Role of Solar Energy in Reducing Greenhouse Gas (GHG) Emission in Makurdi Local Government Area of Benue State

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Abstract
The study investigated role of solar energy in reducing GHG emission in Makurdi LGA. Three research questions were framed and three null hypotheses formulated and tested. Descriptive survey research design was adopted using a sample size of 306 from a population of 1,500 respondents (500 motorcycle and car owners, 400 business owners and 600 households from Fiidi, Wailomayo and Baa council wards in Makurdi LGA). A structured questionnaire was validated by three experts to test for internal consistency. Cronbach's alpha reliability technique was used to ascertain reliability of the instrument with a coefficient index of .87 Mean and standard deviation were used to answer research questions while one way ANOVA was employed to test the null hypotheses. Findings revealed a positive impact of the role of solar energy towards reducing GHG emission. It was recommended that: Government through relevant stakeholders should increase awareness so that citizens will know and increase the use of solar because it produces clean energy devoid of GHG, government at all levels should subsidize solar energy equipment for more citizens to afford since it reduces the emission of GHG into the atmosphere and government should enforce a barn of fossil fuel driven cars so as to reduce environmental pollution.
Keywords: Solar, Energy, Solar Energy, Greenhouse Gas, Emissions

Introduction

Nigeria has continued to experience inadequate electricity supply, making households, commercial establishments, industries, and agricultural enterprises heavily dependent on fossil fuels such as petroleum, coal, and natural gas to meet their energy needs. Although these energy sources have supported economic activities over the years, their continuous combustion releases large quantities of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2 O), which contribute significantly to global warming, climate change, and environmental degradation (Ohunakin, Adaramola, Oyewola & Fagbenle, 2014; Koester, Lis & Nickel, 2022). Beyond environmental impacts, fossil fuel combustion is associated with severe public health problems, including respiratory illnesses, cardiovascular diseases, cancer, and premature mortality (Yali *et al.*, 2023). These concerns have intensified the global search for cleaner and more sustainable energy alternatives.

Among the available renewable energy sources, solar energy has emerged as one of the most viable alternatives because of its abundance, sustainability, and minimal environmental impact. Nigeria is endowed with high solar radiation throughout the year, providing enormous potential for solar energy utilization in electricity generation and other productive activities. Solar technologies, particularly photovoltaic (PV) systems, convert sunlight directly into electricity without producing direct greenhouse gas emissions during operation (International Energy Agency [IEA], 2023). Compared with

conventional fossil-fuel-based electricity generation, solar energy produces substantially lower life-cycle carbon emissions and contributes significantly to reducing environmental pollution and mitigating climate change (IEA, 2022; Lelieveld*et al.*, 2023).

The environmental significance of solar energy lies primarily in its capacity to reduce greenhouse gas emissions. The energy sector remains the largest contributor to global GHG emissions due to its dependence on fossil fuels for electricity generation, transportation, industrial production, and heating (IEA, 2022). Increased adoption of solar energy reduces dependence on these fossil fuels, thereby lowering emissions of carbon dioxide and other greenhouse gases responsible for global warming. Studies by the Intergovernmental Panel on Climate Change (IPCC, 2014) and the National Renewable Energy Laboratory (NREL, 2021) indicated that electricity generated from solar photovoltaic systems produces between 90 and 97 percent fewer greenhouse gas emissions over its life cycle than electricity generated from coal and natural gas. Consequently, expanding solar energy deployment has become a major strategy for achieving national and international climate change mitigation targets.

Despite environmental benefits, the adoption and effective utilization of solar energy remain constrained by several technical, economic, and institutional factors. Solar power generation depends on the availability of sunlight, making electricity production intermittent during cloudy conditions, night, and seasonal variations. Although battery storage systems can improve energy reliability, their high acquisition and maintenance costs limit widespread adoption, particularly in developing countries (Yali *et al.*, 2023). In addition, the high initial investment required for solar panels, inverters, and storage facilities discourages many potential users (Ohunakin*et al.*, 2014). Other challenges include inadequate technical expertise, weak policy implementation, limited financing opportunities, insufficient public awareness, and environmental concerns associated with the manufacturing and disposal of solar panels (IEA, 2022).

