Impact of Solar Photovoltaic as an Alternative Source of Power for Rural Electrification in Ghana.(A Case Study in Pungu – Navrongo Upper East Region)

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Abstract— The dynamics of solar photovoltaic (PV) technology's impact as an alternative source of power for rural electrification has taken centre stage in recent years. Solar PV is seen as a panacea to the energy problems of rural populations in developing countries, aiming partly to address prevailing rampant poor energy levels in households. This study seeks to evaluate the social impact, examine the economic benefits and identify challenges; financial, technical and maintenance of solar PV systems in rural electrification. The study purposively sampled 200 solar PV household heads (120 from JICA PV and 80 from Government PV), in Pungu-Navorongo in the Kassena – Nankana District in the Upper East Region of Ghana, which has one of the lowest levels of electricity access and highest poverty levels among the inhabitants. The study reveals the dynamics of rural electrification and energy needs as well as the livelihood assets such as social, economic and technical aspects. It was found that, the overall impact of solar PV on the quality of life of the local beneficiaries was positively marginal. Challenges were identified, including limited wattage capacity, malfunction of some basic components, high cost of installation and low technical know-how. The findings further indicated that satisfaction derived from solar PV electricity supply among local households was high, social as well as economic impact were enhanced and justifies concessions on fee-for-service and government subsidy for the rural poor. For a decisive enhancement of rural livelihoods, it is strongly recommended that the PV systems be scaled up to include different energy dynamics such as cooking, irrigation, heating and to explore the extent to which technical know-how can affect utilization and sustainability of solar PV systems in rural electrification.

Index Terms— Challenges, Ghana, impact, Rural Electrification, Solar Photovaltic

1 Introduction

Electricity is considered as the most critical carrier for development. However, the rate of rural electrification compared to urban electrification in many developing countries is low and a major cause of developmental disparity between rural and urban communities. As the global economy is increasingly, carbon-constrained and fossil fuel prices rising sharply after the economic global crisis, there is the need for a more non-depleting green source of energy such as renewable energy [1].

Renewable energy is the energy produced by natural resources such as sunlight, wind, rain, waves, tides and geothermal heat that are naturally replenished within a time span of few years [1]. It is naturally abundant, accessible in large quantities, progressively low cost, non-vulnerable to supply or price fluctuations and compatible with the global consensus to increase energy sources with low-carbon emissions [2].

Solar Photovoltaic (PV) energy is seen as the option to provide low-carbon, renewable source that is expected to become a competitive source of bulk power in peak and intermediate loads by 2020 [3]. By virtue of Ghana's geographical location in the tropics, solar radiation is available almost throughout the year across the ten regions. The country receives 4.0 – 6.5 kwh/m2 day of solar radiation and sunshine duration of about 1800 – 3000 h per year [4].

Charcoal and firewood contribute about 63% of the total primary energy supplied to consumers compared to 27% of petroleum products and 9% electricity. The national data also revealed that, from 2000 to 2005, the residential sector consumed the largest share of the energy supply due to high reliance on wood fuel for domestic needs. In addition, the consumption of wood fuel increased by 58% between 2004 and 2008, whilst charcoal also increased by about 50% [4]. Over the years, solar PV systems have attracted attention and excitement, particularly in the current energy crisis. Public solar PV electrification is making great contribution to electricity access and demand. For instance, the Volta River Authority (VRA) solar project in Navrongo in the Upper East Region is producing two megawatts (2MW) of electrical energy at a cost of eight million dollars ($8m), [4]. The off grid solar PV electrification projects has been financed by the Spanish Government, and Japanese International Cooperation Agency (JICA). These solar home systems account for about 4,500 installations across the country mainly in the Northern sector. The enormous socio-economic benefit of solar PV systems includes, solar home systems, water pumping, use of radio receivers, rural telephony, street lighting, rural clinic lighting, micro-enterprise and vaccine refrigeration [5].

Pungu rural community in the Upper East Region near Navrongo is selected because it meets the criteria and was part of the catchment areas the VRA identified as a potential site for solar PV electrification. Solar photovoltaic technology is one of the promising renewable energy technologies due to its high reliability and safety.

The aim of this research is to investigate the impact of solar photovoltaic systems as an alternative source of power for rural electrification in domestic use. It is to study the social, economic and technical elements of solar PV on the livelihood of households. It is envisaged that the study would reveal these elements and serve as a guide to be considered in rural electrification energy advocacy and planning.

