JENRM, Vol. 2, No. 1, 24-29, 2015
Research Article

Evaluating impacts of distributed solar home systems in rural communities: Lessons learnt from Ghana Energy Development and Access Project in the Upper West Region of Ghana

John-Baptist S. N. Naah*

Abstract
This article made a modest impact assessment of isolated solar home systems (SHSs) installed via recently ended five-year flagship Ghana Energy Development and Access Project (GEDAP) on the livelihoods of rural households in the Upper West Region. A total of 250 solar users in both private households and rural clinics in 65 rural communities across 6 districts were interviewed. Lessons learned in the aspects of energy services provision, financial model, local energy preference and practical setbacks facing installed SHSs through GEDAP are discussed. For instance, in terms of energy preference, majority of rural solar users (50%) preferred grid-tied electricity, although they were not connected to the grid yet as compared to 35% who preferred both grid-tied and off-grid forms of electrification while 15% preferred off-grid solar technology. This then suggests that although off-grid SHSs are a viable alternative energy generation option, they may not necessarily be a panacea for the energy poverty situation in rural Ghana due to setbacks. For off-grid solar electrification to achieve parity with conventional energy sources, a combination of increased system capacity, investment and political will is needed to make SHSs more competitive and deliver sustained quality energy services for deprived rural communities where such place-based energy services are needed most for sustainable rural development.

Keywords
Energy services—GEDAP—Ghana—Rural electrification—SHSs

**Institute of Botany, University of Cologne, Zulpicher Str. 47b, D-50674 Cologne, Germany*
***Corresponding author**: jnaahngm@smail.uni-koeln.de

Contents

1. INTRODUCTION

Rural environs can be electrified via a host of energy interventions such as conventional grid extension, coupled with distributed community mini-grids, individual household systems, multifunctional platforms and central charging stations with battery banks ([1]). Rural electrification (RE) is indeed one of the means through which abject energy poverty could be curbed for sustainable development. Electricity generation systems based on decentralized renewable energy technologies (RETs) have nowadays shown a growing public awareness and often recognized as cost-effective options available for providing energy services to households and micro-businesses in remote locations (2). This surge in the deployment and utilization of decentralized renewable energy-based systems to expand energy access to the hinterlands is motivated by a multiplicity of reasons:

- Concerns of negative carbon footprints via the use of conventional fossil fuel resources (global warming) as well as geo-political tensions in oil producing regions, ageing infrastructure, natural disasters, global oil price hikes and climate change issues are a huge deciding factor ([3]).

- These prevailing concerns have been exacerbated by massive increase in current and projected global energy demand in both industrialized and industrializing economies ([4]), which centralized energy generation systems alone cannot fully meet.

- Notwithstanding, approximately 1.3 billion people worldwide still lack access to affordable, modern energy with majority of them are resident in rural sub-Saharan Africa and South East Asia as in 2011 ([5]).
- Research and development (R & D) has led to drastic reduction in production costs of particularly solar cell development ([3]).
- A plethora of literature pointed to a strong uni-directional and/or bi-directional causality correlation between access to affordable and reliable modern electricity to the growth of Gross Domestic Product (GDP) ([6])
- Clean modern energy services could assist in the achievement of the Millennium Development Goals (MDGs) ([7];[8];[9];[10];[11]).

Among the RETs, solar photovoltaic (PV) is one of the most commonly adopted energy generation technologies in deprived rural locations globally and in rural Ghana. For instance, the global installed capacity of solar PV systems has tremendously increased to about 139 GW, with a growth rate of around 22% from 2004 to 2013 ([2]). The implementation of off-grid solar PV technology in RE programs in Ghana has also shown an increasing historical trend over the years ([12]), with current installed wattage capacity of about 3.2 MW as in 2011 ([13]).

Despite the relative popularity of solar PV technology compared to other RETS in Ghana, some past off-grid solar projects implemented in the late 1990 and early 2000 were reportedly quite unsuccessful and unsustainable ([14]). In spite of reduction in production costs of solar cells, the initial cost of acquiring SHSs is still relatively high for majority of the rural poor to bear as well as its limited energy services not being able to adequately meet basic energy needs of rural folks ([15]). This then raises two concerns: firstly, whether off-grid solar electrification in Ghana can be a viable option and secondly, whether it can ensure sustainable rural livelihood enhancement in the country via the recently ended multi-donor sponsored Ghana Energy Development and Access Project (GEDAP) (see details of the GEDAP project in ([15])). This paper therefore seeks to reflect on the lessons learned from GEDAP and provide recommendations with respect to off-grid solar PV efficacy to policy makers and other energy sector players for possible consideration in subsequent solar projects.

