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**Decentralized Rural Electrification in Ghana-
Evaluation of Technical and Socio-Economic
Aspects for Sustainable Solutions**

Master Thesis

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Masterstudiengang

Environmental and Resource Management

**Dezentrale ländliche Elektrifizierung in Ghana-
Bewertung technischer und sozio-ökonomischer
Aspekte für nachhaltige Lösungen**

Masterarbeit

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Statement of Authentication

I declare that this paper has been my original work, unassisted and without using any other resources other than those indicated. All the direct or indirect cited information from other sources (including electronic sources) is duly acknowledged without exceptions. The material, in this or similar form, has not been previously submitted, either in full or in part, for other exams at this or any other academic institution.

Place, Date

Signature

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Abstract

Rural electrification has been one of the challenges faced by the government of Ghana due to extremely high cost of electricity extension to the rural areas. In order to meet up this challenge, the government of Ghana has been keen with the introduction of renewable energy programs as a solution for rural electrification. However, most of programs are also faced with the problem of being sustainable. After government and sponsors hand-over completed project to local users, they usually last only few years of their life span and are abandoned. This challenge has inspired this study to identify the potential barriers to the sustainability of rural electrification programs through technical and socio-economic evaluation of a solar PV rural electrification project in Ghana.

The approach of this study selected an on-going solar PV project (community solar system-CSS), that has been introduced on a pilot base across the whole of Ghana, which is to be adopted as a standard system for electrification solutions in rural areas in Ghana. This project was subjected to both technical and socio-economic evaluations covering 13 rural communities across the southern part of the country. Stakeholder interviews and review of literature were additional methodologies employed to gather information pertinent to the theme of the study.

The results of the study show that technically, the CSS project has simple design and operational technologies, which gives it high integration potential. However, the project faces the problem of technology misuse by the rural users and frequent failure of its components. The socio-economic barriers identified are: (1) ineffective management of the project due to a long chain of bureaucratic administrative management system, inadequate monitoring and supervision, and inconsistency in standardizing the cash flow of the project, and (2) low electricity capacity of the CSS project and other similar small scale renewable projects to meet the electricity requirements of the rural populates. These problems lead to gradual decline of users' interest for such small scale renewable energy projects and subsequently result in project abandonment. It was concluded that small scale renewable energy programs lack the capacity to fully meet the energy requirement of rural populates; however, they are crucial as intervening solutions and play key role in rural development.

Zusammenfassung

Dezentrale ländliche Elektrifizierung ist wegen der extrem hohen Kosten eine der großen Herausforderungen für die Regierung von Ghana. Um diese Herausforderung zu meistern hat die Regierung von Ghana frühzeitig Programme für erneuerbare Energien zur Elektrifizierung in ländlichen Regionen umgesetzt. Allerdings zeigen sich bei der Durchführung dieser Programme erhebliche Probleme bezüglich ihrer Nachhaltigkeit. Nach der Fertigstellung und Übergabe dieser Projekte an die lokalen Benutzer zeigen sich häufig technische Probleme und die Projekte werden nach kurzer Zeit aufgegeben. Diese Schwierigkeiten haben die vorliegende Studie zur Untersuchung der Ursachen und Grenzen der Nachhaltigkeit einer Elektrifizierung in ländlichen Regionen inspiriert. Insbesondere sollen in dieser Studie die technischen und sozio-ökonomischen Probleme von Projekten mit Hilfe solarer PV Elektrifizierung ländlicher Regionen in Ghana untersucht werden.

Die vorliegende Studie untersucht ein zur Zeit laufendes solares PV Projekt (community solar system-CSS), eingeführt als ein landesweites Pilotprojekt in Ghana, welches zu einem Standardsystem zur Stromversorgung ländlicher Gebiete in Ghana werden soll. Das Projekt wird sowohl von technisch als auch sozio-ökonomisch Untersuchungen in 13 ländlichen Kommunen im südlichen Teil des Landes begleitet. Sowohl eingehende Befragungen der beteiligten Partner als auch eine Auswertung einschlägiger Literatur zur Gewinnung zusätzlicher Informationen werden begleitend zu diesem Projekt durchgeführt.

