Assessment of the Environmental and Financial Benefits of Solar Electricity for Homes in the Zongoro Community of Bauchi State

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Abstract
The study explores the relationship between energy consumption and economic development, emphasizing the significance of sustainable energy solutions. Historical advancements in energy efficiency have driven human progress, with developed nations exhibiting higher per capita electricity consumption. However, energy accessibility remains a challenge in rural Nigeria, where a significant portion of the population lacks reliable electricity. The study focuses on Zongoro, Bauchi State, assessing the feasibility of solar energy adoption. Using a contingent valuation survey, it evaluates household willingness to pay for solar power, considering economic and environmental factors. Findings highlight the critical role of renewable energy in bridging the electricity gap, reducing reliance on fossil fuels, and mitigating environmental degradation. The study employs non-market valuation techniques to assess solar power's socio-economic impact and proposes strategies for implementing off-grid solar solutions. By addressing energy poverty through sustainable alternatives, this research aims to contribute to Nigeria's long-term energy security and rural development.

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Introduction

From the discovery of fire for cooking and heating during the Stone Age to the usage of coal and diesel to fuel the energy requirements of the Industrial Revolution to the current advancements in nuclear technologies and renewables, every significant human development throughout human history has been linked to the discovery of more efficient energy sources (Smil, 2017) [28]. The idea that energy efficiency might serve as a gauge of human advancement is not unjustified; in fact, advanced and emerging economies are still distinguished from one another based on energy consumption per capital.

Regardless of whether an energy source is clean, concerns should be focused on source shortage and regeneration rate. The cost of fossil fuels versus renewables and many renewables is a complex topic looking at life circle impacts (Hussain *et al*. 2022) [11]. Today, the worldwide community's greatest difficulty is not addressing the demand and supply of human energy needs but rather doing so while being cognizant of all externalities, particularly with respect to sustainability, global warming, and resource exploitation.

According to Onakoya *et al*. (2013) [21], there is a strong positive correlation between energy and economic growth. For example, a one percent increase in TEC would result in a 28% increase in Real Gross Domestic Product (RGDP). In other words, a 28% rise in RGDP will result from a unit increase in energy use. However, the relationship between energy consumption and economic development reveals that a 42% rise in RGDP will result from every unit increase in the number of kilowatt-hours of power consumed. Electricity usage is observed to rise in tandem with income.

As stated by Etukudor (2015) [9], per capita consumption is a measure of the standard of living of the population as a whole. It is demonstrated by comparing the per capita electricity consumption of less developed nations like Bangladesh, Cambodia, Nigeria, and Myanmar with that of developed nations like the United States of America, Australia, Germany, and Japan, which have respective per capita electricity consumptions of 12,947 kwh/capita, 10,218 kwh/capita, 7,138 kwh/capita, and 7,753 kwh/capita.
The abundance of resources, such as sunshine, is one of the factors that Abdullahi *et al*. (2017) [1] mention as being important when utilizing a different form of energy. However, when implementing solar as an alternative, the geographical area always becomes a factor to take into account. Similar to how hydroelectricity can only be implemented in areas with abundant water supplies, this also holds true for all other renewable energy options. In contrast, non-renewable energy sources, primarily fossil fuels, can import resources to where they are needed or used, so resource availability is not taken into account.
Around 80% of Nigerian rural areas live beneath the poverty line, while the country's northern poverty index is at an all-time low (Ukohol *et al*., 2019) [30]. Like the majority of towns on the northern outskirts of Bauchi state, Zongoro is suffering from deforestation brought on by climate change, which is making it harder to find traditional energy sources like fire wood. With 46.09% of Nigeria's population living without access to the grid, or 83.98 million people, the need for energy is estimated to be 24,380 MW as of 2015, compared to a generating capacity of 7,139.6 MW. Since many of these areas are remote villages like Zongoro, it is morally required to find alternative energy sources to power these areas (Onyekwena & Ishaku, 2017) [22].
In order to present new evidence regarding the demand for renewable electricity connections in a developing context, the study uses a contingent valuation survey to evaluate the consumption of solar energy electricity among non-electrified households in Zongoro Ganjuwa LGA of Bauchi state. More precisely, the aim is to estimate willingness to pay (WTP) need preferences and perception to connect to solar electricity goods using payment plans.
Current research on solar energy mostly ignores the particular requirements of rural, off-grid settlements like Zangoro in favor of concentrating on urban and semi-urban populations or larger regional levels. There are several important gaps, such as an inadequate amount of localized research on how rural households view, resist, and react to solar electricity; a lack of environmental considerations in economic analyses of the effects of solar energy; and a lack of investigation into how household characteristics and collective energy plans affect demand dynamics. By offering an enviro-economic assessment of solar power that is especially suited to the rural setting of the Zangoro community, this study seeks to close these gaps.
The purpose of this study is to determine the environmental and financial benefits of solar electricity for homes in the Zongoro community of Bauchi state in order to evaluate the feasibility of putting in place a community solar energy program. The aim of this study will be achieved via the following objectives:

1. To determine the level of potential effective demand for solar electricity in line with anticipated derivable utilities
2. To established the enviro-economic efficiency of using solar electricity in terms of cost, externalities and benefits in Zongoro.

