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The Role of Residential Solar Energy Adoption in Mitigating the Impacts of Urban Power Outages: A Case Study of FCC Phase 1, Abuja, Nigeria

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ABSTRACT
This study analyses the impact of solar energy adoption on the effects of power outages in residential areas of Federal Capital City (FCC) Phase 1, Abuja, Nigeria. It addresses the question of how the adoption of solar home systems reduces the adverse effects of grid outages. A descriptive research design was adopted, and data on the impact of solar energy adoption on power outages were obtained through questionnaires. A systematic random sampling technique was used to collect data from a sample of 400 households. Data were analysed using the Relative Importance Index (RII) and presented textually and graphically. The results show that the effect of solar energy adoption on power outage impacts is highest in reducing household expenditure on alternative energy sources, with an RII of 0.982. This is followed by noise pollution from generators (RII = 0.964), disruptions in communication and entertainment (RII = 0.946), and air pollution (RII = 0.871). The study recommends that government and private stakeholders promote affordable solar adoption through subsidies, innovative financing, and public awareness campaigns to enhance livelihoods in FCC Phase 1.
Keywords: Abuja, Power outage, Residential Area, Urban Resilience, Solar energy, Sustainability

1.0. Introduction

Meeting the energy demand of a rapidly growing urban population poses significant challenges, as urbanization drives increased residential, commercial, and industrial consumption that places immense pressure on existing energy infrastructure (International Energy Agency, 2021). In many cities, outdated grid systems are ill-equipped to handle the rising load, resulting in frequent power outages and inefficiencies. Additionally, energy access remains uneven, with low-income urban communities often lacking reliable electricity (UN-Habitat, 2020). As urban areas continue to expand, ensuring sustainable, and resilient energy systems becomes a critical priority for policymakers. A renewable energy source like solar energy is an alternative source and solution to the growing energy challenges, especially in the tropics where there is abundant sunshine (Idris *et al*., 2024).

Power outage is a condition of loss of electric power supply to end users (Parihar and Bhaskar, 2018). Electricity is accessible to more than 99% of the population in North Africa while about 600 million of the approximately 1.18 billion people living in sub-Saharan Africa are without electricity (Sanni *et al*., 2021). Nigeria is a giant when it comes to energy. Together with Libya, they accounted for two-thirds of Africa's crude oil reserves (USAID, 2021). Unfortunately, Nigeria is limited in the power sector which constrains growth. For example, just only about 45% of Nigeria's over 200 million population have access to public electricity supply (Electrifi, 2021).

Power outages have assumed an embarrassing dimension in Nigeria over the years (Chanchangi *et al*., 2023). In addition, increase in fuel prices to run generators and increase in electricity tariffs coupled with erratic power supply have made urban residents to seek renewable energy sources, thus the adoption of solar energy as an alternative since it is powered by the gift of nature. There is however a dearth of empirical studies that analyse the extent to which the adoption of solar energy impacts power outage effects in Nigeria. The objective of this study is to analyses the impact of solar energy adoption on power outage effects in Federal Capital City (FCC) Phase 1, Abuja, Nigeria. The findings are expected to contribute as basis for comparative studies on renewable energy and power outage relationship, both within the study area and beyond. The result is also expected to be a source of reference for policy decisions in the advancement of clean energy in Nigeria.

Power outages have significantly affected socio-economic livelihoods and hindered development in Africa. These impacts include financial losses, equipment damage, and reduced productivity in South African SMEs (Ketelhodt & Wöcke, 2008). Moreover, some South African households demonstrate a strong willingness to invest in electricity infrastructure to avoid outages (Nkosi & Dikgang, 2017). In Kenya, power outages undermine electrification benefits, as unreliable supply discourages new connections, reduces investment in appliances, and makes households in outage-prone areas less likely to connect or purchase appliances (Bajo-Buenestado, 2020). In Zambia, outages disrupt households and small businesses, causing reduced quality of life, costly alternatives, and revenue losses (Umar & Kunda-Wamuwi, 2019). These studies highlight socio-economic hardships of power outages which are also prevalent in Nigeria. Despite the impacts of power outages, adoption of alternatives like solar remains limited due to cost and poor information (Musa, 2025). Nkosi and Dikgang (2017) show households' willingness to pay for better electricity reliability but overlook alternatives like solar, highlighting the need to study its potential in easing frequent residential power outages.