Die Resultate dieser Studie zeigen, dass die technischen Aspekte des CSS Projektes, das auf einfach beherrschbaren Technologien bezüglich Design und Betrieb beruht eine gute Perspektiven bietet. Jedoch zeigen sich Probleme durch Fehlbedienung der technischen Komponenten und ein häufiges Versagen einiger Komponenten. Die zugrunde liegenden sozio-ökonomischen Ursachen hierfür sind: (1) ineffizientes Management des Projektes durch bürokratische Verwaltung, nicht hinreichendes Monitoring und Überwachung und eine inkonsistente, nicht kontinuierliche Finanzierung, sowie (2) eine zu niedrige elektrische Kapazität des CSS Projektes and anderer kleiner, nachhaltiger Projekte zur Sicherung der Stromversorgung für die ländliche Bevölkerung. Diese Probleme führen zu einem Verlust des Interesses an kleinskaliger erneuerbarer Energieproduktion und schließlich zur Beendigung der Projekte. Dies liegt daran, dass diese kleinskaligen

erneuerbaren Energieprojekte keine hinreichende Kapazität zur Deckung des Energiedarfes der ländlichen Bevölkerung besitzen. Dennoch sind solche Projekte ein essentieller Schritt für die Entwicklung ländlicher Regionen.

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Glossary of Terms and Abbreviations

- AC — Alternating Current
- AGSI — Association of Ghana Solar Industry
- Ah — Ampere-hour
- BSB — Ghana Standard Board
- CA — Community Agent
- CDM — Clean Development Mechanism
- CSM — Community Solar Management
- CSS — Community Solar System
- DA — District Assembly
- DC — Direct Current
- EC — Energy Commission
- ECG — Electricity Company of Ghana
- ESO — Electrification Supply Ordinance
- GDP — Gross Domestic Product
- GEF — Global Environmental Facility
- GH¢ — Ghana Cedis
- GPS — Global Positioning System
- GRIDCo -Ghana Grid Company
- GWh — gigawatt hour
- IEC — International Electricity Committee
- IPPs — Independent Power Producers
- ISO — Independent System Operators
- JFY — Japanese Fiscal Year
- JICA — Japanese International Cooperation Agency
- KDI — Kerosene Distribution Improvement
- KNUST - Kwame Nkrumah University of Science and Technology

kWh — kilowatt-hour
LCO — Light Crude Oil
LED — m Light-emitting Diode
LPG — Liquefied Petroleum Gas
MOEd — Ministry of Education
MOEP — Ministry of Energy and Petroleum
MW — megawatt
NED — Northern Electricity Department
NEDCo - Northern Electricity Company
NES — National Electrification Scheme
NG — Natural Gas
NGO — Non-Governmental Organization
NREL — National Renewable Energy Laboratory
OpenEI - Open Energy Information
PV — Photovoltaic
PVA — PV Agent
RE — Renewable Energy
REA — Rural Electrification Agency
REF — Rural Electrification Fund
RES — Renewable Energy Sources
RESPRO - Renewable Energy Services Project
RETs — Renewable Energy Technologies
SHEP — Self-Help Electrification Programme
UNDP — United Nations Development Programme
UNEP — United Nations Environmental Programme
VRA — Volta River Authority

1 Introduction

Ghana has an ample reputation with regards to electricity access, recording more than 70% of nationwide access as of 2010. In addition, the National Electrification Scheme (NES) has a great target of achieving universal electricity access (90% of national electricity access) in 2020. In spite of the sound records of Ghana's electricity access and high aspirations, there are significant challenges that inhibit development.

