useful this solar of a thing the capacitycapacity that is what I mean there is I don’t know capacity as in the load it can carry varies. In a situation where you must have one that is capable of carrying, for instance fridge, this that, that needs so much money to be able to install and how I wish the thing could be made like electricity no matter how low it is it carries so many appliances I think that on its own is a major barrier”

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4.3 DRIVERS TO WIDER DIFFUSION OF PV SOLAR SYSTEM

in order to further investigate how social, political, economic, and behavioral factors can influence the spread of PV solar systems The theme's emergent nodes revealed that the drivers for the widespread adoption of PV solar systems are level of awareness, cost effectiveness, level and ease of availability, environmental friendliness, subsidy, and community support as shown in Figure 3.

**Figure 3: Drivers to large scale diffusion of solar PV system**



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LEVEL OF AWARENESS

Knowing the advantages of PV solar systems and the way it works is expected to change people's perception of them and subsequently improve their acceptance. This position was captured in Participant 20's narratives, where he presented the argument in the following excerpt:

“If people really know the advantage of solar over other sources of electricity I think people will be interested. Like I said the major advantage is that it’s a very clean source of energy it doesn’t have negative effect on the environment and secondly cost saving in the long run. If you install it you might not need to pay or very little to keep it running.” Participant 20.

Based on the interviewee’s argument, understanding the benefits of pv solar system, especially as it relates to its environmental friendliness and cost-effectiveness, people will pick interest and begin to adopt it as an alternative energy source.

COST SAVING AT LONG RUN

One of the major advantages of PV solar systems is cost-saving in the long run. Although the initial cost of installation is high, PV solar systems are cheaper compared to other alternative sources of power since its cost-in-use is lower over time. Understanding this advantage is expected to push people towards using PV solar against other alternative sources. For instance, participant 20 vividly captured this reality in the following excerpt:

“I saw it as a way of saving you know unlike other sources of energy whereby you need to like if you are using fuel you need to keep buying fuel over and over again to power your generator. So that alone could be expensive so I felt I could get a source of energy where I don’t need to pay for anything at least getting the charges that’s why I went for solar.” Participant 20



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LEVEL AND EASE OF AVAILABILITY

The natural availability of solar energy and its abundance, especially in the Tropics, is considered an important driver for the adoption of photovoltaic solar systems. Unlike other sources of energy where a huge effort is required before they are exploited and become usable, solar energy is relatively easily available. Thus, making easily available as well as affordable, the components such as the panels, batteries, and the inverters that will allow tapping the naturally freely given solar energy is an important driver that will increase people's use of the PV solar system. Excerpts from the interviews that pointed to this assertion include:

“...solar of course is everywhere especially where you live in the tropics you have very high intensity of sunlight that's first of all my drive.” Participant 20

“what I will like to add is that this solar panel there should be more like what people can easily get everywhere so if it can be gotten anywhere so it mean the price will come down so the different marketers can be selling it so that it can be gotten anywhere.” Participant 8

ENVIRONMENTAL FRIENDLINESS

The fact that solar energy is considered one of the cleanest sources of energy describes how important it is to human survival, especially in this period when the world is facing the threat of global warming. It is expected that as people are increasingly becoming more environmentally conscious, the demand for solar energy will keep increasing. This implies that more people will start to adopt



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the PV solar system as an alternative source of energy to those sources that cause a negative impact on the environment. This position was echoed by participant 32:

“Let’s look on the positive side how it affects customer decision to purchase. The positive side, once you say environmental condition or may be environmental pollution, first you think about the of understanding what environmental pollution for them being aware that the environment is at danger that you need to remedy it or that we need to rescue our environment. Most people are not knowledgeable base on environment how we can keep our environment clean, you understand? So that is one aspect of it on the positive side of it. And then those customers who really understand what the environment needs that we need to protect our environment those are the ones who see that solar, renewable energy, is energy that is green energy there is no carbon this is what the world need now it’s what everybody need to embrace and we need to go in line with that...” Participant 32