Recognizing these constraints, governments and international organizations have introduced several strategies to promote solar energy utilization and enhance its contribution to the reduction of GHG emission. These strategies include renewable energy policies, carbon pricing mechanisms, financial incentives, investment in energy storage technologies, public awareness campaigns, and green financing initiatives (Barata-Salgueiro & Guimaraes, 2020; Latif *et al.*, 2021; Mudaliyar, Sharma & Panja, 2022). In Nigeria, additional recommendations include encouraging local production of renewable energy technologies, strengthening regulatory frameworks, promoting solar-powered transportation, and providing subsidies to improve access to solar energy technologies (Atedhor, 2023). The effectiveness of these strategies, however, depends largely on the extent of their implementation within different geographical contexts.

Benue State, like many parts of Nigeria, experiences persistent electricity shortages despite having abundant solar energy potential. Consequently, many households, businesses, educational institutions, healthcare facilities, and agricultural enterprises continue to rely heavily on fossil-fuel-powered generators, contributing to GHG emissions and environmental pollution. While several studies have examined renewable energy adoption and climate change mitigation at national and international levels, empirical evidence on the role of solar energy in reducing

GHG gas emissions within Benue State remains limited. Furthermore, there is inadequate empirical information on the challenges affecting the utilization of solar energy and the strategies required to enhance its effectiveness in reducing GHG emissions within the state. It is against this background that this study examines the role of solar energy in reducing GHG emissions in Benue State by assessing its contribution to emission reduction, identifying the challenges limiting its effective utilization, and determining strategies for improving its adoption as a sustainable source of clean energy.

Statement of the Problem

Nigeria's power generation has historically relied on fossil fuels like natural gas and diesel, resulting in insufficient power supply, frequent outages and extensive generator usage. This dependence increases GHG emission, intensifies air pollution, and accelerates climate change. Despite government initiatives such as the National Renewable Energy and Energy Efficiency Policy (NREEEP) and Rural Electrification Agency (REA) projects, electricity demand in Makurdi continues to surpass supply, perpetuating fossil fuel use.

The region's abundant solar radiation offers a sustainable alternative that could enhance electricity access and decrease GHG emission. Yet, adoption rates remain low due to high upfront costs, insufficient awareness, inadequate policy implementation and underdeveloped infrastructure. As a result, households and businesses continue depending on fossil fuels, undermining environmental sustainability and climate mitigation goals. Therefore, this study examines the role of solar energy in reducing GHG emission in Makurdi LGA of Benue State.

Purpose of the Study

The study investigated the role of solar energy in reducing GHG emission in Makurdi LGA of Benue State. Specifically, the study:

1. Examines the role of solar energy in reducing GHG emission.
2. Assess challenges affecting the role of solar energy in reducing GHG emission.
3. Explore strategies to address the challenges of solar energy in reducing GHG emission.

Research Questions

The study raised and answered the following research questions:

1. What are the roles of solar energy in reducing GHG emission?
2. What are the challenges affecting the use of solar energy to reduce GHG emission?
3. What are the strategies implored to address the challenges of solar energy in reducing GHG emission?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

1. There is no significant impact in the mean responses of respondents on the role of solar energy in reducing GHG emission.
2. There is no significant impact in the mean responses of respondents on the challenges affecting the use of solar energy to reduce GHG emission.
3. There is no significant impact in the mean responses of respondents on the strategies implored to address the challenges of solar energy in reducing GHG emission.