2. Literature Review

2.1 Overview of Rural Electrification in Ghana

Rural electrification is the process whereby access to electricity is provided to households or villages located in isolated geographical or remote areas of a country [5]. They are at vast distances from the national and regional grids with harsh climatic and environmental conditions that render electrification a perilous task. Currently in Ghana, most rural communities do not have access to electricity, running water, or telephone lines. According to the World Bank, about half of the population of Ghana currently has access to electricity [15]. However, there is a significant disparity in access to electricity between rural and urban areas. Currently, 80 percent of the population living in urban areas is electrified while only 20 percent of the rural population have access to electricity [6]. Ghana's level of electrification is greater than the average electrification rate of Sub-Saharan Africa which is around 25 percent [6]. Expansion of electricity access in Ghana is largely as a result of intensification under National Electrification Scheme (NES) of 1989 when electrification was at a level of approximately 20 percent. This scheme was aimed at rural and urban areas with the hope of connecting all communities with a population of over 500 to the national grid by 2020 [7]. This is being implemented by the two state owned electrical companies: the Electricity Company of Ghana (ECG) and Volta River Authority. Despite the promises of electrification, governments have failed to achieve the NES policy [17]. Again, [7] reiterated that, the NES is to be achieved between a period of 30 years (1990-2020) and under the scheme; grid electricity is to be extended to all districts, towns and villages with more than 500 people by 2020. A complementary undertaking of the NES was the Self-Help Electrification Project (SHEP) where communities within 20km radius of existing 33KV or 11KV sub-transmission line can advance their electrification projects, provided they can secure all low voltage (LV) poles and a minimum of 30% houses wired within the communities [18]. [19] alerted that the government believed that rural electrification in Ghana can significantly improve with adequate, efficient and reliable access to modern energy infrastructure. Most households use electricity services for cooking, ironing, heating, lighting, but those who do not have, meet their power demand with other options such as wood, charcoal, kerosene, diesel, dry cell and anything at hand.

2.2 Solar Energy Potentials in Ghana

The average duration of sunshine varies from a minimum of 5.3 hours per day in the cloudy forest region to about 7.7 hours per day from the dry savannah region and the average peak sun hours in Ghana varies from 5.0 to 5.7 peak hours with Kumasi having the average peak sun of 4.5 [8]. According to [9], the electricity consumption is mainly into household or residential, commercial, industrial and the agricultural sectors at rural electrification rate of 52% as compared to urban of 90%. Ghana aims at achieving 30% rural electrification through decentralized renewable energy for the residential sector by the year 2020 [9].

Across the country, sixteen rural communities located in six regions: Northern, Upper East, Upper West, Volta, Brong-Ahafo and greater Accra have been provided with Solar PV facilities [10]. These communities were identified with relatively high poverty levels. The beneficiaries of these solar home systems were not to pay any bill except to replace their own bulbs and other Balance- of- Components (BOCs), minor maintenance work [11].

Additionally, other communities with similar conditions which are not connected to the national grid, off grid electrification using solar home systems are been explored as an alternative technology [5]. The Ministry of Energy and Petroleum (MOEP) projected an augmentation of the contribution of RETs to the national energy generation mix from less than 1% currently to 10% in 2020 [5]. To help realize this ambitious energy target, demonstrable efforts have been made through the implementation of some notable solar projects such as the Renewable Energy Services Project (RESPRO) in 1998 and the Renewable Energy Development Project (REDP) in 2000 as well as the Ghana Energy Development and Access Program (GEDAP) in 2007. As at 2011, a total of about 106 Community-based Health Planning and Services (CHPS) compounds were provided with about 316 Solar Home Systems (SHSs), Solar Street Light (SSLs) and five thousand (5000) solar lanterns are to be distributed to augment the lighting needs of these impoverished rural communities identified in the selection across the length and breadth of the country in the first phase of implementation [12], [13].

The rationale for targeting rural clinics in the first phase of GEDAP was probably motivated by the critical role these health centers play in saving many lives in less privileged rural communities where maternal and infant mortality rates are likely to be high. Again according to [14], the second phase of GEDAP focused on its individual ownership policy and was piloted in districts of Sissala West, Sissala East and Lawra / Nandom. The rationale was partly to make SHSs more affordable and accessible to interested low income rural householders to improve their livelihood. A study by [16], looked at the specific role of energy in achieving Millennium Development Goal 1 (universal access to energy) in Yoyo. According to [2], rural electrification plays a critical role on the family planning practice in two communities; Kpassa and Tengzuk in Nkwanta and Talensi districts in Volta and Upper East regions respectively because of similarity in population, terrain and climate. The quantitative impact of solar PV on hours of usage in radio and television in particularly off grid communities [16] appears generally to agree that immediate benefit of solar PV comes through improved lighting for powering electronics devices such as radio and television which significantly contribute to increase access to information and entertainment at household levels as reported by [30]. In 1991 there were about 335 solar PV systems installations in Ghana with a total estimated power of about 160KW [16]. The 1990 and 2003 years are postulated to represent significant turning points of solar PV projects in the country. Commitments from government to enforce the NES in the 1990s saw a sharp increase in PV systems from 700KW in 1993 to 2,530KW in 1998 and by 2003 about 4,911PVsystems were installed with total power of 1.0 peak megawatt [2].

Solar energy has been utilized in so many different ways in Ghana over the past twenty years. Solar energy systems mostly installed by Non-governmental Organizations and public institutions number over 5000 across the country. The installed capacity of almost one megawatt can generate between 1-2 gigawatt-hours per annum [2].

2.3 Solar PV Electrification and Quality of Life

Solar PV electrification can improve the quality of life of rural households through positive impacts that cannot easily be expressed in monetary terms [13]. Quality of life is simply life goals expected to be fulfilled: better education, health, access to information, indoor lighting, among others. Significant impacts of solar PV systems include better quality of light, car battery charging, and a reduction in indoor smoke and fire hazards from kerosene lanterns [20].

Furthermore, solar PV electrification contributes to improve quality of life in off-grid rural communities through direct effect of the technology on household wellbeing and enterprise income [20] [21] [22]. It should be stressed that the gradual replacement of fossil energy electrification with renewable will not provide all the energy needs for quality of life improvements. However, there are many applications that can improve the quality of life of rural households. These include among others the replacement of kerosene lanterns and candles with solar PV lighting [23].