Literature Review

Energy and Development

According to predictions, the world's two most difficult and significant problems in the future will be energy and the environment (Popp *et al*., 2014) [24]. British Petroleum claims that during the past 30 years, gasoline consumption has increased dramatically, nearly doubling from 6630 Mtoe in 1980 to 11,630 Mtoe in 2009 (Dudley, 2018) [7]. However, from 9.396 million metric tons in 1960 to 32.083 million metric tons in 2008, the overall amount of CO2 gas emissions rose dramatically (Kurokawa *et al*., 2013) [15]. In order to address sustainability concerns, energy shortages, and the high cost of new power plants, efforts have been undertaken over the past few years to innovate and develop new technologies. To find and apply the best technology to address some of the issues, a great deal of scientific and research effort has been done (Chong *et al*., 2011) [6].
Additionally, the world is greatly impacted by the necessity of avoiding energy loss and storing the energy waste from various commercial, industrial, and home operations. Accordingly, researchers have been interested in energy storage technology because of its potential to lower energy expenditures and consumption as well as serve as a potential alternative energy source (Chong *et al*., 2011) [6].

Energy demand in Nigeria

It is well known that a country's ability to thrive economically depends on its energy supply, particularly its power supply (Ikeme & Ebohon, 2005) [12]. According to the National Bureau of Statistics, Nigeria is divided into six geopolitical zones, with a total land area of 923.769 square kilometers (98.5% highland and 1.5% lowland) (NBS, 2013) [18]. According to a 2014 United Nations research, 50.4% of Nigerians live in rural areas, and only 36% of them have a source of power, with the majority having fewer than four hours per day (United Nations Department of Economic and Social Affairs, 2014). The low socioeconomic standing of Nigeria's rural villages is surely a result of the nation's precarious power situation. Up to 80% of Nigerian rural areas are below the poverty level, as reported by Ukohol *et al*. (2019) [30]. In remote locations, the cost of purchasing or fueling power generating units is out of reach for many small company owners and entrepreneurs. The Federal Government of Nigeria eliminated fuel subsidies in 2012, which made matters worse. Many have so given up on their companies in frustration. Numerous instances have frequently resulted in a significant rural-urban migratory shift in many communities, with the young and productive youths leaving the elderly and weak behind to migrate to the metropolis. The number of impoverished people in metropolitan areas has also increased as a result of this, which has led to rural areas becoming socially disadvantaged with their economic potential being unrealized (Sambo, 2009) [26]. Therefore, it is believed that electricity is one of the most important resources for both the social and economic well-being of rural areas. A location without electricity typically lacks basic facilities like a school, hospital, communication system, portable water supply, etc. Compared to non-electrified societies, electrified cities have higher Human Development Index values (Chaurey, 2010) [5]. Given the distance between the obtainable grid and the load center, national grid extension via the dense jungles and challenging terrain in the majority of villages may be challenging and unfeasible due to the accompanying high cost and transmission interruptions (Sen & Bhattacharyya, 2014) [27].

When used correctly and maintained on a regular basis, diesel generators can be a dependable source of electricity for rural villages. However, they can also have a number of drawbacks, such as noise pollution and environmental contamination from the release of CO_2 and other hazardous gases. Additionally, the unpredictability of diesel price increases, along with the increased expense of delivery to outlying areas, may make it challenging to sustain (Sambo, 2009) [26].

Alternative energy in Nigeria

A system of independent, off-grid power generation must be built for Nigerian remote areas since expanding the national grid to rural regions does not currently appear to be a viable way to improve rural accessibility to electricity. Since renewable energy (RE) supplies and technology are always available and ecologically safe, such an approach would be feasible. Furthermore, rural residents have low electrical needs, which can be readily satisfied by RE-based power sources. Only the hydroelectric source is being used most frequently for power generation in Nigeria, despite the country's enormous quantity of renewable resources, and even then, at a rate of exploitation that falls short of its full capacity (Mohammed *et al*, 2013) [16]. According to Ohunakin *et al*. (2014) [20], solar electricity is primarily utilized by urban households and cities, as well as at a few chosen rural demonstration sites. Every other renewable resource is still not being used to its full potential.

Therefore, a dependable, affordable, and easily accessible power source is essential to the growth of any rural community. Over time, a number of technological developments in the field of renewable energy have made it increasingly practical to use these resources to replace diesel power for load requirements in rural areas. As a result, in rural areas, off-grid alternatives that use renewable energy sources including solar, wind, hydro, and biomass may be preferable to traditional energy sources (Nandi, 2010) [17].

Solar energy potentials and utilization in Nigeria

About 50 weather stations in Nigeria regularly record meteorological data, including temperature, sunlight hours, rainfall, air pressure, and relative humidity, according to the Nigerian Meteorological Agency (NIMET). Nevertheless, only roughly 18 of these 50 weather stations monitor sun radiation (Aliyu *et al*., 2015) [2].