Consistent power outages in Nigeria compel many SMEs to depend on generators, which significantly increases operational costs and reduces competitiveness. In fact, some larger firms have been forced to relocate abroad due to the persistent unreliability of power supply (Akuru and Okoro, 2014). In residential areas, frequent outages disrupt livelihoods, reduce income, and heighten insecurity, while costly alternatives strain household budgets and limit access to education and healthcare (Amadi, 2015). These studies emphasize energy insecurity's socio-economic impacts.

Beyond socio-economic effects, power outages have significant environmental consequences. Farquharson *et al*. (2018) show that unreliable grids in sub-Saharan Africa drive reliance on diesel generators, producing emissions 1.5 to 1,000 times higher than standard grid levels. The study also highlights excessive fossil fuel consumption and unsustainable financial burdens. These findings emphasize the dual environmental and economic costs of diesel dependence. Transitioning to renewable alternatives like solar could reduce pollution, improve reliability, and provide a sustainable pathway for communities vulnerable to frequent outages.

Power outages significantly disrupt residents' socio-economic lives, causing food spoilage, communication and entertainment interruptions, appliance damage, sleeping discomfort, water shortages, and additional expenses on alternatives, while also generating environmental effects such as air and noise pollution from generators (Musa, 2025). Adefarati and Bansal (2019) highlight that integrating renewable energy, particularly solar, into microgrids reduces lifecycle costs and greenhouse gas emissions. These benefits support sustainable energy transitions in residential areas. Similarly, Umeji *et al*. (2023) affirms that replacing fossil fuels with renewables mitigates climate change and related environmental and health impacts.

Ugulu (2029) identifies high upfront cost and lack of finance as the principal barriers to urban solar energy adoption in Nigeria, while unreliable grid supply and potential cost savings from replacing generator use are the main motivators. The study argues for regulatory reform, targeted awareness campaigns, and financial instruments to accelerate urban solar energy adoption. Also, Jesuleye (2020) household survey in Akure found that perceived reliability of PV as a backup to grid failure ranks highest among factors driving residential solar energy utilization. The study highlights the role of private sector and supportive government action to improve uptake and recommends it should be locally tailored. These solar energy adoption studies however focused more on drivers and barriers of adoption rather than the impact of adoption on existing challenges of power outages. This study however, examines how the adoption of solar energy mitigates the socio-economic and environmental effects of power outages in Nigeria, with specific focus on FCC Phase 1, Abuja.

2.0 Methodology

2.1. The Study Area

Federal Capital City (FCC) Phase 1 is situated within the Federal Capital Territory (FCT) of Nigeria, lying between latitudes 8°25′ and 9°25′ North of the Equator and longitudes 6°45′ and 7°45′ East of the Greenwich

Meridian (AGIS, 2008). The FCT is bounded by Kaduna State to the north, Nasarawa State to the east, Niger State to the west, and Kogi State to the south, as illustrated in Figure 1.

