Assessing the Economic Viability of Solar Electrification Against Grid Extension in Rural Ghana

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Abstract:- Electricity availability is crucial for socioeconomic development, particularly in developing nations' rural areas. As a result, solar electrification has therefore been recommended as a more sustainable and cost-effective option for rural electrification. The research aim was to compare the economic viability of solar electrification against grid extension in rural Ghana, by examining the cost-benefit of solar electrification and grid extension and identifying the most cost-effective and sustainable approach for providing electricity to rural communities in Ghana. Hundred respondents were selected for this study using a simple random sampling technique. Most respondents believe that solar systems are cheaper to install estimating between GHS 40000 and GHS 50000 compared to grid extensions which averages about GHS 320000, as they can be installed by professionals. Solar electricity offers a good return on investment and doesn't require monthly bills, making it economically sound. Maintenance is easy and cost-efficient compared to grid extensions. Solar electrification doesn't emit carbon emissions of greenhouse gases, and it improves grid security. Most respondents agree that solar electrification generates employment opportunities and is cost-competitive with conventional electricity. They also believe solar energy ensures clean energy for sustainable development and poverty alleviation. Solar electrification is a cost-effective and environmentally friendly alternative to grid extension, reducing carbon footprint and providing reliable power. Its initial capital investment is crucial for its economic viability. The study recommends research on hybrid systems integrating solar electrification with grid extension, exploring new technologies like energy storage and smart grids, and exploring regulatory frameworks and policy incentives to promote private sector investments in solar electrification in rural Ghana.

Keywords:- *Electrification, Energy, Renewable, Solar.*

I. INTRODUCTION

The availability of electricity is crucial for socioeconomic growth, particularly in the rural areas [1,2]. The high costs associated with grid extensions have made it difficult to bring electricity to rural areas in Ghana. Given that solar electrification is a sustainable and affordable option for electrifying rural areas, it has become a recommended course of action [3]. In the commercial, industrial, social, residential, and economic spheres of development, electrical energy is essential. Its importance in contemporary society cannot be emphasized, particularly in light of the rising environmental awareness and energy requirements. Electrical energy is used by businesses, industries, communication networks, transportation systems, homes (for entertainment, heating, and cooling), and residences [4]. For the purpose of producing electricity, a variety of resources are available, such as solar, geothermal, wind, hydro, biomass, and ocean waves [5]. Both renewable and non-renewable energy sources can be used to classify these sources. Because it comes from natural processes, renewable energy replenishes more quickly than it is used up. Solar, wind, ocean, hydropower, biomass, geothermal, biofuels, and hydrogen are all considered renewable resources by the International Energy Agency (IEA), which emphasizes their sustainability and potential to meet global energy needs [6]. Renewable energy is defined as energy that is produced sustainably from renewable sources, such as hydropower, bioenergy, geothermal energy, ocean energy, solar energy, and wind energy [7]. Urbanization, economic expansion, population growth, technological advancements, and the introduction of new electrical devices have all contributed to an increase in the demand for electrical energy over time [2,8]. Energy is regarded as a necessity in the modern world since it is necessary to support daily activities [9]. To satisfy the broad energy requirements and preserve energy for future generations, it is necessary to adopt and promote energy sources that can meet the rising energy needs [10]. A number of factors, including the availability of resources, population density, historical energy consumption, industry demands, technological viability, political considerations, generation costs, and environmental impact, all play a role in the choice of energy source [11]. Unlike other energy sources, solar photovoltaic electricity provides a multitude of benefits, both energy-related and non-energy-related [12,13]. The uncertainty surrounding fossil fuel resources can be resolved in Ghana by using solar photovoltaic power as a reliable energy source now and in the future. Grid-connected systems and off-grid photovoltaic installations are the two main types of solar energy applications in Ghana. Rural communities still struggle to get dependable energy, even with the National Electrification Scheme's advancements. Solar electrification is a promising replacement for extended grid electrification, which is expensive and slow. Its sustainability and economic viability in Ghana, however, need more research.