2. Materials and methods

2.1 Study area description and sites selection

This study was carried out in the Upper West region (UWR) of northern hemisphere of Ghana from early March to late May, 2011. UWR has a land area of 18,476 km2 constituting 12.7% of Ghana's total landmass and a population of 702,110, with 48.6% (341,182) males and 51.4% (360,928) females as enumerated in the 2010 Population and Housing Census ([16]). This region is ethno-linguistically diverse with major ethnic groups comprising Dagaabas, Sissalas and Waalas ([15]).

In terms of the national electricity coverage statistics, UWR has the lowest penetration rate of about 40% in comparison to the rest of the regions as in 2011([17]). Thus, about 60% of the inhabitants was un-electrified with majority of them are resident in the remotest villages in the region. According to ([18]), UWR also has high level of poverty and experiences out-migration of the youth to the southern sector of Ghana in search of better economic opportunities.

2.2 Solar PV surveys and sampling approach

Firstly, a reconnaissance survey was performed in 2 districts (namely Sissala West and Sissala East districts) to pre-test the structured questionnaires, which were fine-tuned for effective implementation and extraction of adequate information from local solar users. Using a purposive sampling approach, the structured questionnaires were systematically administered to some selected individual household members ([15]). The selection of respondents for the interviews was primarily contingent upon the ownership status and presences of installed SHSs in a particular premises.

Household heads were particularly targeted for the interviews with the view of extracting more information since they are often regarded as the spokespersons in most Ghanaian traditional settings ([15]). However, in situations where the household heads were not present during the interview sessions, any household members willing to volunteer information were subsequently interviewed with the assistance of local interpreters.

Community nurses resident in rural clinics with SHSs installations and including solar street lighting systems (SSLs) were also interviewed. The questionnaires addressed data needs such as local energy sources, quality and quantity of solar PV services, affordability of solar PV technology and financing model used in GEDAP, maintenance and management of balance-of-components and sustainability of installed SHS. Also, group discussions with local inhabitants and institutional interviews with energy sector actors were conducted. Retrieval of relevant secondary data was also done to better appreciate and understand what other researchers have already documented ([15]).

2.3 Data analysis

The collected primary data was prepared using standardized Microsoft Excel application for generating tables and percentages. In-depth content analysis of the interviews was done to have insight into how off-grid SHSs and SSLs contributed to betterment of local inhabitants' livelihoods.

3. Results

3.1 Demography of respondents

Six administrative districts, totaling 250 solar customers in 65 rural communities, were covered for this study representing about 67% of the studied area see Table 1. An average individual household size was 6.5 people while averagely 2.5 nurses were resident in CHPS compounds. In terms of gender composition, 64% of males and 36% of females were sampled for this study. The smaller number of females was interviewed since they were unwilling to participate in the interviews largely due to cultural reasons. About 80% of household heads and 20% consisting of other household members covered.

Table 1. Distribution of the sampled population in the studied area.

Districts	Villages	Resp	% Resp
Sissala West	10	45	18.00
Sissala East	10	35	14.00
Lawra/Nandom	12	35	14.00
Wa West	14	59	23.60
Wa East	9	36	14.40
Nadowli	10	40	16.00
Total	65	250	100.00

Note: *Resp* = *Respondents*. As at the time of this research was conducted, Lawra/Nandom district was not then divided into two districts.

3.2 Lessons learnt from GEDAP initiative

3.2.1 Energy services provision

Energy is not wanted for itself but rather the associated services that come along with it for consumption purposes. That is, the energy carrier(s) are not the main interest to the end-users but rather the benefits they get from the use of electricity. The GEDAP project (via off-grid solar electrification) principally focused on providing local people with main energy services in two folds:

- Brighter lighting in both private households and rural clinics.
- Vaccine refrigeration in rural clinics.