Nigeria is mostly reliant on thermal and hydropower sources, accounting for 86.2% and 13.8% of its installed generation capacity of 12,500 Mega Watts (MW). However, at the moment, only 4,000 MW to 5,500 MW are typically accessible for transmission to the end consumer. Less than half of Nigerians, nevertheless, have access to grid electricity. Consequently, carbon dioxide (CO_2) emissions will decrease when energy is produced using PV system applications. With moderately dispersed solar radiation of 5.58 kWh/m2 per day and an average of 5.5 hours of sunshine per day, Nigeria offers enormous potential for solar energy (Bamisile, 2014) [3].

The PV system's financial viability is its main drawback, particularly when contrasted with alternative energy sources. It is economically possible for Nigeria to generate solar energy, but the main issue is the cost. Government and commercial institutions must increase their investments in solar energy technologies if solar energy is to improve. It will improve the nation's social and economic development and aid in lessening the energy issue (Ozoegwu *et al*., 2017) [23].

The amount of solar energy that reaches the Earth's surface is several thousand times greater than what humans now consume as main energy. Because of its enormous potential, solar energy is a crucial part of the renewable energy portfolio that aims to lower greenhouse gas emissions into the environment worldwide. Nevertheless, fewer than 1% of all electricity produced from renewable sources is now produced using this energy supply according to Global Climate and Energy Project (GCEP) (2006). Compared to 75% in South Africa and 95% in Egypt, just roughly 35% of Nigerians have the luxury of power. Africa consumes less than 5% of the world's total energy usage. Approximately 85% of Africans remain in rural areas without having access to electricity, despite the continent housing 10% of the world's crude oil reserves and 13% of the world's population. Nigeria, Africa's most populous nation, is experiencing a kind of irony: while being the sixth-largest producer of crude oil globally, it has been dealing with an enormous energy shortage for many years (Ngala *et al*., 2006) [19]. With a goal of raising the current 5,000 MW to 16,000 MW by 2015, the government is currently dedicated to finding a long-term solution to this dilemma through the Renewable Energy Master Plan (REMP) Energy Commission of Nigeria (ECN, 2007) [8].

Solar energy potentials in the Semi-Arid region of Nigeria

The average amount of solar radiation and sunshine hours in Northern Nigeria's semi-arid region are 7 kW/m2/day and 9 hours, respectively (Sambo, 2009) [26]. This should be bolstered by the fact that semi-arid regions are endowed with vast amounts of underused flat land and are defined by annual rainfall of 125 to 500 mm and average daily temperatures of 40 to 45 °C (SFSA, 2007) [29], which match to the mesophilic temperature range. The semi-arid area is ideal for developing large-scale solar power projects because of these factors combined.

Economic valuation techniques for non-market goods and services

A collection of methods known as non-market valuation seeks to capture the economic significance of shifts in the quality or availability of commodities and services which are not meant for market exchange (e.g., health care, education and environment). In order to effectively handle these products and services by taking into account their actual value to society, the goal is to evaluate the effects of these changes on one's utility and, consequently, on social welfare (Roussel & Tardieu, 2018) [25].

Allocating values for non-market goods and services with no market pricing is the goal of environmental valuation, a subfield of environmental economics. Evaluating the environment is a challenging and controversial endeavor; most economists have been ridiculed for trying to provide a "price tag" to the environment. However, agencies tasked with conserving and protecting natural resources frequently have to make tough choices involving resource allocation trade-offs (Bateman *et al*., 2002) [4].

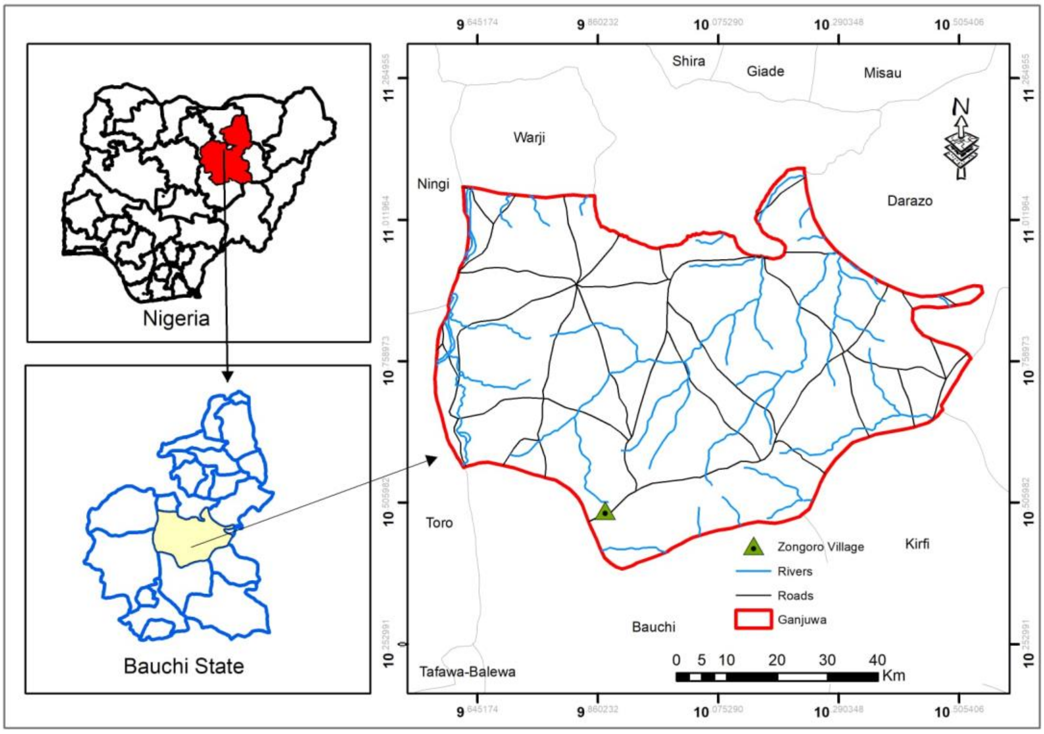
A variety of empirical techniques are used in economic valuation methods for non-market commodities and services to calculate the monetary value of the trade-off that an individual would be prepared to make in order to increase the quantity or quality of an item or service for which there is no market. The methods have evolved and gained professional approval after more than 50 years of development; for instance, they are frequently used as a foundation for oil spill damage evaluations in US court cases, which can amount to several billions of US dollars. According to Kriström *et al*. (2015) [14], there are likely over 10,000 published publications that address a variety of topics related to economic valuation techniques.