On the expenditure side, rural households in developing countries typically spend between $3 and $20 per month on kerosene, candles, or other energy products [23]. With the use of kerosene and dry-cells, it is observed that monthly expenses can be as costly as US$ 10 per family [30]. In [24] it is reported that in Sri- Lanka and Indonesia, recurrent costs on kerosene, candles and batteries could reach $10-$30 per month. These are relatively high expenditures. Though the use of solar PV may reduce the recurrent costs associated with the use of kerosene, candles, and batteries, the amount of the reduction is uncertain and therefore deserves researchers' attention.

The multi-sectorial linkages of solar PV influence on quality of life in off-grid rural communities indicate that some social and economic benefits may be accruing to rural beneficiaries [21]. Though solar PV rural electrification has linkages with several sectors that focus on specific niches, particularly goals relating to education, health, information, agriculture and micro- enterprise which are known as the Energy quality of life framework [22]. These according [24] is a concept of how solar PV influences poverty reduction and can contribute to quality of life improvement within selected niches.

2.4 Solar PV Electrification as a means of promoting education

Most people believe that education offers an escape from poverty and therefore any effort that goes to promote education, especially in poor rural communities is a welcome contribution. In the discourse on well-being, a key concept that is of significant interest to the review is access to education. How does access to solar PV electricity relate to education? It is reported that solar electricity lighting in remote rural schools permits children to extend their studies in the evening and helps retain teachers, especially if their accommodation has electricity [25] [26]. For many children, especially girls in rural areas the lack of electricity translates into a missed opportunity to attend school because they are overloaded with menial tasks such as fetching water and fuel during daylight hours [25].

A survey according to [27] to explore user perception about the positive linkage between rural electrification and education in Tunisia revealed that women and children especially benefited from improved access to education as a result of rural electrification [28]. Although the study was not specifically on solar PV electrification, the findings may also apply to the linkage between solar PV electrification and children's extended study, particularly after sunset when lighting services are most needed. Drawing on this the following investigative question is posed: How does access to solar PV lighting in rural Ghana improve children's education? Does access to solar PV light enhance the academic performance of rural school children?

Furthermore, solar PV lighting enables access to educational media, communications in schools and at home. This increases educational opportunities and allows distance learning [26]. If rural electrification policies, programmes and plans integrate with Solar PV as an alternative service for the supply of electricity services to dispersed rural populations and remote rural communities, children would have access to lighting in the evening to extend their studies. This would go a long way to contribute to the international goal of ensuring that children everywhere will be able to complete a full course of primary schooling by 2015 - MDG Goal 2, Target 3 [15].

2.5 Solar PV Electrification and Health

Public health is a critical sector where the contribution of Solar PV is much felt especially in off- grid communities. As noted earlier, the replacement of kerosene lanterns with solar PV could reduce indoor air pollution, which affects the health and wellbeing of rural families. In this regard, a number of studies focused on environmental health considerations, which refer to the health risks associated with environmental factors into two broad categories namely, traditional and modern hazards [31]. The study further examined the association between traditional forms of lighting and environmental health risks. Traditional hazards are related to poverty and lack of development.

"The World Bank has classed indoor air pollution in developing countries among the four most critical global environmental problems" [28]. Indoor air smoke contributes to respiratory infections that account for up to 20 percent of the 11 million deaths in children each year [26]. This trend if not stopped will have direct effects on future family lives of the poor since children are the future source and wealth of poor families [32]. In the light of this, it is important to re-emphasize the need for pragmatic policies on environmentally-friendly technologies like solar PV. When used as a substitute for a kerosene lantern solar PV can reduce the potential threat of indoor air smoke and visibility [23].

Nevertheless, there is lack of quantitative data on the likely proportion of reduction of indoor air smoke from kerosene lantern by using solar PV light. Solar PV powered refrigerators also play a very significant role in remote rural clinics, where medicines have to be stored for vaccination and the treatment of diseases at the village level. A healthy life is a key indicator in the capability approach to poverty [31]. Women in labour need clean light to have safe child delivery at any time. In a rural clinic where there is no electricity, women deliver under very uncomfortable conditions due to the lack of essential equipment, medical facilities and poor visibility after sunset [33]. Lastly, solar lighting in remote locations helps maintain qualified health staff, which would otherwise opt to work in grid-connected towns and cities. Most people believe that education offers an escape from poverty and therefore any effort that goes to promote education, especially in poor rural communities is a welcome contribution. [26]. In the discourse on well-being, a key concept that is of significant interest to the review is access to education. How does access to solar PV electricity relate to education? It is reported that solar electricity lighting in remote rural schools permits children to extend their studies in the evening and helps retain teachers, especially if their accommodation has electricity [25] [26].

3. Methodology

In this study, a cross-sectional descriptive survey was used as the research design. This is in line with [34] who says findings from a survey can be generalized to be that of the entire population.

3.1 Population and Sampling

The population for the study was mostly household heads of Pungu-Navorongo whose households were connected to PV systems. Heads were particularly targeted because they were considered the spokespersons in their families. Convenience sampling technique was used to select a total of two hundred (200) PV household heads (comprising of 120 JICA PV and 80 Government PV) for the survey. Purposive sampling technique was used to select the company who deals in the sale and import of solar PV equipment for a face-to-face interview because of their indebt knowledge in solar PV equipment. The survey was used to find out their impression or perception about PV systems.