3.2.2 Financial model

The SHSs were installed free of charge in public rural clinics via the Ministry of Power (MoP). As an implementing agent of government of Ghana, MoP played supervisory role to ensure successful implementation of GEDAP project. To encourage individual ownership of clean solar technology to improve rural livelihoods, a piloted credit financial scheme was implemented. Thus, GEDAP funds covered about 80% of the initial cost of SHSs, while the rest of the cost was borne by the beneficiary solar customers via micro-financial credit facility taken from either participating Sissala Rural Bank (SRB) and Nandom Rural Bank (NRB) at interest rates of 28% and 26% respectively which was payable over 2 years. Routine maintenance of the installed SHSs was done by local technicians free of charge within the loan agreement period. This piloted individual ownership of SHSs was only limited to the Sisala West, Sisala East and the then Lawra/Nandom districts ([15]). There was also a requirement to get a guarantor preferably a salaried worker.

3.2.3 Teething drawbacks of GEDAP initiative

One of the obvious setbacks of GEDAP-sponsored SHSs was their limited wattage capacity. Hence, local beneficiaries could only use lighting in the night for only about 2-3 hours which is obviously not adequate to meet other much desired energy needs such as ironing clothes, powering personal fridges (for those who could afford) and other productive uses of electricity, for example, in agriculture since majority of them are subsistence farmers. Other challenges included relatively high interest rates charged by the participating rural banks, unavailability of balance-of-components (BOC) at village level, lack of technical know-how regarding basic maintenance culture, inadequate monitoring exercises and cheaper grid expansion with broader range of energy services, as highlighted by ([15]).

3.2.4 Local preference for available energy sources

There was 100% acceptance for the 'new' solar technology among those who were able to afford it. However, when local people were asked the question which energy source they would prefer, half of them indicated that they preferred grid-connected electrification (50%), 15% of them still preferred to use off-grid solar PV electrification while 35% of them preferred both forms of RE systems.

4. Discussion

The decentralized stand-alone solar PV systems installed via GEDAP provided a modest range of modern energy services for the local end-users. The fundamental energy service was brighter illumination which was very essential for undertaking nocturnal activities in both rural clinics and private homes.

In the health facilities, community nurses used solar lights to handle emergency cases at night ('night calls') conveniently unlike previous use of limited movable torches and smoky kerosene-dependent lanterns. In additional to brighter illumination, the continued availability of cooled vaccines as a result of solar-powered refrigerators for immunization exercises enabled nurses to save time and energy so as to concentrate more on their work in such deprived villages in the studied districts ([15]). The presence of off-grid SHSs and associated energy services also serve as good incentive mechanism for retention of rural health workers ([15]). This was similarly reported in Zambia by ([10]) and in Nepal by ([19]). This could go a long way to improve upon primary healthcare delivery in such deprived villages. Indeed, the health of every nation is a function of healthy people who work to ensure sustainable national development. The replacement of kerosene-based lanterns used in both private homes and clinics has reduced the risk of solar users suffering from indoor air pollution (IAP). It was estimated that off-grid solar lighting was likely to reduce the number of household members being affected by indoor smoke from kerosene lanterns by 50% ([20]).

In private households, GEDAP-sponsored SHSs with mostly 50 peak Watt (Wp) installed under the piloted second GEDAP phase provided solar lighting in the night for household chores such as cooking meals, bathing and movement in the evening due to brighter illumination which was not the case.. The solar customers were also able to use SHSs for free mobile phone charging, evening studies by children at night even under veranda lights ([15]). The far-reaching solar lighting could serve many household members at almost the same time unlike limited movable traditional lighting sources such as flashlights and lanterns. In both rural clinics and individual homes, solar users were able to charge their mobile phone to continuously talk with relatives and friends in other villages and urban centers and exposing children to educational television programs (e.g. Presidential Distant Learning Program).

According to ([15]), off-grid solar PV electrification could affect rural capital types (social, financial/economic, physical, natural and human) in varying degrees. Financially, without the intervention of GEDAP, local folks could have found it very difficult to afford the SHSs. With the installation of SHSs in their homes, solar users could benefit from avoided costs via infrequent buying of kerosene, candles, diesel, and dry-cell batteries for lighting purposes ([15]). The renewability, easily distributable and environmentally-friendly (CO2 emission free) nature and modularity of the solar PV technology, among others, makes it suitable for the remotest and energy-poor communities. The solar technology, therefore, has the potential of fighting against inevitable global warming.