Therefore, by offering a means of defending and establishing standards for policies, programs, or acts that protect and restore the environment and its services, economic valuation can be beneficial. Comparing the benefits and costs of a proposed action is the fundamental component of economic assessment; a project is considered to pass a benefit-cost analysis if the total benefits exceed the whole costs (Koopmans & Mouter, 2020) [13]. Without monetary valuations for the natural goods and services that a proposed intervention might affect, such an analysis is extremely simplistic.

The HM Treasury Green Book manual (2018) provides guidance for evaluating the economic case and recommends the use of cost-benefit analysis (CBA). This means quantifying all of the societal advantages and disadvantages of the policy change in monetary terms. The option with the greatest net social benefits during the course of the program and its legacy is the one that is preferred (Fujiwara, 2019) [10].

Chapter Three: Research Methodology

This study was conducted in Zongoro, Zongoro is located in Ganjuwa local government Area of Bauchi state is situated near by to the locality of Yuli, Takale, Gangu and Kwarba.



Map of the study area
Population of the Study

Fig 1: As of the 2006 census, Zongoro has 2,312 and 297 families, according to the National Population Commission (NPC). Using the population projection method, the population has increased to an estimated 4,370 and 703 homes. The main tribes of the people living there are Hausa, Fulani, and Gerawa. The heads of particular Zongoro households served as the study's sampling unit.

Determination of sample size

The total number of households (n) included in the survey was calculated using the Krejcie and Morgan table. An efficient technique for calculating sample size is required due to the growing requirement for a representative statistical sample in empirical research. Krejcie & Morgan developed a table for figuring the sample size for a given population in order to close the gap. The table offers a simple and user-friendly approach for calculating sample size for convenient reference, and it is frequently used to estimate sampling size in research investigations.

Sample size and sample technique

A population (N) of 703 homes requires a sample (n) of 248 at error.50, according to the Krejcie and Morgan table sample determination table, which was used to determine the final sample size based on the total number of 561 households in the study region as of the time of the study. For this study, the respondents were chosen using simple random selection.

Methods of data collection

A structured survey was used in this investigation. The researcher created the questionnaire using the supervisory committee's input, modified question formats from earlier studies, and a review of the literature. The sociodemographic details of respondents, the degree of probable effective demand in line with expected derivable utilities, and the environmental-economic efficiency of using solar in terms of cost, externalities, and benefits are all included in the questionnaire, which was created in accordance with the study's goals. Ten percent of the study population will pretest the questionnaire to identify any repetitive or offensive questions in order to assess the validity of the data gathered.

Data analysis techniques

Following data collection, the completed questionnaires were classified to guarantee accuracy. To calculate the household WTP as well as identify its predicting factor, a Cost Benefit Analysis and Ordinance Regression Analysis were used. Before the proper data analyses were performed to answer the study's objectives, some preliminary analyses were carried out, sorting missing values where needed and computing and classifying all continuous variables that were needed in categorical form to facilitate analyses.