The problem statement talks about how Ghana's rural areas lack access to electricity and how traditional grid expansion is difficult because of geography and cost [14,15]. In order to inform policymakers about the viability of solar solutions for rural development, the study attempts to evaluate the economic viability of solar electrification compared to grid expansion in rural Ghana.

Analyzing the sustainability and cost-effectiveness of solar electrification in comparison to grid extension in rural Ghana is the main goal of the project. The objectives are to ascertain the expenses and advantages of solar electrification, evaluate its economic feasibility via cost-benefit analysis, and pinpoint the elements impacting its acceptance and accomplishment.

It is anticipated that the incorporation of solar electrification in Ghana's rural areas will result in significant economic benefits, including lower costs associated with importing electricity, increased job opportunities, improved accessibility to electricity, and compliance with Sustainable Development Goal 7. The urgent need to address energy poverty and find affordable, long-term electrification options for Ghana's rural areas justifies the study. The study's methodology compares the two options and offers recommendations for investment and policy decisions using cost-benefit analysis and financial modeling techniques.

II. LITERATURE REVIEW

Energy is used to obtain and move essentials like food and water. There are three major categories of the world's energy resources namely: fossil energy, nuclear energy, and renewable energy [16]. The world's energy resources are, of course, fossil, nuclear, and renewable. Most of the energy sources that are now in use are limited and will soon run out due to increased demand [17]. Global energy figures for 2014 show that the total primary energy supply in terms of renewable energy (RE) and non-renewable energy (NRE) was 14.1% and 85.9%, respectively [18]. Non-renewable energy has been the backbone of modern manufacturing and economic growth for many years. However, because these resources are limited, it is necessary to investigate and create sustainable alternatives, such as solar and wind energy. Oil makes up 31.3% of NRE resources, followed by the coal family (28.6%), natural gas (21.2%), and nuclear (4.8%) [18]. Even if the energy source for renewable energy technology is free and unique to the resource site, it is expensive to operate due to the immature technology to convert the fuel source to electricity. The state has been a major player in the development of energy infrastructure, helping to finance projects like electricity distribution and transportation systems. On the contrary, a lot of emerging nations have long ignored the problem of access to energy. To ensure effective production, transmission, and distribution, most developing nations have not decentralised energy production and distribution. Distribution points are located far from production points. Infrastructures for transmission are inefficient and out-of-date [19]. Access to energy is strongly correlated with the national income. In metropolitan areas, grid extensions are used to provide energy access, whereas, in rural regions, a random selection of grid extensions, mini-grids, and off-grid choices is used [20].

III. METHOD AND DATA

The study employed a mixed method in the collection of data. This study utilized both the quantitative and qualitative approaches in the collection and analysis of data. The quantitative approach enables a policy researcher to understand complex phenomena through numbers, charts, and basic statistical analysis. This approach relies on measuring variables using numerical systems and analysing this measurement using a variety of statistical models and associations among the studied variables. Also, Interviews were used under the qualitative approach for data collection in terms of verbal responses from policymakers, energy experts and solar energy providers. This approach enables researchers to understand concepts, opinions, and experiences.

➢ *Study Area*

Koforidua is the regional capital of the Eastern Region and is the municipal capital of New Juaben Municipality. It lies between latitude 6° 4’ 59’’ North and longitude 0° 15’ West. It shares boundaries to the northeast with East Akim Municipality, Akuapem North District to the east and south, and in the west with Suhum-Kraboa-Coaltar District. Koforidua covers a land area of about 110 km², representing 0.57 % of the total land area of the Eastern Region [21]. The study will focus on Akyeremateng township.