3.2. Data Collection Instruments and Administration

The instruments involved in this survey were Questionnaires and Interview. The Questionnaires were used to solicit information from the household heads. They (the questionnaires) comprised of two parts; the first section consisted of demographics of household heads while the second part handles the usage and impact of PV systems where test items were measured on a five point Likert- scale (1=strongly disagree, 5=strongly agree) and sought to find out from households about the level of agreement or disagreement on the social, economic and technical challenges (e.g., environmental pollution, health enhancement, entertainment, household chores, affordability, safety and operation) of solar PV systems. In collecting the data, official permission was sought by the researcher which was granted by the respondents prior to the administering of the questionnaires. With the assistance of local interpreters questions asked in English were translated into the local Kassen dialect for those who were illiterate households. In total, two hundred (200) questionnaires were distributed and all were retrieved successfully.

3.3 Validity and Reliability

The reliability and validity of the instrument was ensured through the finding of preliminary study carried out. The questionnaires were first of all pre- tested. In all ten (10) respondents (5 males and 5 females) from the northern sector were selected among peers at the University of Education Winneba, Kumasi to check the clarity of the question items for the study. The responses were found to be successful with regards to the time given. Comments and suggestions were received and difficulty levels corrected, adjusted and subsequently fine-tuned as some of the statements were too restrictive.

3.4 Data Analysis

The questionnaire data were entered and analyzed using simple statistical package techniques (SPSS). The in-depth content of the analysis is to gain insight into the contribution of off-grid Solar House Systems (SHS) to the local inhabitants' livelihoods. Mean values were used by scoring the instruments, grouping the responses and converting them into percentage scores. The opinions that had the highest responses were considered the general view of the respondents. Comments, views and suggestions were compiled upon compiled upon careful scrutiny through tabulation. Besides, various charts were also used in analyzing the data for further clarifications.

3.5 Profile of the Study Area

Pungu is a rural community located about 10km away from Navorongo in the Kassena-Nankana District in the Upper East Region of Ghana. The community has about 110 households unit and a total population of about 750 inhabitants [4]. The dominant dialect is the Kassen. Most of the people are subsistence farmers, livestock farmers, smock weavers and few petty traders. It has a CHPS compound, a basic school and boreholes. This community has been selected because they have benefited from Japan International Cooperation Agency (JICA) Solar House Systems (SHSs) pilot projects. Again, the V.R.A made a feasibility study as a potential site for solar PV system electrification for which the authority has currently built eight million dollar ($8) solar pack generating 2MW of electricity connected to the national grid system. Also, it meets the criteria of a minimum of 100 households units within 500m radius for sustainable community-level isolated grid system [9].

4. Results and Discussion

4.1 Demographic data of Respondents

The demographic characteristics of the respondents in this study was ascertained and it covered the gender (sex), age, educational level, occupation, household size, average monthly income, mode of payment of PV system and electrical appliances of the household heads. In terms of gender composition, more men (79.2%) than women (20.8%) in JICA households were surveyed. More than half (62.5%) men as against (37%) women were surveyed in Government PV connected households. In total, majority (72.5%) men as against (27.5%) women were surveyed in the study. The responses was skewed towards males because in Ghanaian traditional setting, males are the heads of their family, and the main decision makers and so women must seek permission from their husbands before speaking to the interviewer.

In the case of age, majority (54%) household heads were in the 36-45 year group for JICA households whereas 42.5 % were above 46 year group in Government PV households. The modal average age (43%) was 36-44 years while 11% represented the least average age of below 20 years. The distinction patterns may be due to age-wealth and age technology issues. In rural Ghana, the imbalance in resources between the youth and older people ultimately determine the choices of their needs [2]. Moreover, younger people tend to be more adventurous and greater affinity with new technology, compared to the more cautious nature of the elderly.

Educational attainment was a key factor which influences the understanding of the adoption patterns of solar PV in rural Ghana. Majority (90%) had attained education from basic to tertiary level whereas (10%) had no formal education. Among the educational levels, more than half (54%) had attained senior high (Appendix 2). It can be argued that, the non-formal education could be due to the lack of enthusiasm for education in the past and with the main economic activities being farming, education could reduce the family labour. Appendix 2 further reports the monthly average income of households. Majority (28%) earns below $25, followed by $25-75 (27.5%). One- third (26.5%) earns between $75-125 whereas 18% earns above $125.

4.2 Occupation of Respondents

Fig 1 reveals the differences in occupation between the two groups (JICA and Government PV) households. The dominant occupations in the households were farming (41.7%) and civil service (53.7%) for JICA and Government PV households' respectively. Artisans constituted 17.5% in JICA households as against 25% in Government PV households. There are slightly more traders (1.2%) in Government PV households than JICA PV households. Again, other forms of occupations such as weaving, charcoal burning and livestock rearing had the least share of 3.3% for JICA households and 3.8% for Government PV households. It can be analyzed that most of the respondents who earn regular income opted for the Government PV system rather than the JICA PV system, probably because of the mode of payment, wattage capacity of PV type and income generation levels.

4.3 Usage and Impact of Solar Photovotaic Systems

An interview with key informants of PV households, plus observation revealed different ways in which solar PV has been used and its impact to rural households. This second part of the questionnaire was to obtain their impressions and feelings. The associated results from the usage and impact are discussed in this section. This is approached through the activities of the rural society including households, social and communal services.