One of the major challenges in the NES is extension of electricity to the rural areas in Ghana. This concern has been elaborated by the Director of Renewable Energy in a speech that as one of the key challenges, "there exist over 2000 lakeside and island rural communities in Ghana not likely to be connected to the national grid in the foreseeable future" (Togobo, 2012). Consequently, he also called for intervening solutions of decentralized renewable energy with off-grid and mini-grid options. This call is in line with the fact that grid electricity connection to the rural communities is expensive mainly due to lack of access roads and geographical remoteness. In addition, low population rates coupled with high poverty level of the rural populates make grid extension of electricity to rural communities increasingly ineffective.

The government of Ghana, however, is devoted to rural electrification and is currently one of the prioritized strategies on the policy agenda of the NES. Since grid extension to most of the isolated rural areas is currently not cost effective, solar photovoltaic (PV) systems have emerged as prominent solutions to rural electrification in Ghana. The Ghana government in collaboration with international organizations and non-governmental organizations (NGOs) have implemented a number of solar PV systems for electrification and other energy solutions in the rural communities. The emergent of solar PV system as an intervening solution to rural electrification in the country is not only due to the fact that renewable energy sources (RES) have increasingly become the plausible solution for sustainable energy access in rural communities, as emphasized by Glemarec (2012), but is also consistent with the fact that, Ghana is raising its effort to utilize its well-endowed solar radiation, which is abundant in all parts of the country. In addition, this era has become concurrent with Ghana's commitment to increasing its renewable energy sources in the national energy mix (Glemarec, 2012; Togobo, 2012).

Generally, rural electrification projects are often characterized by frequent failures. According to García et al (2010), the failure of rural electrification solutions from renewables is most often related to the design and implementation of the systems. Other factors for the failure of rural electrification systems include funding and commercialization mechanisms (García et al., 2010). The situation is not different from Ghana. The country's rural electrification efforts have yielded tremendous results with the introduction of many rural electrification projects based on renewables, especially solar PV systems. However, most of the projects do not see the light of the day after implementation. As a result, the government and other sponsoring agencies are discouraged from extending such projects into other communities. Since the government of Ghana is highly committed to rural electrification with renewables, finding solutions to the underlined challenges would be crucial for sustainable rural electrification solutions in Ghana.

Given the above context, this study is committed to identifying the technological and socio-economic factors that may directly or indirectly influence the successful implementation of small scale renewable energy technological solutions to promote improved and sustainable rural electrification projects in Ghana. The study focuses on solar PV systems, which is currently prevalent for the provision of electricity solutions in rural Ghana. In order to accomplish the stated goal, the study is designed to answer three major questions: that are: (1) what are the potential barriers to successful implementation of solar PV programs in rural Ghana? (2) To what extent do the small scale rural electrification solutions meet the needs and expectations of the rural populates; and (3) in what ways can rural electrification programs be improved to ensure effectiveness and sustainable rural development? In order to get answers to these questions, the study focuses on an extensive evaluation of a major project, (Community Solar System—CSS), involving solar PV systems for the provision of electricity in 20 island and isolated rural communities across the country. The evaluation of the CSS project involves system operational performance, system's component performance, system financial performance, management structure performance, and project impacts on the communities.

This CSS project was jointly initiated by the government of Ghana and the Japanese International Cooperation Agency (JICA) for the provision of electricity in some 20 selected rural communities across Ghana. The project is in the second and final pilot stage and was selected for this study because it extends across all regions

in Ghana. In addition, it involves small scale solar PV systems, which have emerged as dominant renewable energy technological options for rural electrification interventions in Ghana. Moreover, the CSS project has been developed as a standard system to be adopted for rural power supply in Ghana.