➢ *Research Population, Sampling Technique and Sample Size*

The research population according to the 2021 population indicates that Koforidua has a population of approximately 125, 256 [22]. For this study, respondents were selected through simple random sampling. This sampling technique is a type of probability sampling where the researcher randomly selects a subset of participants from a population to approximate a response for the entire group. This technique provides an equal opportunity for any of the samples within the population will be selected. This technique was employed for this study because it is manageable, cost-effective and ensures a valid generalisation of the entire population.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL588

Using a sample size calculator, a total number of 100 respondents were interviewed for this study. The sample calculator utilized the Cochran formula to determine the sample size. To carry out this calculation, the desired margin of error (ε) will be set. The z-score was also predetermined depending on the confidence level hence a confidence level of 95% will have a z-score of 1.96. The equation for calculating sample size is shown in Equation 1.

$$n_o = \frac{z^2pq}{\varepsilon^2} \quad \text{Equation 1}$$

n_o = sample size,
z = critical value of desired confidence level,
p = estimated proportion of population,
q = 1 – p, ε = Margin of error.

A small sample size correction was conducted using Equation 2 to indicate the actual sample size.

$$n = \frac{n_o}{1+\frac{n_o-1}{N}} \quad \text{Equation 2}$$

n = corrected sample size,
n_o = sample size,
N = Population

➢ *Source of Data*

The research utilized primary data obtained from the data collection process. The primary data was obtained by carrying out interviews and surveys which provide the researcher with raw information and first-hand evidence. The primary research allowed for direct access to the respondents in the acquisition of the data. This research also made use of secondary data obtained from policymakers, energy experts, and solar energy providers to understand the economic and social viability of solar electrification in rural Ghana is thoroughly investigated, providing the necessary insight into how to accelerate the adoption of this technology.

➢ *Data Collection Instrument*

Questionnaires and interview guides were the instruments utilised to collect the data. Respondents were given a structured questionnaire to complete, and replies were collected. The instrument of choice for this study was a questionnaire due to its flexibility for respondents regarding where and when to complete it, its correctness, the anonymity of the respondents, which puts respondents at rest and encourages them to answer honestly, and, finally, its speed of distribution. The survey questions were multiple-choice with a Likert scale, allowing respondents to express their degree of agreement and choose the best response. This made it easier to collect quantitative data for further study. To collect secondary data from important stakeholders (such as policymakers, energy experts, and solar energy providers), an interview guide was also created. High-level themes that must be covered during the interview were listed in the interview guide, along with high-level questions that must be addressed under each topic.

➢ *Data Analysis*

The Statistical Package for Social Science (SPSS) was used to analyse the data acquired for this study, and a descriptive analysis was utilised to generate frequency analyses and mean scores for the individual questionnaire items. The data was also subjected to additional thematic and econometric analysis. Tables with the analysed data were shown.

➢ *Ethical Consideration*

The respondents' anonymity, safety, confidentiality, and privacy were all respected for this study. The surveys that were used to gather the data did not allow participants to give their identities or any other information that may be used to trace the document back to them, so they were completely honest while responding to the questions. Participants were made aware that the surveys are only intended for academic use and that they may be completed in less than five minutes with the researcher on hand to assist.

IV. RESULTS AND DISCUSSION

This chapter presents the results and discussion obtained from the data collected from respondents. A total of 380 questionnaires were administered to respondents and a 100 percent response rate was recorded.

➢ *Reliability Analysis*

Reliability analysis allows the properties of measurement scales and the items that compose the scales to be studied. Cronbach's alpha was identified to measure the internal consistency and relationship between the individual items in the scale. The Cronbach's Alpha ratings are presented in Table 1 below.