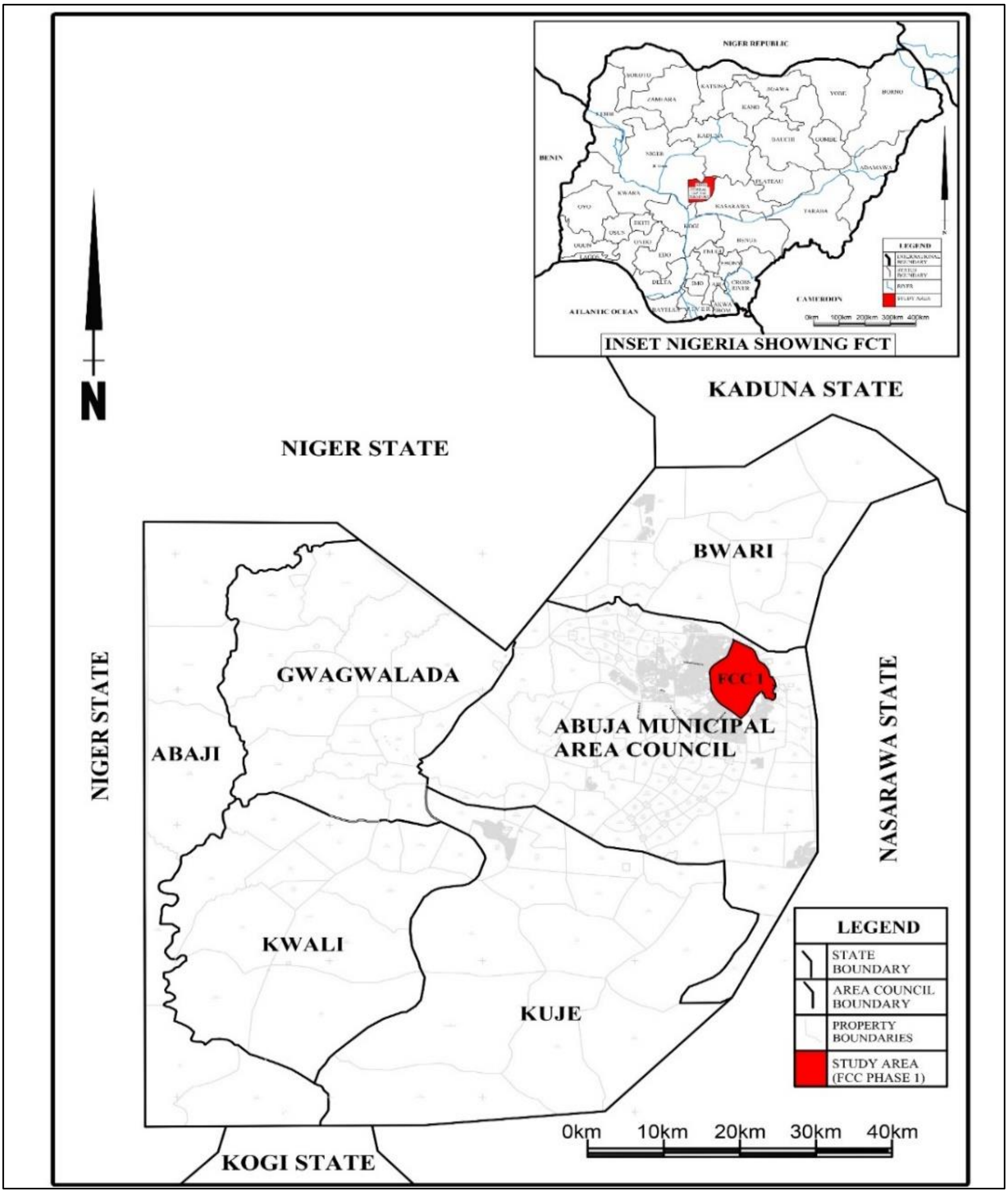

Figure 1: Locational Map of Federal Capital City Phase 1, in FCT.
Source: Abuja Geographical Information System (AGIS) (2008).

Federal Capital City (FCC) Phase 1 is situated within the Federal Capital Territory (FCT) of Nigeria, lying between latitudes 8°25′ and 9°25′ North of the Equator and longitudes 6°45′ and 7°45′ East of the Greenwich Meridian (AGIS, 2008). The FCT is bounded by Kaduna State to the north, Nasarawa State to the east, Niger State to the west, and Kogi State to the south, as illustrated in Figure 1.