SUBSIDY

The PV solar system is characterised by a high initial installation cost, which in most cases proves to be prohibitive for many individuals to afford. However, the provision of subsidies that can reduce the price burden on individuals and serve as an incentive to attract people to start using sustainable energy is a very important step for the government and other stakeholders to consider. In his view, participant 32 highlighted that:

“Finance will help in easing the customer or client access to the solar. If finance is available almost everybody can easily afford it. Let me give an example, like in the developed countries there is kind of government subsidy. Government subsidize solar so if you don’t have the actual cash to pay government can come in and say ok I am paying



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for this from your salary so if that customer couldn't pay will have like an insurance to cover up for the person. So

Nigerian government should enact a policy to support renewal energy use there should be an incentives." Participant 32

COMMUNITY SUPPORT

Another important driver for the wide diffusion of PV solar, especially at community level in rural areas, is community support. Concerted efforts by communities to protect the PV solar installations within their jurisdiction against vandalism and theft are expected to increase the coverage of use of PV solar systems. This single act can encourage government agencies and other donor agencies to provide more PV solar systems to rural areas.

LEVEL OF AWARENESS

The research attempted to capture the participants' opinion on the level of awareness of the PV solar system among the general population in the study areas. Analysis of the responses revealed that the level of awareness fell within the low, average, and high range, as shown in Figure 4.

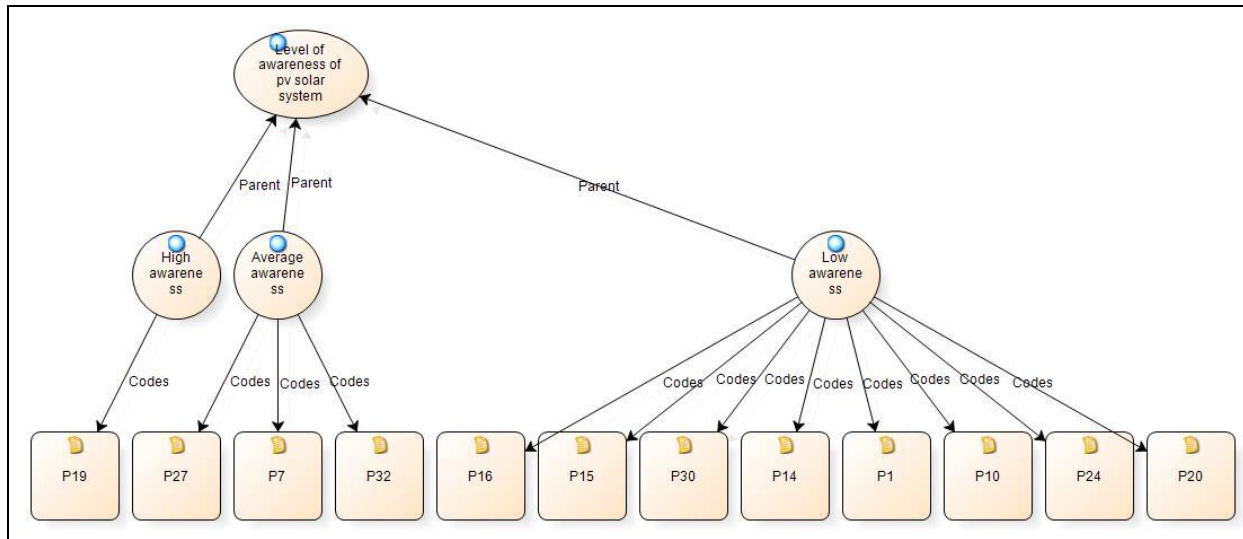


Figure 4: Level of awareness of PV solar System

The majority of the participants deemed that the level of awareness of PV solar systems among the population is low. Others viewed that there is average awareness, while only one participant expressed that the awareness is high.