Methodology

The study employed a descriptive survey research design with a population

of 1,500 respondents, comprising 500 motorcycle and car owners, 400 business owners and 600 households from Fiidi, Wailomayo and Baa council wards in Makurdi Local Government Area of Benue State—all users of fossil fuels. Data was obtained from the Benue State Board of Internal Revenue Services (BIRS) 2025 fourth-quarter report. These areas were chosen due to their high fossil fuel usage. Using Krejcie and Morgan's table, a sample size of 306 respondents was proportionately selected. A 15-item researcher-developed instrument titled: Role of Solar Energy in Reducing GHG Emission Questionnaire (ROSEIRGHGQ), based on a four-point rating scale (Strongly Agree=4 to Strongly Disagree=1), was validated and tested for reliability using Cronbach's Alpha Technique, which yielded a coefficient index of .87. Data collection was done through direct contact with the help of two research assistants.

Mean and standard deviation was used to answer research questions, while one-way Analysis of Variance (ANOVA) was used to test the null hypotheses at 0.05 significance level. The decision rule was based on the rating scale (0.00–1.24 = Strongly Disagree; 1.25–2.49 = Disagree; 2.50–3.74 = Agree; 3.75–4.00 = Strongly Agree). Additionally, p-values were compared with α-values—if $p > \alpha$, the null hypothesis was rejected, and if $p < \alpha$, the hypothesis was accepted. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 27.

Result and Discussion

Data collected is analyzed and presented in tables in the order of research questions:

Research Question One: What are the roles of solar energy in reducing GHG emission?

Table 1: Mean and Standard Deviation on the Roles of Solar Energy in Reducing GHG Emission

S/No	Items	M_1	SD_1	M_2	SD_2	M_3	SD_3	M_T	SD_T	Remark
1	The use of solar energy lowers carbon dioxide (CO_2) emission	3.75	.46	3.71	.68	2.95	.82	3.40	.78	Agreed
2	Solar energy usage reduces methane (CH_4) emission in the atmosphere	3.82	.65	3.65	.83	3.78	.56	3.76	.67	Strongly Agreed
3	Nitrous oxide (N_2O) emission is reduced as a result of using renewable energy	3.59	.66	3.80	.49	3.17	1.04	3.47	.85	Agreed
4	Renewable energy emits less gas in the atmosphere	3.20	1.20	3.36	1.03	3.00	.83	3.16	1.02	Agreed
5	Renewable energy is a better alternative towards energy generation	3.75	.83	3.62	1.00	3.88	.33	3.77	.73	Strongly Agreed
	Grand Mean							**3.51**	**.81**	**Agreed**

Key:*M_1:Motorcycle and car owners, M_2:Business Owners, M_3:Households and M_T:Overall Mean*

Table 1 above showed respondents perception on the role of solar energy in reducing GHG emission. The data revealed a mean score of 3.51 and a low standard deviation of .81, signifying that the responses were

clustered around the mean. This implies that solar energy play a significant role in reducing GHG emission in Benue State.

Research Question Two: What are the challenges affecting the use of solar energy to reduce GHG emission?

Table 2: Mean and Standard Deviation on the Challenges Affecting the use of Solar Energy in Reducing GHG Emission

S/No	Items	M_1	SD_1	M_2	SD_2	M_3	SD_3	M_T	SD_T	Remark
6	Batteries used for solar energy storage are too expensive	3.34	.98	3.90	.30	2.74	1.02	3.23	.99	Agreed
7	Solar panels installation occupy a lot of space especially in places with limited land	4.00	.00	3.13	1.10	3.61	.89	3.60	.87	Agreed
8	Solar panel manufacturing involves emissions from chemical processing which contains hazardous materials such as cadmium	3.72	.52	3.93	.27	3.55	.79	3.70	.62	Agreed
9	Improper disposal at end-of-life solar materials could create toxic waste issues	3.11	1.03	3.50	.76	2.58	.83	2.99	.96	Agreed
10	Solar energy has is its dependency on sunlight availability	4.00	.00	4.00	.00	4.00	.00	4.00	.00	Strongly Agreed
	Grand Mean							**3.50**	**.69**	**Agreed**

Key:*M_1:Motorcycle and car owners, M_2:Business Owners, M_3:Households and M_T: Overall Mean*

Table 2 above showed respondents perception on the challenges affecting the use of solar energy to reduce GHG emission. The data revealed a mean score of 3.50 and a low standard deviation of .69, signifying that the responses were clustered around the mean. This implies that challenges such as: Expensive batteries, limited space for solar panel installation, cadmium emission during solar panel manufacturing, poor disposal of end-of-life solar materials and solar energy dependency on sunlight affect the use of solar energy to reduce GHG emission in Benue State.