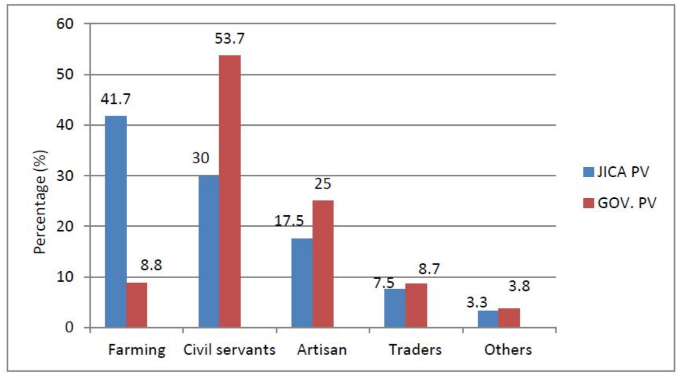

Figure 1 Occupations of Respondents

Household heads were requested to indicate the types of electrical appliances they used in their homes. They were at liberty to select multiple answers in the categories (Figure 2). TV and radio both had a share of 100% each as the dominant electrical appliances in the households, followed by others (64%) and fan (57%). Refrigerator (44.5%) is the least electrical appliance used in the households.

Households were to respond to how they were introduced to solar PV technology. Options given included friends, public demonstration, market survey and radio. Friends (37%) were the most important factor that influenced how PV technology was introduced, followed by market survey (22%) and radio (19%). Others sources of how PV was introduced had a share of (15%) while public demonstration (7%) were of less importance to householders. This is an indication that government and other stakeholders have not intensified the campaign on PV technology enough [18].

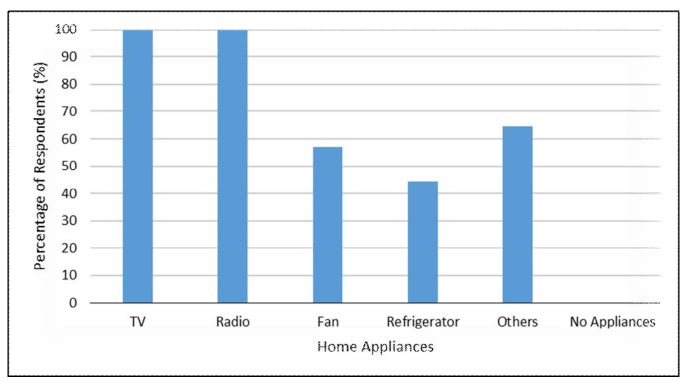

Figure 2 Electrical Appliances used by Respondents in their homes

Households were also requested to indicate the difficulties they encountered in maintaining their PV systems (Table 1). Household heads significantly agreed or strongly agreed (60.5%) that, high initial cost is a difficulty in maintaining PV systems. More than half (54.5%) agreed with the statement "low technical know-how" affect their PV maintenance. Fifty percent agreed or strongly agreed that, unavailable BOCs such as batteries, inventers and bulbs contribute to difficulties in PV system maintenance while 46% disagreed or strongly disagreed that grid extension is a difficulty in PV maintenance. One respondent also reported why he thought grid extension was his greatest challenge and stated that “politicians have promised us the extension of the grid system very soon”.

Table 1 Difficulties encountered in maintaining PV systems

Category	5 %	4 %	3 %	2 %	1 %	Mean	SD
High initial cost	22	39	12	23	5	3.25	1.3
Low technical know-how	14	41	10	25	14	3.49	0.5
Grid Extension	8	28	18	39	7	2.38	0.7
Unavailable BOCs	16	35	14	27	9	3.04	1.1

Key: Strongly Agree=5; Agree=4; Neutral=3; Disagree=2; Strongly Disagree=1

4.4 Data Gathered and Measurement Scores

In order to identify households’ perception on solar PV, five point Likert’s scale, as a measuring tool was used in the survey to provide quantitative indication of qualitative judgments. The response categories ranged from “strongly disagree (1) to strongly agree (5)”. Their mean is determined in Tables 3, 5, 7 and 8.

Table 2 reports household heads responses to the current state of PV systems in Pungu. The mean responses of seven out of eight characters were above the threshold value of 3.0, indicating that household heads generally perceive the current state of PV in Pungu to be beneficial. The statement “my household is connected to PV system” had the highest acceptance (M = 4.25) followed by “solar PV electricity services management is efficient and effective in my locality” (M = 3.43). Seventy-three percent agreed or strongly agreed that stakeholder participation in PV technology is high while 68% agreed that solar PV is safe to use and operate. More than half (60%) were in agreement that, there is adequate public information on solar PV technology. The satisfaction of solar PV as alternative quality power was endorsed by 59% of the households.

Appendix 1 shows Spearman’s correlation matrix of the current state of PV system among the independent variables. The correlation coefficient values ranged from 0.001 to 0.673. Age associated positively with few of the statements. Younger households are more likely than older counterparts to perceive solar PV to be safe to use and operate ($r = 0.213$, $P < 0.01$) as well as their average electricity consumption ($r = 0.362$, $P < 0.01$). Education associated positively with few of the statements, an indication that higher education households are in agreement that PV systems in their households is compatible with future grid services ($r = 0.264$, $P < 0.01$) as well as PV is safe to use and operate ($r = 0.226$, $P < 0.01$) and high stakeholder participation ($r = 0.204$, $P < 0.01$).