Table 1 Reliability Analysis

Variables	Number of Items	Alpha
Cost of Solar Electrification and Grid Extension	6	0.334
Benefits of Solar Electrification and Grid Extension	7	0.595
Economic Viability of Solar Electrification and Grid Extension	7	0.083

Source: Field Survey, 2023

Table 1 depicts Cronbach's Alpha values for the variables to determine the level of reliability of data. The highest value was recorded for the benefit of solar electrification and grid extension whereas the lowest was recorded for the economic viability of solar electrification and grid extension. The highest Alpha coefficient score represents the most reliable part of the questionnaire.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL588

➢ *Demographic Characteristics of Respondents*

Table 2 presents data on the demographic background of the total number of respondents (n = 100). A total of 110 questionnaires were administered and 100 were selected with the remaining 10 being discarded due to inappropriate responses. The demographic data included gender, age, education, and labour force status. The results indicated that most of the respondents were males 51 % and females had the least response at 49 %. Again, the results showed that 34 % of the respondents were between the ages of 31 - 40, 27 % were between the ages of 21 - 30, 23 % were between 41 - 50 years, 13 % were above 50 with only 3 % between 12 - 20. From the results 60 % of the respondents have completed tertiary education, 18 % have also completed secondary school education and 12 % have completed basic school education whereas only 10 % of the respondents have no formal education. About 47 % of the respondents are employed whereas 22 %, 18 % and 13 % of the total respondents are unemployed, performing home duties and hunting for jobs respectively.

Table 2 Demographic Characteristics of Respondents

Demography	Characteristics	Percentages (%)
Gender	Male	51
	Female	49
Age	12-20	3
	21-30	27
	31-40	34
	41-50	23
	Above 50	13
Education	Basic	12
	Secondary	18
	Tertiary	60
	No formal Education	10
Labour force Status	Employed	47
	Home Duties	18
	Unemployed	22
	Job Hunting	13

Source: Field Survey, 2023

➢ *Cost of Solar Electrification and Grid Extension*

Table 3 presents the mean score of each dimension for the cost of solar electrification and grid extension. Most of the respondents agreed that initial installation of solar systems is cheaper than grid extension and solar panels are cheaper than grid extension because the panels can be installed by professionals and not just the Electricity Company of Ghana (m = 2.380 and m = 2.33 respectively). The International Renewable Energy Agency claims that renewable energy is the least expensive source of electricity. Investments in renewables in 2021 will reduce global energy generation costs by US$55 billion in 2022, despite rising fossil fuel prices [3]. Most respondents were neutral on the statement that solar electricity ensures a good return on investment and agreed that solar electricity does not require a monthly bill payment hence economically sound (m = 2.700 and 1.820 respectively). Again, most respondents agreed that solar electrification allows people to save money but selected neutral for the statement: maintenance of solar systems is easy and cost-efficient compared to grid extensions (m= 1.882 and m= 2.810 respectively). Traditional energy sources, such as fossil fuels, are limited and costly, whereas sunlight is abundant and free. Individuals and businesses can drastically reduce or even eliminate their electricity bills by installing solar panels. The amount saved on energy expenses can be large over time, and the original investment in solar panels can be recouped [12].

Table 3 Cost of Solar Electrification and Grid Extension

Statement	Mean	Standard Deviation
The initial installation of solar energy is cheaper than grid extension	2.380	1.251
Solar panels are cheaper than grid extension because the panels can be installed by professionals and not just the Electricity Company of Ghana.	2.330	1.215
Solar electricity ensures a good return on investment.	2.700	1.322
Solar electricity does not require a monthly bill payment hence economically sound.	1.820	.757
Solar electrification allows people to save money	1.820	.757
Maintenance of the solar system is easy and cost-efficient compared to grid extensions	2.810	1.089

Source: Field Survey, 2023.