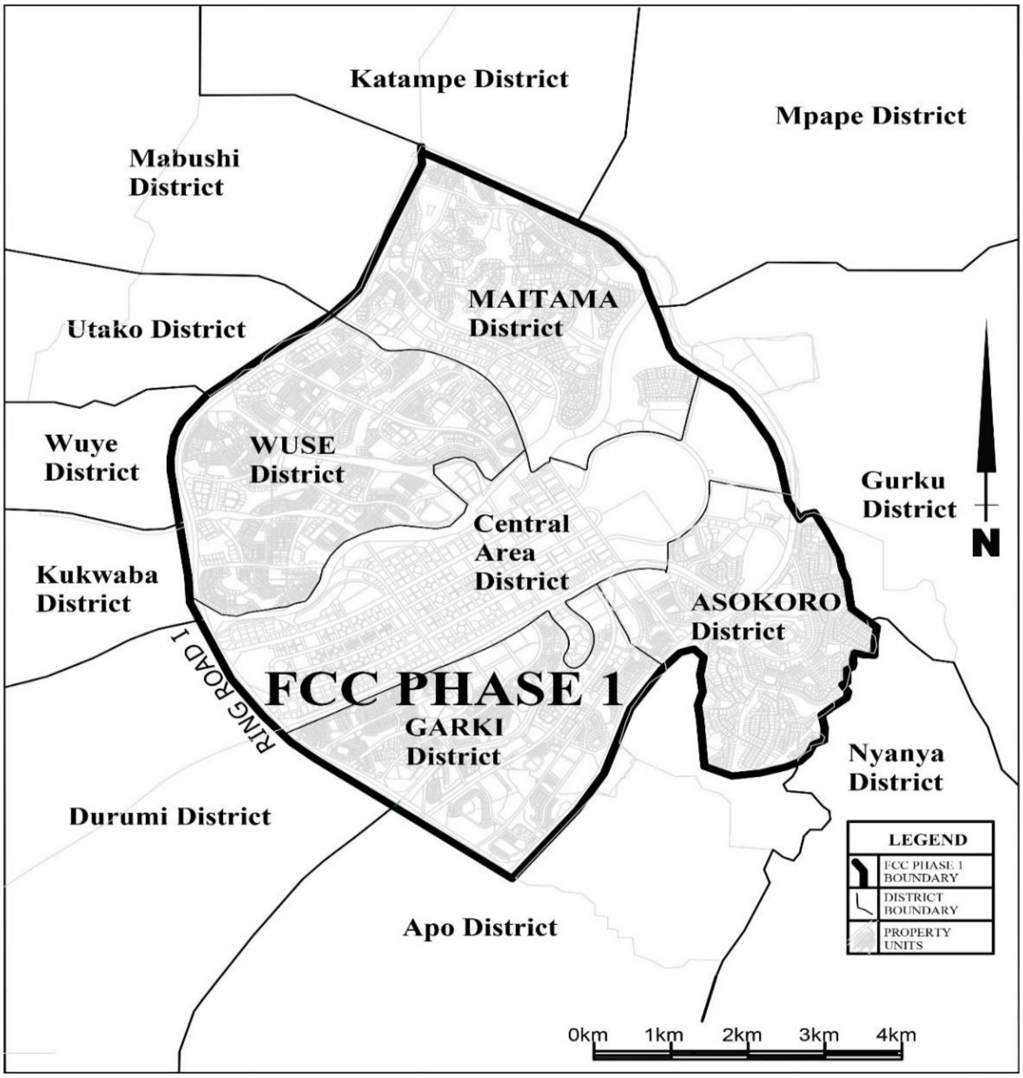

Figure 2: Map of Federal Capital City Phase 1.
Source: Abuja Geographical Information System (AGIS) (2008).