1.1 Background

Ghana's renewable energy campaign has been on the increase in recent years, and this is partly as a result of Ghana's increased commitment to rural electrification. Being aware of the plausibility of renewable energy technologies for rural electrification, Ghana in partnership with international and donor organizations have introduced many projects based on renewables for rural electrification in the country. As mentioned earlier, most of the projects have focused on solar PV systems including PV street lighting systems, PV public systems (e.g. PV for schools and clinics), PV charging systems, solar PV water pumping systems, and PV lantern systems. There has been increased emphasis on solar PV systems in the country's renewable energy campaign because Ghana has good solar radiation resources across all regions. These solar PV projects have contributed immensely to rural development through improved access to safe drinking water, safe health delivery, improved education, information dissemination, and increased economic activities in the rural communities (Togobo, 2010).

The problem is that despite the pronounced positive impacts of the rural electrification programs on the lives of the rural people, most of the programs are faced with the challenge of being sustainable. Again, Mr. Togobo (2010), has lamented on this problem that after developing partners pull-out and hand over project to local users, the project usually last for 3 years after which they are abandoned. This is a big challenge to the success of solar rural electrification and other small scale solutions because these small scale programs have become the feasible solution to rural electrification since the possibility for grid extension to most of the isolated and island communities are not predictable in the near future. This concern has prompted this study with the major focus on assessing and identifying the underlying factors that contribute to ineffectiveness and frequent failure of rural electrification programs in Ghana from both technological and socio-economic perspectives.

1.2 Rationale of the study

Rural life in Ghana, just like many other developing and African countries is very challenging. Although the rural people play leading role in the supply of local food and other national commodities, they are the least beneficiaries of infrastructure, social and other developmental amenities. Besides the high risks involved in their crude farming and other economic activities, they are mostly deprived of necessary life needs such as basic health care, safe drinking water, and electricity. Rural people scarcely benefit from developmental projects, but the most unfortunate aspect is that most rural projects are faced with sustainability challenges. As a result, it is very crucial that the necessary barriers that hinder successful implementation of rural developmental programmes are critically identified and addressed to ensure improved and sustainable rural development.

This issue has been a major motivational factor behind this study. The central ideology of the study is to identify the necessary barriers that significantly contribute to ineffectiveness of small scale renewable energy solutions for rural electrification and to provide possible measures, which could contribute to improved and sustainable solutions. In another dimension, the study will also serve as a knowledge resource base to complement the efforts of the government of Ghana to improving rural life through sustainable implementation of rural developmental programs.

The study essentially focuses on renewable energies (RE), especially, solar PV technologies for the provision of electricity for domestic purposes in the rural areas of Ghana. The emphasis on solar PV systems is relevant with regards to their dominance and high prospect for rural electrification solutions in Ghana.

The choice of the CSS project for the purpose of this study also stem from the fact that it is a major rural solar PV electrification project across almost all the regions of Ghana. It pre-suggests that the results of the study would give fair and representative implications. On a broader perspective, the study will also contribute to the global effort in ensuring energy security through sustainable energy supply with green returns of environmental protection and mitigation of climate change.

1.3 Statement of tasks and objectives

As mentioned already, the primary task of the study is to investigate and identify the potential barriers that may significantly hinder the successful implementation of

rural electrification programs. In this task, the CSS project is selected and evaluated from two perspectives: One, technical perspective; which includes evaluation of the operational and components performance of the system and two, socio-economic perspective; which includes evaluation of the performance of CSS management structure; performance of business operations and impact of the CSS project on rural life as well as implied evaluation of the human resource development component of the CSS project.

The execution of the above tasks is geared towards three major objectives. They are:

1. To identify the potential technical and socio-economic barriers that are of significant hindrance to successful implementation of rural electrification programmes in Ghana;
2. To assess and determine whether or not the JICA CSS pilot project is worth recommending for further implementation as a standard for rural electrification solutions; and
3. To assess the significance of small scale renewable energy solutions in rural developments.

1.4 Research approach and structure of thesis

The principal approaches to achieving the objectives of the study are through extensive review of literature, interview with stakeholders and field visit for data gathering and retrieval of first-hand information. The major task of data collection, however, is the evaluation of the CSS project, which involves 4 weeks of evaluation exercise in 20 communities across the southern part of Ghana.