5.0 RESEARCH POLICY RELEVANCE

Policy formulation and implementation are key in the management of technological resources. This study is looking at ways to overcome the challenges of large-scale deployment of solar PV electricity and hence has tremendous relevance to the ambitious



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national policies on energy security, economic development and emissions reductions. The research will lead to the identification of factors such as financing, investment, public-private partnerships, etc. that will require policy input for their success.

6.0 CONCLUSION

The study aims to explore drivers and barriers for rural electrification using solar PV in Nigeria. The expected outcomes of the research are:

- Increased pace of rural electrification and economic development
- Rural private sector agro-industrial development
- Enhancement of rural-urban economic balance through industrial dispersal
- Industrial governance and public private sector partnerships
- Strengthening industry's institutional support base

The following are the anticipated impacts of the research:

- Addressing the challenges of low power generation and utilization through rural solar energy development
- Stimulating non-oil economic growth and providing a base for private sector led development
- Reduction in rural-urban migration
- Employment opportunities for Nigerians to ensure increased level of self-reliance
- Reduction in greenhouse gases that contributes to meeting the INDC 2030 targets

REFERENCES



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- 1) Ahlborg, H., & Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique—Grid-extension, off-grid, and renewable energy technologies. *Renewable Energy*, 61, 117–124.
- 2) Barry, M., Steyn, H., & Brent, A. (2009a). The use of the focus group technique in management research: the example of renewable energy technology selection in Africa. *Journal of Contemporary Management*, 6(1), 229–240.
- 3) Barry, M. -L., Steyn, H., & Brent, A. (2011). Selection of renewable energy technologies for Africa: Eight case studies in Rwanda, Tanzania and Malawi. *Renewable Energy*, 36(11), 2845–2852.
- 4) Barry, M. -L., Steyn, H., & Brent, A. C. (2009b). Determining the most important factors for sustainable energy technology selection in Africa. *South African Journal of Industrial Engineering*, 20(2), 33–51.
- 5) Byrnes, L., et al. (2013). Australian renewable energy policy: Barriers and challenges. *Renewable Energy*, 60, 711–721.
- 6) De Jongh, D., Ghoorah, D., & Makina, A. (2014). South African renewable energy investment barriers: An investor perspective. *Journal of Energy in Southern Africa*, 25(2), 15–27.
- 7) Eleftheriadis, I. M., & Anagnostopoulou, E. G. (2015). Identifying barriers in the diffusion of renewable energy sources. *Energy Policy*, 80, 153–164.
- 8) Lidula, N., et al. (2007). ASEAN towards clean and sustainable energy: Potentials, utilization and barriers. *Renewable Energy*, 32(9), 1441–1452.
- 9) McCormick, K., & Kåberger, T. (2007). Key barriers for bioenergy in Europe: economic conditions, know-how and institutional capacity, and supply chain co-ordination. *Biomass and Bioenergy*, 31(7), 443–452.
- 10) Mikkelsen, M. (2005). *Methods for development work and research. A new guide for practitioners*, Sage Publications, second edition, 2005, New Dehli/Thousand Oaks/London
- 11) Ohunakin, O. S., et al. (2014). Solar energy applications and development in Nigeria: drivers and barriers. *Renewable and Sustainable Energy Reviews*, 32, 294–301.



A Peer Reviewed Journal

- 12) Painuly, J. P. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, 24(1), 73–89.
- 13) Reddy, S., & Painuly, J. P. (2004). Diffusion of renewable energy technologies—Barriers and stakeholders' perspectives. *Renewable Energy*, 29(9), 1431–1447.
- 14) Sovacool, B. K. (2009). Rejecting renewables: the socio-technical impediments to renewable electricity in the United States. *Energy Policy*, 37(11), 4500–4513.
- 15) Trotter, P. A., McManus, M. C., & Maconachie, R. (2017). Electricity planning and implementation in sub-Saharan Africa: A systematic review. *Renewable and Sustainable Energy Reviews*, 74, 1189–1209.
- 16) Yin, R.K. (2009). Case study research. Design and methods, SAGE Publications, 4 ed., Applied social research methods series, Vol. 5, 2009, Los Angeles.