Table 2 Frequencies and Mean Scores for current state of PV systems in Pungu

Statements	5 %	4 %	3 %	2 %	1 %	M	SD
1. My house household is connected to solar PV systems	39	61	0	0	0	4.25	1.11
2. There is adequate public information on solar PV technology system	39	21	14	20	6	3.17	1.25
3. My solar PV electricity system is well maintained	11	9	28	31	21	3.03	1.24
4. My solar PV power is safe to use and operate	43	25	5	14	13	3.22	1.27
5. The PV system in my household is	45	28	10	10	7	3.43	1.31
6. Solar PV electricity services manage-	39	27	16	13	5	3.31	1.38
7. I am satisfied with the power quality provided by my solar PV systems	35	24	6	15	20	3.1	1.23
8. There is high degree of stakeholder participation in PV technology in my locality	43	30	8	11	8	3.23	1.25

Average electricity consumption correlated positively with very few of the statements, an indication that household heads who have lived longer in the locality are more likely than new counterparts to be conscious of their average electricity consumption ($r = 0.548$, $P < 0.01$) and perceive adequate information on PV ($r = 0.382$, $P < 0.01$). Average monthly income had no significant correlation with the statements. Households perceived that the number of years one lived in the locality improved their PV system maintenance ($r = 0.196$, $P < 0.01$), compatible with grid services ($r = 0.142$, $P < 0.05$) and are satisfied with the power quality provided by PV systems ($r = 0.145$, $P < 0.05$).

Again, it can be seen from Table 16 that households who expressed concerns about adequate public information on solar PV technology correlated more positively with most the statements and believed that solar PV electricity is well maintained ($r = 0.450$, $P < 0.01$), solar PV is save to use and operate ($r = 0.351$, $P < 0.01$) and compatible with future grid services ($r = 0.418$, $P < 0.01$). They also express their satisfaction in high stakeholder participation in PV systems ($r=0.383$, $P < 0.01$) but disagreed solar electricity services management is efficient and effective ($r = 0.204$, $P < 0.05$). Most of the statements correlated positively to adequate public information on PV tech-

nology and PV services management and effectiveness, suggesting these two statements present the stronger side in the current state of PV technology in Pungu.
Household heads were requested to indicate their responses on the social impact of solar PV systems in rural electrification (Table 3).

Table 3 Frequencies and mean scores for social impact of PV systems in rural electrification

Statement	5 %	4 %	3 %	2 %	1 %	M	SD
1. PV has reduced environmental pollution	40	27	14	15	4	3.37	1.42
2. PV has improved access to information	24	45	7	13	11	3.10	1.23
3. PV system has enhanced entertainment	30	39	3	19	9	3.22	1.47
4. PV system has improved educational delivery	29	27	11	13	20	2.94	1.38
5. PV system has enhanced security	21	33	25	6	15	3.03	1.24
6. PV system has improved health delivery	52	25	2	12	9	3.67	1.28
7. Privacy has improved through PV system	32	25	23	8	12	3.17	1.25
8. Local capacity for women empowerment has improved	38	30	9	11	12	3.33	1.39
9. Solar PV systems has replaced dirty energy source for lighting	85	11	4	0	0	4.16	1.14
10. Availability of PV systems has improved community social activities	50	22	13	12	3	3.93	2.95
11. I feel proud of having PV system in my household	44	31	5	10	10	3.67	1.28

Households indicated significantly concerns about social impact of solar PV, majority (96%) “Agreed” or “strongly agreed” that solar PV has replaced ‘dirty’ energy source for lighting. Seventy-two percent agreed or strongly agreed that, PV system has improved community social services. The statement “PV system has improved health delivery” had an acceptance of (M = 3.67) while 75% feel proud of having PV system in their households. More than half (67%) agreed that PV system has reduced environmental pollution.

Improvement in local capacity for women empowerment was endorsed by 68% of the household heads. Again, households perceived PV has enhanced entertainment (M = 3.22), followed by privacy (M = 3.17) and information access (M = 3.10).

Appendix 2 shows Spearman’s correlation matrix among the independent variables on the social impacts of solar PV system in rural electrification. The correlation coefficient values ranged from 0.000 to 0.598. Age had no significant relationship with most of the statements but correlated negatively to average electricity consumption. Older households are more likely than younger counterparts to be more conscious on their average electricity consumption (r = -0.362, P < 0.01) and feel proud of having PV system in their households (r = -0.181, P < 0.05). Education associated positively with very few of the statements, an indication that higher education households are in agreement that PV systems have improved educational delivery (r = 0.197, P < 0.01) and health delivery (r = 0.144, P < 0.05). Average electricity consumption correlated positively with few of the statements. Household heads who tends to be more conscious about their average electricity consumption perceived local capacity for women empowerment have improved (r = 0.218, P < 0.001) when one stays in the area for longer periods (r = 0.548, P < 0.01). They also perceived that conscious electricity consumption has improved security (r = 0.180, P < 0.05) and replaced ‘dirty’ energy for lighting (r =-0.177, P < 0.05). How long households have lived in the area had no significant correlation with most of the statements but however correlated positively to perceive improvement in privacy (r = 0.256, P < 0.01) and replaced ‘dirty’ energy source for lighting (r = 0.232, P < 0.01). Average monthly income had no significant correlation with the statements.