Results and Discussion
Frequency Tables (Socio-Demographics)

Table 1: Gender of respondent

Variable		Frequency	Percent	Valid Percent	Cumulative Percentage
Gender	Male	67	28.9	28.9	28.9
	Female	165	71.1	71.1	100.0
	Total	**232**	**100.0**	**100.0**	
Age	16	1	.4	.4	.4
	17	2	.9	.9	1.3
	18	34	14.7	14.7	15.9
	19	26	11.2	11.2	27.2
	20	59	25.4	25.4	52.6
	21	22	9.5	9.5	62.1
	22	6	2.6	2.6	64.7
	23	13	5.6	5.6	70.3
	24	7	3.0	3.0	73.3
	25	5	2.2	2.2	75.4
	27	2	.9	.9	76.3
	28	1	.4	.4	76.7
	30	17	7.3	7.3	84.1
	31	1	.4	.4	84.5
	32	1	.4	.4	84.9
	34	2	.9	.9	85.8
	35	10	4.3	4.3	90.1
	38	1	.4	.4	90.5
	40	4	1.7	1.7	92.2
	42	2	.9	.9	93.1
	45	8	3.4	3.4	96.6
	60	4	1.7	1.7	98.3
	65	4	1.7	1.7	100.0
	Total	**232**	**100.0**	**100.0**	
Educational level	Never been to school	78	33.6	33.6	33.6
	Primary school	73	31.5	31.5	65.1
	Secondary school	44	19.0	19.0	84.1
	Higher Education	37	15.9	15.9	100.0
	Total	**232**	**100.0**	**100.0**	
Marital Status	Married	201	86.6	86.6	86.6
	Single	21	9.1	9.1	95.7
	Widow	10	4.3	4.3	100.0
	Total	**232**	**100.0**	**100.0**	
Households' ownership	Owner	218	94.0	94.0	94.0
	Rent	7	3.0	3.0	97.0
	Squatting	7	3.0	3.0	100.0
	Total	**232**	**100.0**	**100.0**	
Housing Type	Traditional	202	87.1	87.1	87.1
	Modern	30	12.9	12.9	100.0
	Total	**232**	**100.0**	**100.0**	
Number of dwellers	0-10	123	53.0	53.0	53.0
	11-20	71	30.6	30.6	83.6
	21-30	38	16.4	16.4	100.0
	Total	**232**	**100.0**	**100.0**	
Occupation	Employment with Government	19	8.2	8.2	8.2
	Employment with private sector	26	11.2	11.2	19.4
	Self-employment	118	50.9	50.9	70.3
	Unemployment	69	29.7	29.7	100.0
	Total	**232**	**100.0**	**100.0**	

(Field Survey, 2024)

4.2 Discussion of demographic variables
Important details about the population of Zongoro villages are revealed by the demographic analysis of the respondents. The fact that women make up the majority of responders (71.1%) may indicate that women participate in household surveys at a higher rate or are more readily accessible to do so. With a sizable percentage of responders (51.3%) between the ages of 18 and 20, the age distribution shows a largely youthful population, one that is probably enrolled in school or just starting their jobs. Regarding education, the majority have either never gone to school (33.6%) or finished primary school (31.5%), indicating a sizeable segment of the population with no formal education. The community appears to have a stable family structure, as seen by the high percentage of married people (86.6%) compared to the low percentage of widows (4.3%) and singles (9.1%). Conventional housing structures are preferred by the majority of households, which own their homes (94.0%) and reside in traditional housing (87.1%). The majority of the residents in each home (53.0%) are in the 0–10 range, indicating rather small family sizes. Employment trends indicate that a sizable percentage of people are self-employed (50.9%) and

unemployed (29.7%), with fewer working for the government (8.2%) or private sector (11.2%). These demographics offer a thorough insight of the socioeconomic environment of the community, which is essential for comprehending the background of energy choices and needs.

Objective 1: The level of potential effective demand for solar electricity in line with anticipated derivable utilities

Table 2: Descriptive statistics showing the level of potential effective demand for solar electricity in line with anticipated derivable utilities

Statement	N	Mean	Standard Deviation
The households' willingness to pay between 0-10,000 for solar	232	4.72	.730
The households' willingness to pay between 11,000-20,000 for solar	232	3.03	1.197
The households' willingness to pay between 21,000-40,000 for solar	232	2.50	1.213
The households' willingness to pay between 41,000-60,000 for solar	232	1.87	.940
The households' willingness to pay between 61,000 above for solar	232	1.49	1.065
Valid N (listwise)	232		

(Field Survey, 2024)

Based on families' willingness to pay varying price ranges, Table 2 presents descriptive statistics that illustrate the potential effective demand for solar electricity. The average score of 4.72 indicates a significant preference for solar energy at this price range, suggesting a high willingness to pay between 0-10,000. The willingness to pay, however, sharply declines as the price range widens; the mean falls to 3.03 for quantities between 11,000 and 20,000, 2.50 for amounts between 21,000 and 40,000, 1.87 for amounts between 41,000 and 60,000, and 1.49 for amounts over 61,000. As the price increases, the standard deviations also show growing heterogeneity in answers, especially in the middle ranges (21,000–40,000 and 61,000 above), suggesting that consumers have differing views about rising expenses.