The FCC's indigenous population includes the Gbagyi, Koro, Ganagana, Gwandara, Afo, and Bassa, alongside Hausa and Fulani (Balogun, 2001). Today, the area is ethnically diverse due to its status as Nigeria's administrative center. The FCT had 1,406,239 people in 2006 (NPC, 2010), while FCC Phase 1 grew from 267,671 in 2015 (Musa *et al.*, 2016) to a projected 544,409 in 2023, based on a 9.28% inter-census growth rate (NPC, 2010). The strength of Abuja's economy is attributed to its diverse socio-economic activities ranging from construction and real estate, tourism and leisure, agriculture and a dynamic service sector that includes infrastructure development (Obiadi, Ezezue and Uduak, 2019). Electricity in the FCC is distributed by the Abuja Electricity Distribution Company, one of Nigeria's 11 DisCos. The rapid population growth in the FCC has intensified pressure on existing infrastructure, particularly electricity supply. Persistent power outages undermine economic productivity, household welfare, and essential public services, highlighting a critical energy deficit. Solar power presents a viable solution, offering households a decentralized and sustainable energy source.

2.2. Methods

This study employed a descriptive research design, incorporating survey method. A systematic random sampling technique was used to collect data from a sample of 400 households. Questionnaires were systematically administered to 400 participants. This process was essential in determining the extent to which solar energy adoption affects the impacts of power outages. At the end of the survey, however, only 330 questionnaires were retrieved from respondents. The analysis was therefore based on 330 questionnaires, representing 82.5% of the total administered, which is acceptable in research given a threshold of 55% (Sataloff & Vontela, 2021). The study applies the Technology Acceptance Model (TAM), developed by Davis (1989), to explore the relationship between power outages and the adoption of solar energy within residential areas of FCC Phase 1. TAM provides insights into how practical perceptions, such as usefulness and ease of use, impact adoption decisions.

Data were analyzed using the Relative Importance Index (RII) because it gives a clear distinction of significant variables (Tonidandel and LeBreton, 2011).

Relative importance Index (RII) is given by the formula:

$$\text{RII} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A * N} \quad 1$$

Where:
n_5 = Number of respondents for extremely significant
n_4 = Number of respondents for significant
n_3 = Number of respondents for slightly significant
n_2 = Number of respondents for insignificant
n_1= Number of respondents for extremely insignificant
A (Highest Weight) = 5
N (Total number of respondents) = 67
(Johnson and Lebreton, 2004).

The analysed data were presented both textually and in tabular form to enhance clarity, facilitate comparative analysis, and support effective interpretation of the findings. This methodology provided a reliable framework for generating valid data, ensuring that the analysis accurately reflects household experiences with power outages and the adoption of solar energy in FCC Phase 1.

3.0 Results and Discussion

The findings of this study present the outcomes of the data analysis, highlighting, household responses the extent of solar energy adoption in FCC Phase 1. The results are organized to align with the study objective and provide insights into the socio-economic and environmental implications of solar energy adoption on power outage effects.

3.1 Adoption of Solar Energy

Table 1: Adoption of Solar Energy by Respondents

Adopted Solar Energy	**Frequency**	**Percent (%)**
Yes	67	20.3
No	263	79.7
Total	330	100.0
Period of Adoption		
Less than 1 year	12	17.9
1-2 years	30	44.8
3-4 years	13	19.4
Above 4 years	12	17.9
Total	**67**	**100.0**

Source: Field Survey (2023).

The results presented in Table 1 indicate that only 20.3% of respondents reported having adopted solar energy systems in their households, whereas a significant majority, 79.7%, have yet to embrace this technology. These statistics demonstrate that although the adoption of solar energy is gradually increasing, the penetration rate remains relatively low within the study area. Given the socio-economic and environmental benefits associated with solar energy such as cost savings in the long term and the reduction of environmental degradation according to Umeji *et al*. (2023), there is a compelling need to encourage greater adoption.