The study is composed of five major sections: Section is the introductory chapter, which entails the investigating problem, the objectives of the study and an overview of the approach of the investigation as well as review of relevant literature. The second section describes the energy situation in Ghana entailing general energy overview, national electrification trends, and rural electrification efforts in Ghana. The third section comprises the materials and methodology chapter, which describes the materials and approach of the study, including brief description of the project sites, detailed description of the CSS project, and the evaluation procedure. The fourth section is the results and discussion chapter, which presents the results of the

investigations and evaluation as well as their interpretations. The final section is the conclusions and recommendations chapter, which describes the potential barriers to sustainable rural electrification programmes identified in chapter four and corrective measures for improved and sustainable electrification solutions in rural areas in Ghana.

1.5 Literature review

The issue of electricity access, particularly, in Sub-Saharan African needs urgent attention, especially with regards to rural electrification, to ensure any significant success in the future. According to World Energy Outlook report (2012), the trend in electricity access in other regions such as developing Asia has high potential to improve remarkably. The region is likely to reduce electricity poverty from about 630 million people without electricity in 2010 to about 335 million in 2030, which would be about 50% improvement. The situation is, however, different in Sub-Saharan Africa. Even though Sub-Saharan Africa was ranked highest with record of 589 million people without electricity access in 2010, projections indicate that the situation could exacerbate to about 655 million people in 2030 due to fragility of intervening actions. The situation is even alarming in the rural areas where most of the people have never had access to electricity. According to UNEP (2012), rural electricity access rate in the sub-region is only 8 per cent, whereas 85 per cent of the population rely on biomass for energy (UNEP, 2012; World Energy Outlook, 2012).

The good news, however, is that Africa and the Sub-Saharan Regions have abundant resources of renewable energy, which studies have shown that, they are the most plausible forms of energy for rural electrification, particularly with respect to solar and wind. Recent studies also show that the attempt to increase the share of renewable energy is very high on the policy agenda of most leaders in developing countries, including Sub-Saharan Africa (Gómez et al., 2010; Javadi et al., 2013; Lahimer et al., 2013; UNEP, 2012;).

Ghana is in Sub-Saharan African with sound record of electricity access, about 72%; however, the problem with rural electrification in the country is no different from that of the Sub-Region. In spite of Ghana's progress, there is still huge disparity in electricity access between the urban and the rural areas. This suggests that the problem of rural electrification, in accordance with future projections, could be

worsen-off in the near future, if efforts aimed at improving rural electrification are not raised. Expansion of electricity access, however, is very high on the development agenda of the government of Ghana. The government has a sound policy of achieving universal electricity access by 2020 as well as strategies of increasing the share of small scale renewable energy technologies, especially for rural electrification. This advocacy is not only meant to raise Ghana's voice in the global cleaner energy campaign, but most importantly, to supplement Ghana's energy capacity with increased share of renewables and to improve rural electrification for poverty reduction. Initial attempts concerning formulation of legal energy policies in Ghana was realized as far as 1920, that saw the passage of Electricity Supply Ordinance (ESO); which according to Kemausuor et al. (2011), provided for the private generation of electricity and inspection of generation activities by government officials. The Ordinance also saw the establishment of Electricity Department as the state regulatory agency, which later became the sole agency responsible for generation, transmission and distribution of power in Ghana. Following other development, such as the Volta River Project, which realized the completion of Ghana's largest hydro power exploitation project, rural electrification program was established in 1972 to foster rural electrification in the country. In later development, the NES was established in 1989, through which the Government of Ghana charged the country to increase electricity access to all communities with population above 500 by the year 2020. Rural electrification under the then NES was envisaged through national grid-extension through a Self-help Electrification Program (SHEP). The SHEP was challenged by fundamental problems of low population of rural consumers, low income levels of rural communities, geographical remoteness of the rural communities, and subsequently, high costs of grid-extension. These problems have remained the major hindrance to all developmental efforts aimed at rural electrification until present times (Kemausuor et al., 2011).