Table 3: Frequency table showing the level of potential effective demand for solar electricity in line with anticipated derivable utilities

Statement	SD	D	N	A	SA	Total
The households' willingness to pay between 0-10,000 for solar	0	11 (4.7%)	5 (2.2%)	23 (9.9%)	193 (83.2%)	232 (100%)
The households' willingness to pay between 11,000-20,000 for solar	13 (5.6%)	98 (42.2%)	15 (6.5%)	81 (34.9%)	25 (10.8%)	232 (100%)
The households' willingness to pay between 21,000-40,000 for solar	42 (18.1%)	113 (48.7%)	12 (5.2%)	48 (20.7%)	17 (7.3%)	232 (100%)
The households' willingness to pay between 41,000-60,000 for solar	87 (37.5%)	115 (49.6%)	8 (3.4%)	17 (7.3%)	5 (2.2%)	232 (100%)
The households' willingness to pay between 61,000 above for solar	180 (77.6%)	24 (10.3%)	3 (1.3%)	17 (7.3%)	8 (3.4%)	232 (100%)

Key: Strongly Disagree – SD, Disagree – D, Neutral – N, Agree – A, Strongly Agree - SA
(Field Survey, 2024)

A frequency analysis of families' willingness to pay for solar electricity across various price ranges is presented in Table 3 to support these findings. The high demand seen in Table 2 is further supported by the fact that a sizable majority of respondents (83.2%) completely concur with paying this amount in the 0-10,000 range. The percentage of strong agreement, however, sharply declines as the price rises. Just 10.8% of respondents strongly agree with the 11,000–20,000 range, whilst 42.2% disagree. With 48.7% disagreeing in the 21,000–40,000 range and 49.6% at the 41,000–60,000 range, this pattern persists as the price rises more. A sizable majority (77.6%) strongly disapprove with sums beyond 61,000, suggesting that there is little demand at this level. A substantial sensitivity to cost among families is highlighted by this frequency analysis, which also shows the falling willingness to pay as prices rise. It also highlights the significance of cheap pricing in promoting demand for solar electricity.

Table 4: Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Intercept Only	457.220			
Final	402.606	54.614	10	.000
Link function: Logit.				

Table 5: Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	672.145	98	.000
Deviance	362.129	98	.000
Link function: Logit.			

Table 6: Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[C = 1]	-1.034	.816	1.605	1	.205	-2.633	.565
	[C = 2]	1.715	.817	4.406	1	.036	.114	3.316
	[C = 3]	2.044	.821	6.192	1	.013	.434	3.653
	[C = 4]	3.819	.865	19.483	1	.000	2.123	5.515
Location	[Occupation=1]	.505	.563	.806	1	.369	-.598	1.608
	[Occupation=2]	2.142	.714	9.001	1	.003	.743	3.542
	[Occupation=3]	1.578	.378	17.452	1	.000	.837	2.318
	[Occupation=4]	0[a]	.	.	0	.	.	.
	[Education=1]	.149	.426	.121	1	.728	-.687	.984
	[Education=2]	.900	.452	3.966	1	.046	.014	1.786
	[Education=3]	-.434	.496	.766	1	.381	-1.405	.538
	[Education=4]	0[a]	.	.	0	.	.	.
	[Monthly_Income=1]	-.770	.666	1.335	1	.248	-2.075	.536
	[Monthly_Income=2]	.634	.666	.906	1	.341	-.671	1.939
	[Monthly_Income=3]	-1.204	.781	2.374	1	.123	-2.735	.328
	[Monthly_Income=4]	-2.402	.817	8.636	1	.003	-4.004	-.800
	[Monthly_Income=5]	0[a]	.	.	0	.	.	.

Link function: Logit.
a. This parameter is set to zero because it is redundant.
(Field Survey, 2024)

In order to assess the factors impacting families' willingness to pay for solar electricity, an ordinal regression analysis was performed for Objective 1. A significant Chi-Square value (54.614, $p < 0.001$) is displayed in the model fitting information, suggesting that the model fits well. According to the parameter estimates (C = 1 to C = 4), occupation and education have a considerable impact on willingness to pay. Significantly positive results (2.142 and 1.578, respectively) indicate that people who work in the private sector (Occupation = 2) and those who work for themselves (Occupation = 3) are more likely to be prepared to pay for solar electricity. Higher education levels also have a beneficial impact on willingness to pay (Education = 2). Another important factor is monthly income; as the negative estimates for income levels 4 and 5 show, greater-income groups are less ready to pay. This analysis shows that wealth, education, and occupation are important factors that influence the prospective demand for solar electricity. This finding is consistent with the research conducted by Ayodele *et al*. (2021), which found that respondents' WTP is significantly influenced by age, income, marital status, and educational attainment. Respondents' willingness to pay for renewable energy is influenced by their favorable attitude toward it and their level of awareness about it. In a similar vein, Entele (2020) discovered that the value of initial bid prices, age, location, income level, and educational attainment of the households all play a significant role when assessing the extent to which households are prepared to pay for the connection of electrical service. In a different study, Lay *et al*. (2013) investigated the variables influencing Kenyan households' fuel preferences, including solar home systems. The adoption of solar home systems is strongly influenced by household income and educational attainment, as this study demonstrated. Additionally, higher educational status, household age, marital status, access to credit facilities, household occupation, media access, and high household average monthly income were identified by Nnaji *et al*. (2023) as the major socioeconomic factors driving demand for solar energy. On the other hand, Zulu *et al*. (2022) in their study revealed that the willingness to embrace solar energy solutions is influenced by individual preferences, benefits, mindset, and trust. Mindset, trust and advantages also indirectly affect the decision to use solar energy solutions.