Households who expressed concerns about environmental pollution reduction in PV systems correlated positively to improved access to information (r = 0.377, P < 0.01), enhanced entertainment (r = 0.276, P < 0.01) and education (r = 1.89, P < 0.01). They also believed that reduced environmental pollution can enhance security (r = 0.483, P < 0.01), health (r = 0.275, P < 0.01) and community social activities (r = 0.224, P < 0.01). Most of the statements correlated positively to improved community social activities, health and education, suggesting the real social impact of solar PV systems in rural electrification.

Table 4 reports households’ responses to economic benefits of solar PV in rural electrification. The mean (M) responses of nine out of the ten statements were above the threshold value of 3.0, suggesting that households generally perceive solar PV in rural electrification to be economically beneficial. The statement “PV has reduced time to perform household chores” had the highest acceptance (M = 4.30), followed by “PV has drastically reduced electricity bills” (M = 4.04) and “reduced poverty level” (M = 3.55). Sixty-eight percent agreed or strongly agreed that PV system have reduced household expenditure while 69% agreed they feel motivated to conserve energy through PV systems. More than half (60%) agreed that they have plans of upgrade their PV systems in the future. Improvement in income generating activities and reduction in unemployment by PV systems was endorsed by 57% and 59% households respectively.

Table 5 shows households responses to challenges of PV systems in rural electrification. The mean (M) responses of the ten statements were above the threshold value of 3.0, suggesting that households generally perceive solar PV in rural electrification to be challenging.

Table 4 Frequencies and mean scores for economic benefits of solar PV in rural electrification

Statement	5 %	4 %	3 %	2 %	1 %	M	SD
1. Improved income generating activities.	29	28	23	21	9	3.22	1.47
2. Has reduced unemployment in the area.	25	34	15	12	14	3.29	1.17
3. Reduced household expenditure.	38	30	5	16	11	3.38	1.49
4. Has reduced time to perform household chores.	45	52	3	0	0	4.30	0.96
5. Has drastically reduced electricity bills.	40	33	7	9	11	5.57	1.33
6. Poverty levels have reduced through household income.	38	30	9	13	10	3.55	1.31
7. PV systems service is affordable for users.	29	11	15	16	29	2.98	1.32
8. I feel motivated to conserve energy through PV systems.	32	36	10	4	18	3.33	1.39
9. I have plans to upgrade my PV system in the future	36	24	11	14	15	3.28	1.46
10. PV system have affected my electricity consumption rate	24	12	22	19	23	3.23	1.27

Key: Strongly agree=5; Agree=4; Neutral=3; Disagree=2; Strongly disagree=1

on social, economic and technical challenges.

Table 5 Frequencies and Mean Scores for challenges of PV systems in rural electrification

Statement	5 %	4 %	3 %	2 %	1 %	M	SD
1. Lack of resources to expand the facility	53	40	6	1	0	3.68	1.25
2. Low generation capacity	66	33	1	0	0	3.72	1.36
3. Low technical expertise	53	36	8	2	1	3.45	1.26
4. High cost of installation	80	18	2	0	0	4.04	1.19
5. Power fluctuations are regular	34	24	26	8	8	3.23	1.27
6. Risk or hazard of electrical shock is minimal	61	16	11	7	5	3.37	1.38
7. Irregular supply of spare parts	46	46	6	2	0	3.29	1.05
8. Frequent purchase of florescent bulbs due to outdated equipment	44	36	13	4	3	3.34	1.29
9. Frequent malfunctioning of batteries PV services	5	8	10	34	43	3.18	1.36
10. Advanced notice about planned service disruption is given to users	35	24	6	15	20	3.21	1.27

4.5 Discussions of Results

The purpose of this study was to investigate the livelihood impact of solar PV as an alternative source of energy in rural electrification. The relatively high energy situation in rural communities in Northern Ghana has the potential to further impoverish the lives of peoples in such generally resourced-poor areas if concerted energy efforts are not continuously taken by key stakeholders to address it. The deployment of isolated solar PV systems via JICA and the Government in such areas has led to the provision of essential energy services for these underprivileged rural dwellers despite limited systems capacity.

The results from the present study show that lighting was the major energy services provided by SHSs, followed by conversation telephony and entertainment. Heating was very few while cooking was non-existent. According to [14], within the sustainable livelihood framework, five main livelihood capital forms i.e. human, social, natural, economic and physical must be emphasized. The livelihood improvement opportunities can potentially be stimulated among rural dwellers with accessibility to timely decentralized renewable energy-based electricity programmes [2]. The current study emphasized

The social impact as noted by [14] pursues networks, relationships and security systems in different, coordinated and collective livelihood strategies. The study shows that, improved social resources of local people are positively utilized in the quality of life of children, women and adults in society. For instance, improved health delivery according to [5] and [31] has saved 1.5 million people especially women and children from debilitating respiratory infections through “dirty” energy sources such as kerosene lamps. In line with literature, solar PV electrification in remote areas permits children to extend their studies in the night and help retain teachers [25] [26]. Improvement in community social activities such as community gathering meetings at night without security concerns is assured. The presence of SHSs at private homes provides source of information and entertainment to householders.