The current policy regarding Ghana's renewable energy is in two folds: first, to increase the share of renewables in the energy mix to 10% by 2020 (excluding large scale hydro) and secondary, to increase the use of renewables for electricity use in rural areas to 30% by 2020. Major strategies the government intend to adopt in execution of this plan are by creating incentives to attract private sector investment, issuing of licenses for the operation of large scale renewable energy power plants as well as creation of feed-in-tariffs to allow independent producers to connect to the

national grid. Specific strategy regarding rural electrification is the establishment of a Rural Electrification Agency (REA) and Rural Electrification Fund (REF) to manage and coordinate rural electrification efforts. REA will also support local agencies to solicit funds for rural electrification projects from international donor facilities such as the GEF and CDM (Ghana Energy Commission, 2009).

There are already many intervening renewable energy solutions in rural Ghana and most of the solutions have been based on solar PV systems. According to Togobo (2012), over 6,300 solar systems alone were installed in 11 Districts from 2009 until 2012. The profound positive impacts of rural electrification programs on rural lives have already been mentioned. In addition, Obeng et al. (2008) also demonstrated that solar PV rural programs help to improve rural energy-poverty in off-grid communities with access to solar PV solutions than rural households without solar PV. Lahimer et al. (2013), even put much emphasis on the importance of rural electrification programs by stating that rural electrification should be adapted globally as part of human right to enhance the quality of life. These are little evidences that demonstrate the need and the importance of rural electrification. The other facet of renewable rural electrification programs is that they are characterized by frequent failure. This is partly due to the fact that sponsors and funding agencies become discouraged and usually pull-out of on-going project because project only last few years after implementation due to poor managerial effort (Togobo, 2010). From the view point of Gómez et al., another contributing factor to the frequent failure of rural renewable energy solutions is that rural electrification programmes tend to focus more on technology with less emphasis on social dimensions. This problem is not different in Ghana, most renewable energy solutions, especially solar PV systems are received enthusiastically in the rural communities, system work very well within the first three years and then collapse after development partners pull-out.

The above problem has been identified as a major challenge to Ghana's rural electrification campaign because small scale renewable solutions, especially solar PV system, are currently the alternative solutions to rural electrification in Ghana since there are significant number of island and isolated rural communities whose chance of being connected to the national grid are not predictable in the near future (Togobo, 2010). Although academic commitments on Ghana's renewable energy campaign are high, most of the studies have focused mainly on resource feasibility studies and policy framework, without specific attention on the core issues, which

may be of barrier to the sustainable implementation of small scale renewable solutions for rural power supply in Ghana. This research gap is the focus of this study. Having also realized that most literatures, which cover the problems of rural electrification have focused on either social or technical aspects, this study considers both technical and sociological factors that might be of significant hindrance to sustainable solar PV rural electrification programs in Ghana. It is also important to point out that the scope of this study does not cover other renewable energy sources such as bioenergy and wind but only solar PV systems due to time constraint and limited resources. This could be a limitation, but the focus on solar PV systems is reasonable because they are currently the dominant systems in many programs for rural electrification solutions in Ghana than other technologies. The choice of the CSS pilot project as a solar PV system for the research is also in line with the fact that the project is meant to be adopted as a national standard solar PV system for rural electrification and for further deployment across all parts of Ghana. This implies that the result of the research would be representative and a fair indication of the situation in Ghana.