➢ *Benefits of Solar Electrification and Grid Extension*

Table 4 presents the mean score of each dimension for the benefit of solar electrification and grid extension. Most of the respondents agreed that solar electrification creates no carbon emission and other greenhouse gases and avoids the environmental damage associated with mining for fossils and deforestation (m = 1.950 and m = 1.960 respectively). The rate of temperature rise is rising, and it is expected to reach

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL588

1.5 °C within 15 to 20 years if greenhouse gas (GHG) emissions are not severely decreased (Mason *et al.*, 2021). Despite the 2015 International Paris Agreement to limit GHG emissions, global temperatures have continued to rise due to the rising worldwide use of fossil fuels and deforestation. With prolonged reliance on fossil fuels as the dominant energy source, a temperature increases of 3 °C or more is expected by the end of this century. Meanwhile, renewable energy sources (solar, wind, hydro, geothermal, biomass, and so on) are the world's emission-free energy sources [23]. Again, most of the respondents agreed that solar electrification improves grid security and is applicable everywhere (m = 2.070 and m = 2.250 respectively). Most of the respondents selected neutral and agreed to the statements: Solar electrification failures are generally low and hence reliable and Solar electrification is readily accessible respectively (m = 3.120 and m = 2.500). Lastly, most respondents agreed that solar electrification is advantageous for the energy needs of households (m = 2.050). The idea of energy security guards against negative environmental impacts guarantees the dependability of energy sources, and keeps an adequate supply of energy at a reasonable cost. Energy security and electric system safety are enhanced by the integration of renewable energy using smart grid technologies [24]. Over two billion people, especially in developing nations, lack access to grid-connected power and reside in rural areas. Whether through stand-alone "Mini-grids" powered by diesel generator sets, the extension of existing grids, or even mini-grids based on renewable energy, conventional approaches to power supply require large investments that are unlikely to take precedence over more politically and economically appealing investments in urban areas. Nonetheless, solar electrification is a financially feasible solution that meets rural communities' fundamental energy requirements [14]. Solar energy is one of the many abundant, limitless, and readily accessible forms of renewable energy. The world's energy needs, both current and future, may be satisfied by these resources [2].

Table 4 Benefits of Solar Electrification and Grid Extension

Statement	Mean	Standard Deviation
Solar electrification creates no carbon emissions and other greenhouse gases	1.950	.783
Solar electrification avoids the environmental damage associated with mining for fossils and deforestation	1.960	.803
Solar electrification improves grid security	2.070	.856
Solar electrification is applicable everywhere	2.250	1.114
Solar electrification failures are generally low hence reliable	3.120	1.157
Solar electrification is readily accessible	2.500	1.176
Solar electrification is advantageous for the energy needs of household	2.050	.947

Source: Field Survey, 2023.

- *Economic Viability of Solar Electrification and Grid Extension*

Table 5 presents the mean score of each dimension for the economic viability of solar electrification and grid extension. Most of the respondents agreed that the big companies are investing in solar energy but were neutral that solar electrification generates ample employment opportunities which creates a robust economy (m = 2.210 and m = 2.960 respectively). The 2018 Annual Review of the IRENA reports that employment related to renewable energy reached 10.3 million worldwide in 2017, an increase of 5.3% over the number reported in 2016. Of the 164,400 jobs in solar PV, 92,400 were related to on-grid use, a 36% increase in employment. According to IRENA's analysis, 46% of these occupations involved construction and installation, while 35% and 19% involved operations and maintenance (O&M) [25]. Again, most of the respondents were neutral that government subsidy and policy have ensured the growth of the solar energy sector and agreed that the benefit derived from the usage of solar energy outweighs the cost of producing solar energy (m = 3.230 and m = 2.020 respectively). Most of the respondents agreed and were neutral to the statements: the cost of generating electricity from conventional grid extensions has been rising along with the price of natural gas which influences the electricity prices and solar energy has been moving towards cost competitiveness with conventional electricity (m = 2.160 and m = 2.950 respectively). In most governments in the world, subsidies are a vital tool for promoting the growth of solar energy. The following are possible forms of subsidies: output- or production-based payments, soft loans (interest-free loans), and capacity payments or investment grants. At the wholesale or retail levels, many solar energy systems are still more expensive than conventional energy commodities. Therefore, until strong legislative incentives are provided, no large-scale solar energy deployment will be conceivable. Realising this, numerous governments have aided in the development of solar energy through a variety of commercial, regulatory, fiscal, and other tools. To generate highly visible support for the majority population, energy subsidies are an easily accessible government weapon that requires very minimal administrative requirements [3,4]. Additionally, researchers found that over the examined period, PV costs declined at a faster rate than values did. As a result, in 2017 at most of the modelled locations, the advantages to the market, health, and climate outweighed the costs of PV systems [26].