Objective 2: Enviro-economic efficiency of using solar electricity in terms of cost, externalities and benefits in Zongoro.

Table 7: Descriptive Statistics which shows the enviro-economic efficiency of using solar electricity in terms of cost, externalities and benefits in Zongoro

Statement	N	Mean	Std. Deviation
The households' is satisfied with the monthly cost to be incurred for the provision of solar energy	232	3.25	1.272
solar energy provision will significantly reduce negative externalities associated with other form of energy	232	4.43	.693
the enviro-economic benefits of use of solar s very enormous	232	4.19	1.088
Valid N (listwise)	232		

(Field Survey, 2024)

The statistical findings that evaluate the cost, externalities, and benefits of using solar electricity in Zongoro are shown in Table 7. With a mean score of 3.25 and a standard deviation of 1.272, the first item assesses how satisfied households are with the monthly cost of solar energy. This suggests that although many households find the price reasonable, some may have doubts. It also shows a reasonable degree of satisfaction among the respondents, with some variation in opinions. With a high mean of 4.43 and a comparatively low standard deviation of 0.693, the second item looks at how solar energy is regarded to reduce negative externalities related to other energy sources. This implies that there is broad agreement among respondents in the sample that solar energy will greatly reduce negative externalities. Finally, a high mean of 4.19 and a standard deviation of 1.088 are displayed by the third item, which evaluates the perceived environmental and financial advantages of using solar energy. Though there is a little more variation in views than with the externalities item, this shows that the majority of respondents are aware of the significant advantages of solar energy. All things considered, these figures indicate that although considerable consensus exists in Zongoro regarding the beneficial effects of solar energy on the environment and the economy, perspectives on how affordable solar energy is for homes are more varied. This result is in alignment with the work of Otapo *et al*., (2019) who found that solar PV power supply system is quite economical even as a standalone system.

Table 8: The frequency table showing the maximum projected utility derivable with respect to the cost incurred

	YES		NO		TOTAL	
Statement	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Does your household expect to derive maximum utility of 7,000 from the solar provision monthly; given the cost incurred are 10,000?	70	30.17%	5	2.16%	75	32.33%
Does your household expect to derive maximum utility of exactly 10,000 from the solar provision monthly; given the cost incurred is 10,000?	61	26.29%	6	2.59%	67	28.88%
Does your household expect to derive maximum utility of 20,000 from the solar provision monthly; given the cost incurred is 10,000?	49	21.12%	7	3.02%	56	24.14%
Does your household expect to derive maximum utility of 25,000 from the solar provision monthly, given the cost incurred is 10,000?	30	12.93%	4	1.72%	34	14.65%
TOTAL:	**210**	**90.51%**	**22**	**9.49%**	**232**	**100%**

(Field Survey, 2024)

A frequency study of Zongoro households' highest possible utility obtained in relation to the cost of solar energy provision is shown in Table 8. The table displays four distinct situations in which households were questioned regarding the utility they anticipated receiving from a $10,000 monthly solar energy investment. Seventy respondents (30.17%) endorse the first scenario, in which households predict a maximum utility of 7,000, whereas only five respondents (2.16%) disagree, for a total of seventy-five respondents (32.33%). A total of 67 respondents (28.88%) agreed with the second scenario, which expects exactly 10,000 in utility, whereas 6 respondents (2.59%) disagreed. Of the 56 respondents (24.14%), 49 (21.12%) agree with the scenario in which households anticipate to obtain 20,000 in utility, whereas 7 (3.02%) disagree. Furthermore, 30 respondents (12.93%) agree with the scenario wherein households expect 25,000 in utility, whereas 4 respondents (1.72%) disagree, for a total of 34 respondents (14.65%). In all, 22 respondents (9.49%) do not anticipate receiving the maximum amount of utility from the solar service, whereas 210 out of 232 respondents (90.51%) do. This suggests that a substantial proportion of households think that the utility they anticipate receiving from the solar energy provision justifies the $10,000 cost, with forecasts spanning 7,000 to 25,000.

Table 8 shows an indication where fewer respondents are willing to accept that level of utility when the predicted utility or benefit of solar energy provision rises in relation to the cost. First, 70 respondents (30.17%) agreed that households should expect a utility of N7,000 for a monthly expenditure of N10,000, suggesting a comparatively larger willingness to accept lesser utility. The percentage of responders who agree decreases to 61 (26.29%) as the predicted utility rises to precisely N10,000. Just 49 respondents (21.12%) are willing to accept when the projected utility increases to N20,000, and this number drops to 30 respondents (12.93%) when the expected value reaches N25,000. According to this pattern, a smaller population are willing to think that, given the same N10,000 cost, they will receive such significant amounts of utility from the solar energy provision as the expected benefit (utility) rises.