Notwithstanding, a myriad of teething challenges identified in GEDAP initiative ranging from financial implications, BOCs unavailability, system wattage capacity limitation, low technical know-how to rapid grid extension could be serious threats to diffusion of SHSs and long-term sustainability of the GEDAP initiative. ([21]) asserted that failures in policy and institutional structures are the bane for SHSs dissemination in Ghana. For instance, the generally limited wattage capacity of installed solar modules could not adequately meet basic energy needs of end-users unlike the conventional grid extension. It was also revealed that the relatively high interest rates charged by the participating rural banks were serving a great disincentive to many solar customers and threat to sustainability of these installed SHSs despite GEDAP subsidies. It is still a handful of local people who could afford the SHSs while the majority excluded also need such modern energy services amounting to social exclusion.

Another challenge of unavailability of balance-of-components (BOC) at village level made it difficult for immediate replacement of dysfunctional BOC, as well as lack of technical know-how regarding basic maintenance culture of solar technology on the part of the solar users. Additionally, the relatively rapid and cheaper grid expansion with broader range of energy services make expensive off-grid solar less competitive energy source, as these drawbacks were also highlighted by [15]. The low technical know-how is a serious setback since that would lead to poor maintenance of the installed SHSs ([15]).

The least local preference perception for off-grid SHSs was partly attributable to the above outlined drawbacks despite 100% acceptance by local end-users. The other reasons for the preferential perceptions of different energy sources among respondents were varied. The highest preference perception for the grid-tied electricity was as a result of its broad range of energy services at a cheaper price vis-a-vis that of the off-grid SHSs with limited range of energy services and still quite costly . Those who preferred both energy sources was basically for backup purposes in order to ensure continuous supply of electricity (backup strategy). The least number of them still preferred off-grid solar technology since it is easily deployable and could provide brighter lighting than traditional lighting sources, and therefore, an equally good source of energy.

As ([3]) asserted, only decentralized energy systems as a means of RE is not currently feasible and highly desirable but rather a careful combination of both centralized and decentralized supply systems. According to ([22]), to improve upon "Energy-Poverty Index Score (EPIS)" of rural household members, they should invest in reliable and quality energy delivery systems to improve upon quality of life since they cannot save money with frequent buying of poor traditional energy sources such as kerosene, candles and dry-cell batteries. However, access to modern electricity without linking it to productive uses of energy such as promotion of local agri-business and other economic activities to generate enough income to diversify livelihood opportunities is likely to be ineffective.

5. Conclusion

Drawing from the lessons learnt in the GEDAP initiative, isolated solar PV technology implementation in unelectrified remote villages does have its pros and cons. For instance, local people were able to get improved healthcare services, brighter lighting, cheaper mobile phones charging and among others at night through the installation of solar PV systems. On the other hand, these basic essential benefits are not sufficient enough to significantly better their standard of living as compared to their counterpart in peri-urban and urban centers. This is because the rural people are still faced with food insecurity, poor road networks, poor general infrastructure, water scarcity and post-harvest losses and extra financial burden of acquiring new SHS systems by entering into loan contractual agreements in the case of private household users.

This therefore suggests that although the off-grid solar technology is a clean alternative energy source yet it may not necessarily lead to improved quality of life unless conscious efforts are made to link solar PV services to productive uses of electric power. As ([11]) indicated, consistent and conducive policy and regulatory frameworks are key to the successful dissemination of decentralized renewable-based energy sources in especially Africa. Creating the enabling environment for RETs including solar PV systems via sustained financial support and political commitment in the country may help achieve low-carbon economy and at the same time fight against global warming and its consequences.

6. ACKNOWLEDGMENT

The German Academic Exchange Service (DAAD) is duly acknowledged for provision of financial support for this research. Many thanks also go to staff members of the Renewable Energy Directorate under Ministry of Power for their assistance during my fieldwork. My thanks equally go to all contact persons at Electricity Company of Ghana (ECG), Volta River Authority (VRA), Wilkins Engineering Ltd, Toyola Solar Company Ltd, KITE, DENG Ltd, APEX Rural Bank, Tumu Rural Bank and Nadom Rural Bank for granting me institutional interviews.

References

[1] Yadoo, A..2012. *Delivery models for decentralised rural electrification: Case studies in Nepal, Peru and Kenya.* International Institute for Environment and Development, London.