Research Question Three: What are the strategies implored to address the challenges of solar energy in reducing GHG emission?

Table 3: Mean and Standard Deviation on the Strategies Implored to Address the Challenges of Solar Energy in Reducing GHG Emission

S/No	Items	M_1	SD_1	M_2	SD_2	M_3	SD_3	M_T	SD_T	Remark
11	Favourable public policies will advance the use of solar energy	4.00	.00	3.24	.60	3.85	.45	3.74	.52	Agreed
12	Sensitizing citizens on the impact of renewable energy will lower green house gas emissions.	3.10	.84	3.70	.56	2.87	.90	3.16	.87	Agreed
13	Investing in solar energy will lower greenhouse gas emission into the society	3.15	1.07	3.33	1.05	3.05	.63	3.15	.91	Agreed
14	Investing in wind energy will lower environmental pollution	4.00	.00	4.00	.00	4.00	.00	4.00	.00	Strongly Agreed
15	Enforcing the barn on importing fossil fuel vehicles will reduce greenhouse gas emission	3.51	.85	3.90	.30	3.11	.77	3.44	.78	Agreed
	Grand Mean							**3.50**	**.61**	**Agreed**

Key:*M_1: Motorcycle and car owners, M_2:Business Owners, M_3:Households and M_T: Overall Mean*

Table 3 above showed respondents perception on the strategies adopted to address the challenges of solar energy in reducing GHG emission. The data revealed a mean score of 3.50 and a low standard deviation of .61, signifying that the responses were clustered around the mean. This implies that strategies such as: Favourable public policies on the use of solar energy, sensitization on the impact of renewable energy, increased investment in solar energy, increased investment in wind energy and enforcing barn on importing fossil fuel vehicles will reduce GHG emission in Benue State.

Hypothesis One: There is no significant impact in the mean responses of respondents on the role of solar energy in reducing greenhouse gas emission.

Table 4: Analysis of Variance (ANOVA) on the Role of Solar Energy in Reducing Greenhouse Gas Emission

Role of Solar	Sum of Squares	df	Mean Square	F	Sig.	Remark
Between Groups	135.53	2	67.77	25.17	.00	**Statistically**
Within Groups	815.91	304	2.69			**Significant**
Total	**951.44**	**306**				

Table 4 shows a statistically significant difference in the responses of respondents on the role of solar energy in reducing GHG emission $F(2, 304)=25.17$, $p=.00<.05$. Scheffe post-hoc test was carried out to ascertain where

the difference lied. Results from the post-hoc test revealed no significant difference in the responses of motorcycle and car owners and business owners (.99). However, there was a significant difference in the responses of business owners and household (.00) as well as household and motorcycle and car owners (.00). This implies that there is a significant difference in the mean responses of respondents on the role of solar energy in reducing GHG emission in Benue State.

Hypothesis Two: There is no significant impact in the mean responses of respondents on the challenges affecting the use of solar energy to reduce greenhouse gas emission.

Table 5: Analysis of Variance (ANOVA) on the Challenges of Solar Energy in Reducing Greenhouse Gas Emission

Challenges	Sum of Squares	Df	Mean Square	F	Sig.	Remark
Between Groups	249.98	2	124.99	56.50	.00	**Statistically**
Within Groups	670.26	304	2.21			**Significant**
Total	**920.235**	**306**				

Table 5 shows a statistically significant difference in the responses of respondents on the challenges affecting the use of solar energy to reduce GHG emission F(2, 304)=56.50, p=.00<.05. Scheffe post-hoc test was carried out to ascertain where the difference lied. Results from the post-hoc test revealed no significant difference in the responses of motorcycle and car owners and business owners (.48). However, there was a significant difference in the responses of business owners and household (.00) as well as household and motorcycle and car owners (.00). This implies that there is a significant difference in the mean responses of respondents on the challenges that affect the use of solar energy in reducing GHG emission in Benue State.