With respect to the duration of adoption, the findings reveal that most of the respondents (44.8%) have been utilizing solar energy for a period of one to two years. This is followed by 19.4% who reported usage spanning between three and four years, while 17.9% indicated adoption for less than a year, and another 17.9% have maintained usage for over four years. This result suggests that the adoption of solar energy in the study area is relatively recent, implying that households are only beginning to perceive its usefulness and ease of use, as explained by the Technology Acceptance Model (TAM). This early stage of adoption reflects both growing awareness of renewable alternatives and the influence of persistent power outages in shaping attitudes, but it also indicates that wider diffusion will depend on how strongly these perceptions continue to drive acceptance and sustained usage.

3.2Impact of Solar Energy Adoption on Power Outage Effects in FCC Phase 1

This section examines the extent to which the adoption of solar energy mitigates the socio-economic and environmental impacts of power outage within the study area. The empirical results, as presented in Table 2, demonstrate that 65 out of 67 respondents affirmed that solar energy significantly reduces the economic burden associated with reliance on alternative power sources. Specifically, the finding highlights that solar adoption evidently lowers expenditure on alternatives such as fuel-powered generators, which are often costly and environmentally unsustainable. This suggests that beyond the initial investment, solar systems provide long-term financial relief and sustainable energy security.

Table 2: Impact of Solar Energy Adoption on Power Outage Effects

Variables	EI	I	SS	S	ES	Total
Food Spoilage	6	18	0	25	18	67
Communication/Entertainment disruption	0	0	0	18	49	67
Damage to electrical appliances	0	18	6	12	31	67
Sleeping Discomfort	0	18	6	12	31	67
Water supply Interruption	19	24	0	18	6	67
Air Pollution from Generators	0	6	0	25	36	67
Noise Pollution from Generators	0	0	0	12	55	67
Lateness to Work	0	24	19	0	24	67
Expenditure on other Alternatives	0	2	0	0	65	67

Source: Field Survey (2023).

This result is a significant benefit, as the cost of these recurrent alternatives can be a burden for many households who may have to buy fuel when there are power outages. Whereas, water supply interruption shows the highest number for extremely insignificant effect of solar energy on reduction of power outage impact. A detailed analysis of this objective is presented on Table 3.

The results of the Relative Importance Index (RII) analysis presented in Table 3 illustrate the effect of solar energy adoption on mitigating the socio-economic and environmental impacts of power outages. Expenditure on alternative energy sources, with an RII value of 0.9821, is ranked first, indicating the highest level of significance. This finding suggests that the adoption of solar energy substantially reduces household reliance on costly alternatives such as fuel-powered generators, thereby alleviating the recurrent financial burden associated with power outages.

Table 3: Relative Importance Index (RII) of the Impact of Solar Energy Adoption on Power Outage Effects

Variables	Weighted Total	N	A*N	RII	Significance
Food Spoilage	232	67	335	0.692537313	6
Communication/Entertainment disruption	317	67	335	0.946268657	3
Damage to electrical appliances	257	67	335	0.767164179	5
Sleeping Discomfort	257	67	335	0.767164179	5
Water supply Interruption	169	67	335	0.504477612	8
Air Pollution from Generators	292	67	335	0.871641791	4
Noise Pollution from Generators	323	67	335	0.964179104	2
Lateness to Work	225	67	335	0.671641791	7
Expenditure on other Alternatives	329	67	335	0.982089552	1

A (Highest Weight) = 5
N (Total number of respondents) = 67
Source: Field Survey (2023).