The economic benefit of rural residents denotes the economic potentials including finance, infrastructure, equipment and technologies in pursuit of livelihood strategies. Despite the decline in solar cell production cost over the years [24] SHSs is still relatively expensive for many low-income earners. The relatively high interest rate

(28%) on loans from banks for low-income earners has the potential of creating inconveniences for end users. It is however envisaged that after the two-year payback period for the loan, there may be more financial benefits resulting from no payment of monthly bills, free phone charging and safely performing household chores at night. The findings further indicates that poverty levels have improved through households' income because of Government of Ghana's fee-for-service mode of payment approach to encourage the use of PV in rural off-grid areas to extend working hours of weavers at night (Institute of Economic Affairs, 2013). However, rapid grid extension of cheaper electricity as a subtle competitor to solar PV is a concern as in line with [24]. Technical challenges are major drawback in the solar PV technology in many of the rural communities in Northing Ghana. They are confronted with lack of resources to expand the current facility which result in low generation capacity for other higher consuming energy services. High cost of installation was a major concern to beneficiary householders'. Despite local peoples' endowment in rich natural resources, these resources are fast depleting due to unsustainable agricultural and wood fuel (biomass) production activities, usually with "low-tech" implement. Solar PV technology as a clean, CO2-free, non-pollutant and renewable source of electricity has positive environmental footprint. It is estimated that 50% of global CO2 emissions from power generation could be cut by adopting a decentralized energy pathway [14]. While environmental services are useful for livelihood improvement strategies, it is a concern that SHSs can be a good candidate for CO2 emission mitigation in Clean Development Mechanism (CDM) projects in developing countries.

8. Conclusion

This research reveals that, the physical resources base for solar PV in rural Ghana is effectively unlimited and possessing this alone is not a panacea for successful solar PV dissemination to rural areas.

The inadequacy of generated energy services, unavailable BOCs, low technical know-how and high cost of installation (for private solar users) makes PV „second class' energy option in the Ghanaian context due to a more competitive, cheaper conventional grid connected electrification system. The adoption or non-adoption of solar PV in rural Ghana is contingent on multiple circumstances such as technical, social, economic and governmental factors.

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APPENDIX 1

Correlation matrix of current state of PV system and respondent characteristics

statement	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	1												
2. Level of education	.0.14	1											
3. Average electricity consumption	.362**	0.001	1										
4. How long have you live in the area	0.02	0.07	.548**	1									
5. Average monthly income	-.0.66	-0.023	0.007	0.103	1								
6. My household is connected to solar PV technology system	-0.034	0.099	0.072	0.126	0.049	1							
7. There is adequate public information on solar PV technology system	.285**	0.123	.382**	0.085	0.073	.470**	1						
8. My solar PV electricity is well maintained	-0.021	0.119	0.124	.196**	0.006	.450**	.549**	1					
9. My solar PV is safe to use and operate	.213**	.226**	0.136	0.115	0.06	.471**	.351**	.492**	1				
10. The PV system in my household is compatible with future grid service	.145**	.264**	0.1	.142*	0.78	.418**	.409**	.609**	.673**	1			
11. Solar PV electricity services management is efficient and effective	0.068	-0.102	-0.098	-0.54	0.04	.204**	.204**	.214**	.240**	.406**	1		
12. Satisfied with the power quality provided by my solar PV	0.066	-0.061	0.055	.145**	0.034	.187**	0.006	-0.097	.167*	-0.116	.466**	1	
13. There is high degree of stakeholder participation in PV	-0.057	.204**	0.001	0.119	0.308	.383**	.242**	.410**	.367**	.359**	-0.009	0.019	1

APPENDIX 2

Correlation matrix of social impacts on solar PV and respondents characteristics

Spearman's rho	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Age	1															
Level of education	0.014	1														
Average electricity consumption	-.362**	0.001	1													
How long have you live in the area	0.02	0.07	.548**	1												
Average monthly income	-0.066	-0.023	0.007	0.103	1											
PV system has reduced environ-mental pollution.	-0.026	0.004	0.032	0.023	0.005	1										
PV system im-proved access to information.	-0.072	0.018	-0.004	-0.003	-0.071	.377**	1									
PV system en-hanced entertain-ment.	0.06	0.105	-0.017	0	-0.04	.276**	.508**	1								
PV system im-proved educational delivery.	0.043	.197**	-0.007	-0.046	-0.047	.189**	.442**	.598**	1							
PV system en-hanced security.	-0.043	-0.002	.180*	-0.014	0.081	.483**	.324**	.408**	.357**	1						
PV system im-proved health de-livery.	0.111	.144*	-0.093	0.022	-0.02	.275**	.561**	.558**	.537**	.391**	1					
Privacy has im-proved through PV system.	0.036	-0.055	-.174*	.256**	-0.022	.154*	.156*	.240**	.149*	0.145	0.096	1				
Local capacity for women empower-ment has improved.	0.122	0.02	.218**	-0.083	-0.069	.177*	.436**	.405**	.193**	.169*	.371**	.204**	1			
Solar PV systems has replaced “dirty” energy source for lighting.	0.042	-0.057	-.177*	.232**	0.068	0.107	-0.071	-0.014	-0.108	0.037	-0.069	0.13	0.141	1		
Availability of PV has improved community social activities.	0.061	-0.025	-0.095	-0.057	-0.098	.224**	.538**	.474**	.355**	.243**	.462**	0.117	.485**	0.045	1	
I feel proud of having PV system in my household.	-.181*	0.069	0.121	0.088	0.12	-0.114	-.276**	-.340**	-.285**	-.215**	-.404**	-0.145	-.145*	.154*	-.233**	1