Cost benefit analysis

Four distinct scenarios are used to display the cost-benefit analysis (CBA) results, each of which shows a different degree of utility obtained from the solar electricity installation in Zongoro, Ganjuwa, Bauchi, Nigeria. The monthly payment per respondent, the number of respondents who are willing to pay, the months in a year, and the project's overall cost are the main characteristics used in this investigation. The perceived value or benefits that households anticipate from the solar electricity plant are reflected in the utility values. The ratio of the Present Value of Benefits (PVB) to the Present Value of Costs (PVC) is known as the Cost Benefit Ratio (CBR).

$$PVC = Monthly\ payment\ of Respondents * Number\ of\ Respondents\ willing\ to\ pay * Months\ in\ a\ year$$

$$PVB = Projected\ utility * Number\ of\ Respondents\ willing\ to\ pay * Months\ in\ a\ year$$

$$Cost\ Benefit\ Ratio\ \frac{Present\ Value\ of\ Benefits\ (PVB)}{Present\ Value\ of\ Costs\ (PVC)} \ldots\ldots (1)$$

Table 9: Maximum utility less than the monthly cost incurred

PARAMETERS	
Monthly Payment per Respondent	10000
Number of Respondents	70
Months in a year	12
Cost Incurred	8400000
Projected utility	7000
PVC	8400000
PVB	5880000
Cost Benefit Ratio (PVB/PVC):	0.7

M (Field Survey, 2024)

A CBR of 0.7 is obtained in this case since the anticipated utility is less than the monthly expense. This means that households only receive 0.7 Naira in benefits for every Naira spent. Given that the costs exceed the benefits, a CBR of less than 1 indicates that the project is not economically feasible under current circumstances.

Table 10: Maximum utility same as the monthly cost incurred

PARAMETERS	
Monthly Payment per Respondent	10000
Number of Respondents	61
Months in a year	12
Cost Incurred	7320000
Projected utility	10000
PVC	7320000
PVB	7320000
Cost Benefit Ratio (PVB/PVC):	1

(Field Survey, 2024)

In this scenario, it was seen that the CBR equals 1 since the projected utility equals the monthly cost incurred. This shows that the project has obtained a break-even point where the benefits exactly match the costs. This indicates the viability of the project although there is no surplus value to the households.

Table 11: Maximum utility twice the monthly cost incurred

PARAMETERS	
Monthly Payment per Respondent	10000
Number of Respondents	49
Months in a year	12
Cost Incurred	5880000
Projected utility	20000
PVC	5880000
PVB	11760000
Cost Benefit Ratio (PVB/PVC):	2

(Field Survey, 2024)

A CBR greater than 1 signifies that the project is economically viable and also offers a significant benefit to the households. In this case, the projected utility is twice the monthly cost incurred, resulting in a CBR of 2. This means that for every Naira spent, the households receive 2 Naira in benefits.

Table 12: Maximum utility more than twice the monthly cost incurred

PARAMETERS	
Monthly Payment per Respondent	10000
Number of Respondents	30
Months in a year	12
Cost Incurred	3600000
Projected utility	25000
PVC	3600000
PVB	9000000
Cost Benefit Ratio (PVB/PVC):	2.5

(Field Survey, 2024)

With a predicted utility of 25,000 Naira, the final scenario predicts that the homes receive more than twice the monthly expenditure in utility. According to the resulting CBR of 2.5, families profit by 2.5 Naira for every Naira spent. A project with substantial returns on investment (ROI) and great economic viability is indicated by this scenario.

According to the analysis, the utility that the homes in Zongoro, Ganjuwa, Bauchi, acquire is a major factor in the project's economic feasibility. Only when the perceived value of the project is at least as high as the expense can it be justified. Increased perceived utility leads to better cost-benefit ratios, which enhances the project's appeal and financial viability. For the solar electricity project to be successful and sustainable, it is imperative that it either meet or surpass the standards of the community.

Conclusion

The purpose of this study was to assess the environmental and financial benefits of solar power for homes in Bauchi State's Zongoro neighborhood. A sample of 248 houses, selected from an estimated 703 in Zongoro, participated in the study. Structured questionnaires were used to gather data, and multiple regression analysis, ordinal regression, and descriptive statistics were used for analysis. The findings provided some important novel details. The survey shows that households in Zongoro have a strong preference for solar electricity and have a positive opinion of its financial and environmental benefits. The capacity of solar energy to reduce adverse externalities from other energy sources is acknowledged as a significant advantage, although some reservations regarding the expense. According to these results, solar electricity is a practical and advantageous way to increase community energy access, with an opportunity to enhance economic and environmental situations.

It is advised that governmental and non-governmental groups provide financial incentives to lower upfront costs and increase the accessibility of solar energy in order to promote a larger adoption of solar electricity. Additionally, educational initiatives that emphasize long-term savings should be put in place to increase public understanding of its economic and environmental advantages. It is crucial to support neighborhood projects, such as collaborations with companies and interested parties to develop solar power solutions tailored to a community. In order to maximize the cost-effectiveness of solar energy solutions for comparable situations and investigate the long-term effects of solar adoption on communities, more research is also required.

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