Hypothesis Three: There is no significant impact in the mean responses of respondents on the strategies employed to address the challenges of solar energy in reducing greenhouse gas emission.

Table 6: Chi-Square Statistics on the Strategies employed to Address the Challenges of Solar Energy in Reducing Greenhouse Gas Emission

Strategies	Sum of Squares	Df	Mean Square	F	Sig.	Remark
Between Groups	92.06	2	46.03	19.58	.00	**Statistically**
Within Groups	712.41	304	2.35			**Significant**
Total	**804.47**	**306**				

Table 6 shows a statistically significant difference in the responses of respondents on the strategies employed to address the challenges of solar energy in reducing GHG emission F(2, 304)=19.58, p=.00<.05. Scheffe post-hoc test was carried out to ascertain where the difference lied. Results from the post-hoc test revealed no significant difference in the responses of motorcycle and car owners and business owners (.23). However, there was a significant difference in the responses of business owners and household (.00) as well as household and motorcycle and car owners (.00). This implies that there is a significant difference in the mean responses of respondents on strategies

employed to address challenges affecting the use of solar energy in reducing GHG emission in Benue State.

Discussion of Findings

The study shows that solar energy plays a significant role in reducing GHG emission in Benue State. This affirms the view of Li, Zhou and Wang (2019) who observed that renewable energy play a key role in reducing GHG emission. The study also upholds the position of Odufuwa, Kusakana and Numbi (2020) who insisted that in the face of adopting optimal energy, GHG emission will be drastically reduced in the environment.

The study also revealed that challenges such as: Expensive batteries, limited space for solar panel installation, cadmium emission during solar panel manufacturing, poor disposal of end-of-life solar materials and solar energy dependency on sunlight among others affect the use of solar energy to reduce GHG emission in Benue State. This aligns with the view of Aliyu, Deba, Saidu, Mohammed and Usman (2017) who stressed that high production cost is identified as one of the challenges facing biofuel production in Nigeria. Findings from the study also corroborated the submission of Adewale (2020) who insisted that weak government policies and lack of public awareness are challenges to biofuel acceptance in Nigeria.

Findings from the study indicated that strategies such as: Favourable public policies on the use of solar energy, sensitization on the impact of renewable energy, increased investment in solar energy, increased investment in wind energy and enforcing barn on importing fossil fuel vehicles among others will reduce GHG emission in Benue State. This correlates with the view of Giwa, Sulaiman and Nwaokocha (2017) who noted that increased public awareness on the role of renewable energy will reduce GHG emission in Nigeria. This also affirmed the findings of Chanchangi, Adu, Ghosh, Sundaram and Mallick (2022) who stressed that reducing the importing of fossil fuel vehicles, motorcycles and generators among others will reduce over dependence of fossil fuel.

Conclusion

The study revealed that energy produced from solar is not only clean but also plays a vital role in reducing GHG emission. Even in the face of numerous challenges, strategic actions, investments and environmental friendly policies from stakeholders, will go a long way to reduce pollution emanating from the burning of fossil fuel.

Recommendations

In line with findings of the study, it was recommended among others that:

1. Government through relevant stakeholders should increase awareness creation so that citizens will know and use solar energy considering the role it plays in reducing GHG emission.
2. Government at all levels should subsidize solar energy equipment for all citizens to afford since it produces clean energy and will reduce the emission of GHG into the atmosphere.
3. Government should enforce the barn of fossil fuel driven equipment so as to save the environment and citizens from environmental pollution.

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