This infers that the impact of solar energy adoption on the socio-economic effects of power outages, particularly in terms of expenditure on alternative energy sources, is highly significant. It implies that most residents no longer spend on other alternatives once they have adopted solar energy. Noise pollution from generators and environmental effect, ranked second with an RII value of 0.9642. This indicates that it is the next most significant impact of solar energy adoption on the effects of power outages. This finding highlights the critical role solar energy plays in alleviating the pervasive noise challenges associated with generator use, which are common in urban residential areas such as FCC Phase 1. The reduction of noise pollution not only improves the overall quality of life for residents by fostering a quieter and healthier living environment but also mitigates the psychological stress and community disturbances often linked to prolonged generator operations during power outages. Communication/entertainment disruption with RII of 0.9463 ranked as number 3 most significant impact solar energy has on the effects of power outage in the study area. This entails that communication and entertainment especially the use of mobile phones, or television can be sustained since there will be adequate supply to power the gadgets.

The environmental benefits of solar energy adoption are further demonstrated through its impact on air pollution caused by the frequent use of generators. With an RII ranking of 0.8717, air pollution is positioned fourth among the identified effects, indicating that while not the most significant, it remains a considerable area of improvement associated with solar energy use. This finding highlights how the transition to solar energy reduces the dependence on fossil fuel-powered generators, which are a major source of harmful emissions such as carbon monoxide, nitrogen oxides, and particulate matter. By curbing these emissions, solar energy contributes to improved air quality, thereby promoting healthier living conditions for residents and mitigating broader environmental concerns such as greenhouse gas accumulation and climate change. These results show that indeed, solar energy reduces the negative effects of power outage and that solar energy is a panacea for the electricity generation crisis in Nigeria (Agbo *et al*., 2021).

The variables that show the least significance are: water supply interruption and lateness to work with RII of 0.5045, ranked number 8 and 0.6717, ranked number seven respectively. This is because, the use of solar water pumping machines is not widespread among households in the study area, as such, they still have to depend on the grid to pump water to their storage tanks as it is the status quo in some part of the study area. Another factor that affects the result is that some homes are connected to pipe borne water from the municipality, as such they may not need solar energy for water supply. Also, lateness to work does not show high significance since activities such as ironing are high energy consuming activities and require high capacity of solar energy systems which is not easily affordable to households at this time. This is an indication for a need for investments into the solar energy sector that reduces cost of acquisition of high-capacity solar energy systems for homes.

In the lens of the Technology Acceptance Model, solar energy is perceived as useful because it mitigates the adverse effects of power outages by ensuring uninterrupted power supply, reducing financial losses such as food spoilage and generator costs, and improving health and comfort by eliminating noise and air pollution. Its ease of use, enhanced by advancements in solar technology may boosts its acceptance. TAM's focus on usability and benefits drive solar energy adoption, directly reducing the frequency and severity of outage-related impacts, while also fostering long-term resilience and environmental sustainability. This perspective highlights the importance of aligning technological innovation with user-centered motivations to accelerate solar energy adoption.

4.0 Conclusion

The study establishes that the extent of solar energy adoption in FCC Phase 1 Abuja is 20.3% ,whereby the larger population have not adopted it. However, solar energy adoption in the study area significantly reduces the adverse socio-economic and environmental effects of power outages. The most profound socio-economic impact is observed in reducing household expenditure on alternative energy sources, thereby relieving residents of the financial burden of recurrent fuel costs. Although the initial investment in solar systems is relatively high, the long-term economic advantage becomes evident, as solar installations require little to no recurrent expenditure for at least five years. Additionally, the adoption of solar energy mitigates environmental challenges by reducing noise pollution from generators, while also addressing other socio-economic concerns such as communication and entertainment disruption. Viewed through the Technology Acceptance Model (TAM), solar energy is perceived as highly useful by residents, as it not only ensures uninterrupted power supply but also enhances household welfare by minimizing both financial losses and environmental degradation. It is recommended that Government and private stakeholders should promote affordable solar adoption through subsidies, tax incentives, micro-credit schemes, solar panel import policy, innovative financing, and public awareness to enhance socio-economic welfare and environmental sustainability in FCC Phase 1.

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