Lastly, most respondents agreed that solar energy ensures clean energy for sustainable development and poverty alleviation (m = 1.850). Energy is the most important factor in any country's ability to eradicate poverty, advance economically, and maintain national security. Today, uninterrupted energy supply is a crucial concern for any nation. The long-term availability of energy from sources that are accessible, inexpensive, and ecologically friendly is

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL588

critical for future economic growth. Energy has a direct impact on public health, security, and climate change. Necessities like cooked food, a comfortable temperature for living, lighting, appliance use, piped water or sewerage, vital health care (refrigerated vaccinations, emergency and intensive care), educational tools, communication (radio, television, email, the Internet), and transportation are all made possible by energy. Mining, manufacturing, trade, agriculture, and other productive industries are all fuelled by energy. On the other hand, a lack of energy access can lead to economic downturn as well as poverty and misery. Not only are energy and poverty reduction tightly related, but socioeconomic development—which includes productivity, income growth, health, and education—is also intimately related to energy.

Table 5 Economic Viability of Solar Electrification and Grid Extension

Statement	**Mean**	**Standard Deviation**
Big companies are investing in solar energy	2.210	1.085
Solar electrification generates ample employment opportunities which creates a robust economy	2.960	1.100
Government subsidy and policy has ensured the growth of the solar energy sector	3.230	1.146
The benefit derived from the usage of solar energy outweighs the cost of producing solar energy	2.020	.804
The cost of generating electricity from conventional grid extensions has been rising along with the price of natural gas which influences the electricity prices	2.160	.929
Solar energy has been moving towards cost competitiveness with conventional electricity	2.950	1.140
Solar energy ensures clean energy for sustainable development and poverty alleviation	1.850	.833

Source: Field Survey, 2023.

➢ *Themes from Study*

The findings of the study are presented in the form of themes and sub-themes. The following table (Table) presents the outline of the themes.

Table 6 Themes

4.7.1. Cost Of Solar Electrification Against Grid Extension
4.7.2 Benefits of solar electrification and grid extension in rural communities
4.7.3 Economic Viability of Solar Electrification and Grid Extension
4.7.4 Policies and Initiative

Source: Field Survey, 2023.

- *Cost of Solar Electrification Against Grid Extension*

This theme focused on finding out the estimated cost of solar electrification and grid extension in rural areas in Ghana and therefore asked some stakeholders and policymakers as well as experts to share their views. All respondents interviewed in this study indicated the high cost involved in grid extension as compared to solar electrification. Respondents also stated that the quality and availability of materials are the major cost drivers of both solar electrification and grid extension.

- *An Assistant Solar Engineer Stated:*

"The estimated cost of solar electrification in rural areas of Ghana is between GHS 40,000 and GHS 50,000 depending on the area, availability of water, and the topography of the land whereas the estimated cost associated with grid extension in rural areas of Ghana is around GHS 320,000 depending on whether it is close to a grid or not" (13th October 2023).

- *A Director of Renewable Energy also Stated:*

"The estimated cost associated with solar electrification ranges from GHS 20,000 to GHS 50,000 depending on the area whereas that of grid extension is estimated around GHS 350,000 depending on the proximity of the grid to the site" (15th October 2023).

- *Benefits of Solar Electrification and Grid Extension in Rural Communities*

The purpose of this theme is to highlight some benefits of solar electrification and grid extension in rural communities in Ghana. All the respondents indicated that solar electrification has a better environmental impact while grid extension provides reliability. Grid extension frequently uses conventional power generation methods, which can have a negative influence on the environment and exacerbate climate change. It requires extensive infrastructure development and may face challenges in reaching remote or economically unviable areas.