[2] REN21.. 2014.*Renewables 2014 Global Status Report*, REN21 Secretariat, Paris.

[3] Bouffard, F., Kirschen, D.S..2013. Centralized and decentralized electricity systems. *Energy policy* 36(2008) 4509- 4513.

[4] EIA.2013. *The international Energy Outlook* 2013, U.S. Energy Information Administration. http://www.eia.gove/forecasts/ieo/pdf/0484%282013%29. Viewed 9 December, 2013).

[5] EIA.2013. *World Energy Outlook* 2013. International Energy Agency, OECD/IEA, Paris.

[6] Soytas, U. and R. Sari.2002. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. *Energy Economics* 25 (2003) 33-37.

[7] AGECC .2010. Energy for a Sustainable Future. Report and Recommendations. *UN Secretary-General's Advisory Group on Energy and Climate Change, 28 April 2010, New York*

[8] Bawakyilenuo, S., .2011. Shifting the policy paradigm of solar photovoltaic and other renewable energy technologies supply in Ghana. Policy Issue (PI), *World Renewable Energy Congress, Linkoping, Sweden.*

[9] EIA.2009. *World Energy Outlook* 2013. International Energy Agency, OECD/IEA, Paris.

[10] Mfune, O. and E. K. Boon .2008.Promoting renewable energy technologies for rural development in Africa: Experiences of Zambia. *Journal of Human Ecology* 4(3):175-189.

[11] UNIDO..2009. Scaling up Renewable Energy in Africa. United Nations Industrial Development Organization. *12th Ordinary Session of Heads of State and Governments of the African Union, Addis Ababa, Ethiopia.*

[12] [Obeng, G. Y., H.-D., Evers. 2009. Solar PV rural electrification and poverty reduction: A review and conceptual framework with reference to Ghana. ZEF working paper series 36, ISSN 1864-6638.http://mpra.ub.uni-muenchen.de/17136 (accessed on 12th September, 2012).

[13] MoP. 2011. An exhibition of policies, projects and activities of MDAS and MMDAs. GEDAP. Ministry of Power, Ghana Policy Fair. 26-30 April, 2011.

[14] Bailey, P., O. Chotimongkol, S. Isono . *Demand Analysis and Optimization of Renewable Energy: Sustainable Rural Electrification of Mbanayili, Ghana.*-, University of Michigan, USA, MSc.

[15] Naah, J-B. N. and J., Hamhaber.2015. Lighting Up The Villages: Livelihood Impacts Of Decentralized Stand-Alone Solar Photovoltaic Electrification In Rural Northern Ghana. *Journal of Natural Resources and Development.* 05: 1 – 13. DOI number: 10.5027/jnrd.v5i0.1.

[16] GSS,.2013. *2010 population and housing census. Regional Analytical Report. Upper West Region.* Ghana Statistical Service, Ghana. http://statsghana.gov.gh/publications.html (accessed on 05th March, 2014).

[17] Ahiataku-Togobo, W., . 2012. IAccess to sustainable energy in Ghana: Role of renewable energy

as prerequisite for MDGs. *AREA Conference at the Rockyfeller Bellagio center*, may 22-26, 2012, Italy.

[18] Blench, R., . 2006. *Interim evaluation of UWADEP working paper: Background conditions in Upper West Region, Northern Ghana, 2005.* IFAD-office of evaluation, Cambridge.

[19] Zahnd. A. and H. M. Kimber. 2009. Benefits from a renewable energy village electrification system. *Renewable Energy* 34 362–368.

[20] Obeng, G.Y, F.O. Akuffo, I. Braimah, H-D. Evers, E. Mensah, . 2008. Impact of solar photovoltaic lighting on indoor air smoke inoff-grid rural Ghana. *Energy for Sustainable Development Volume XII No. 1*

[21] Bawakyillenuo, S. 2009. Policy and institutional failures: The bane of photovoltaic solar household system (PV/SHS) dissemination in Ghana. *Energy and Environment Journal*, Vol. 20, No. 6, pp. 927-947.

[22] Obeng, G.Y, H-D. Evers, F.O. Akuffo, I. Braimah, A. Brew-Hammond, . 2008. Solar photovoltaic electrification and rural energy-poverty in Ghana. *Energy for Sustainable Development Volume XII No. 1.*