- *A Respondent Stated:*

"The major benefit of solar electrification in rural communities include the reduction in carbon footprint and cost-effectiveness whereas, for grid extension, the key benefit includes enough capacity and reliability from constant supply" (13th October 2023).

- *Another Respondent States:*

"Solar electrification for rural communities in Ghana ensures the promotion of clean technology that saves and conserves the environment while increasing the quality of life and increase socioeconomic activities whereas for the grid extension, it increases agricultural productivity and ensures

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24JUL588

the growth of rural industries, raising the livelihood of the indigenous people" (15th October 2023).

- *Economic Viability of Solar Electrification and Grid Extension*

This theme focused on highlighting the economic viability of solar electrification and grid extension projects within rural areas. The Ghana Energy Development and Access Project (GEDAP), which includes the implementation of solar home systems in rural areas made use of cost-benefit analyses were conducted to evaluate the economic viability and financial sustainability of the project.

- *A Respondent Stated:*

"The initial capital for the installation of solar panels, batteries, inverters, and other system components plays a crucial role in the economic viability of solar electrification projects. The benefits derived from solar electrification outweigh the cost of installing the panels initially. The grid extension has a relatively higher cost, and although provides reliability and a constant supply of electricity the benefits derived from this take a bit longer over longer periods. Also, the maintenance of the solar system is less expensive as compared to the grid system and hence ensures a good return on investment." (13th June 2023).

- *Policies and Initiatives*

The purpose of this theme is to highlight some policies and initiatives by stakeholders to promote solar electrification and grid extension in rural areas. These policies are enacted to help ensure rural areas and communities get access to reliable energy supply to help boost productivity and the livelihood of people within the area.

- *A Respondent Stated:*

"The government implemented the Renewable Energy Act (2011). The Renewable Energy Act provides a legal framework to promote the development and use of renewable energy sources in Ghana, including solar energy. It establishes provisions for feed-in tariffs, net metering, licensing of renewable energy projects, and the creation of the Renewable Energy Fund to support renewable energy development, including solar electrification initiatives". (13th October 2023).

- *Another Respondent Stated:*

"The National Energy Policy was implemented by the government which aims at ensuring that renewable energy constitutes 10% of Ghana's total energy mix by 2030. Also, Ghana has implemented feed-in tariff programs to incentivize the deployment of renewable energy systems, including solar photovoltaic (PV) projects. The feed-in tariffs provide guaranteed payments for renewable energy producers, encouraging private sector investment in solar electrification projects. Additionally, tax incentives, duty exemptions, and other financial benefits are offered to promote the importation and use of renewable energy equipment." (15th October 2023).

V. SUMMARY OF MAIN FINDINGS

➢ *From the Results, the Key Findings are:*

- The cost of solar electrification and grid extension in rural areas of Ghana is estimated to be higher than solar electrification. Initial installation of solar systems is cheaper due to professional installation, while solar panels are cheaper due to their cost-effectiveness. Solar electricity offers a good return on investment and does not require monthly bill payments, making it economically sound. Maintenance of solar systems is also easier and cost-efficient compared to grid extensions. The cost of solar electrification in rural areas ranges from GHS 40,000 to GHS 50,000, depending on factors like water availability and land topography. The cost of grid extension varies depending on the location and proximity of the grid. Investment in solar panels can be recouped over time.
- The study reveals that solar electrification and grid extension have significant benefits for rural communities. Solar electrification generates no carbon emissions and avoids environmental damage from fossil fuel mining and deforestation. It also improves grid security and is applicable everywhere. Solar electrification failures are generally low, making it reliable and easily accessible. It is advantageous for households, as it ensures energy security and reliable supply. Over two billion people, particularly in developing nations, lack access to grid-connected power and reside in rural areas. Solar electrification is a financially feasible solution that meets their fundamental energy needs. Grid extension, on the other hand, often uses conventional power generation methods, which can negatively impact the environment and exacerbate climate change. It requires extensive infrastructure development and may face challenges in reaching remote or economically unviable areas. Solar electrification in rural communities reduces carbon footprints and cost-effectiveness, while grid extension increases agricultural productivity and rural industries, raising indigenous people's livelihoods.
- The economic viability of solar electrification and grid extension projects is a topic of interest. While big companies are investing in solar energy, most respondents agree that it generates ample employment opportunities and creates a robust economy. The 2018 Annual Review of the IRENA reported that employment related to renewable energy reached 10.3 million worldwide in 2017, an increase of 5.3% over the number reported in 2016. Most respondents also agree that government subsidies and policies have ensured the growth of the solar energy sector, with the benefit derived from solar energy outweighing the cost of producing solar energy. Support for solar energy development is crucial, as it provides clean energy for sustainable development and poverty alleviation. Energy is essential for public health, security, and climate change, and is essential for various industries, including mining, manufacturing, trade, and agriculture. The Ghana Energy Development and Access Project (GEDAP) focuses on the economic viability of solar electrification and grid extension projects in rural

areas. The initial capital for solar panel installation plays a crucial role in the economic viability of solar electrification projects, with the benefits derived from solar electrification outweighing the cost of installing panels initially.

VI. LIMITATION

➢ *Despite the Thoroughness of the Study, there are Several Limitations that have been Acknowledged:*

Firstly, the sample size is limited to Akyeremateng township, potentially limiting the generalizability of findings to other rural areas in Ghana.

Additionally, reliance on self-reported data and a single data collection point may introduce bias and overlook temporal variations. Low Cronbach's Alpha values suggest possible measurement errors, impacting reliability.

The study's narrow focus on economic viability neglects broader socio-cultural and environmental factors. External influences like policy changes and technological advancements were not adequately considered. Lastly, while some ethical considerations were addressed, others may have been overlooked.

Addressing these limitations in future research could enhance the robustness and applicability of findings, providing more accurate insights into the economic viability of clean energy solutions in rural Ghana.

VII. RECOMMENDATION

➢ *From the Study it can be Recommended that;*

- In certain regions, research ought to be conducted to examine the possibility of hybrid systems that integrate solar electrification with grid extension. To maximise the advantages of both strategies, evaluate the hybrid solutions' viability from an economic, technological, and social standpoint.
- More studies should be conducted to determine how new technologies, such as energy storage options, smart grids, sophisticated photovoltaic systems, and energy management systems, might improve the operational effectiveness and financial sustainability of solar electrification in Ghana's rural areas.
- Studies on the potential for regulatory frameworks and policy incentives to promote private sector investments in solar electrification as well as the effects of policy interventions like feed-in tariffs, tax breaks, and supportive regulations on the expansion of the solar industry in rural Ghana should be conducted.

VIII. CONCLUSION

➢ *This Study Assessed the Economic Viability of Solar Electrification against Grid Extension in Rural Ghana. It can be Concluded that:*

Grid extension which averages a cost of GHS 320,000 is much more expensive compared to solar electrification which is estimated between GHS 40,000 and GHS 50,000. Again, solar electrification causes a reduction in carbon footprint, thus protecting the environment and providing enough capacity and reliability from constant supply due to the abundance of solar energy. Solar electrification is economically viable as the initial capital for the installation of solar panels, batteries, inverters, and other system components plays a crucial role in the economic viability of solar electrification projects. The benefits derived from solar electrification outweigh the cost of installing the panels initially.

➢ *Conflicts of Interest*

The authors declare that there are no conflicts of interest regarding the publication of this paper.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of Bui Power Authority and Kwame Nkrumah University of Science and Technology for their support.

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