2 Energy situation in Ghana

2.1 Brief country profile

Ghana, formerly known as Gold Coast, was formed from the merger of the then British colony of the Gold Coast and the Togoland trust territory. Ghana was the first country in Sub-Saharan Africa to gain independence in colonial Africa in 1957. Ghana is located latitudes $4^{\circ} 44'N$ and $11^{\circ} 11'N$ and longitude $3^{\circ} 15'W$ and $1^{\circ} 12'E$ and is bounded by Ivory Coast and Togo to the west and east, whereas Burkina Faso and the Gulf of Guinea bound the north and south (Figure 2-1). The country has 10 administrative divisions (regions) with Accra being the National capital. According to CIA (2014), the population of Ghana as of July 2013 is 25,199,609 with growth rate of 2.19%. The country has a GDP per capita of US\$3,300 and a real growth rate of 7.9% since 2012 (CIA, 2014, Ghana Energy Commission, 2009).

Ghana has well organized administrative structures and strong institutional arrangements that are responsible for various regional and sectorial developments under the national governance. One of such sectors that has seen keen

development over the years is the energy sector. The remaining of this section describes the details of Ghana's energy governance, including overview of stakeholders, policies, plans and strategies that are keeping the energy sector of Ghana.



Figure 2-1 Geographical map of Ghana

Source: University of Texas library, 2014

2.2 General energy overview

2.2.1 National energy policy, plans and strategies

The institutional arrangement and responsibilities in the Ghanaian energy sector is summarized in Table 2-1.

Table 2-1 Institutional responsibilities in the Ghanaian Energy Sector

Agency	Responsibility
MINISTRY OF ENERGY	Formulation of broad Policies, Programs and Project for the entire sector
Volta River Authority, Bui Power Authority, IPPs	Power Generation
Ghana Grid Company (GRIDCo)	Power Transmission , Independent System Operator (ISO)
Electricity Company of Ghana,	Power Distribution (Southern Ghana)
Northern Electricity Company (NEDCo)	Power Distribution (Northern Ghana)
Energy Commission of Ghana	Licensing, Technical Performance Standards formulation, Policy advisor, MOEP
Public Utilities Regulatory Commission	Setting of Tariffs, Quality monitoring consumer protection
Energy Foundation	NGO devoted to the promotion of Energy Efficiency and Renewable Energy in Ghana

Source: Adopted online from Global Clean Energy Development

The overall vision of the Ghana energy sector is to develop an “Energy Economy”, which implies securing a reliable supply of high quality energy services for all sectors of the Ghanaian economy and also to become a major exporter of oil and power by 2012 and 2015 respectively. In order to realize this vision, the energy sector has instituted various policies, plans and strategies that address issues and challenges relating to the following areas and sub-sectors:

- i. Power Sub-sector;
- ii. Petroleum Sub-sector;
- iii. Renewable Energy Sub-sector;
- iv. Waste-to-Energy;
- v. Energy Efficiency and Conservation;
- vi. Energy and Environment;
- vii. Energy and Gender; and
- viii. Managing the future of the sector.

The power sub-sector policy has a goal to increase installed power generation from about 2,000 MW today to 5,000 MW by 2015; and increase electricity access to universal access by 2020. The challenge in the sub-sector is how to attract investments to build the necessary infrastructure for the generation; transmission and distribution of electricity throughout the country to ensure the sustainable development of the sector. Apart from financing, the policy also has another focus on institutional and human resource capacity strengthening as well as regulatory reforms to create a competitive electricity market. The overall goals of the petroleum sub-sector are to ensure the sustainable exploration, development and production of the country’s oil and gas endowment; the sustainable management of the oil and gas revenue for the overall benefit and welfare of all Ghanaians; and the indigenisation of related knowledge, expertise and technology. Regarding this objective, the policy of the petroleum sector focuses on the regulation of the petroleum industry with respect to licensing and operation of the oil and gas companies; improving Ghana’s institutional and human resource capacity; enhancing local content; and fiscal incentives that will ensure maximum benefits to the people of Ghana as well as ensuring transparency in the use and distribution of the oil revenue (Ministry of Energy, 2010).

Regarding renewable energy, the sector has the strategy of increasing the proportion of renewable energy in the total national energy mix and ensuring its efficient production and use. Hence the policy emphasizes on improving production and promoting the efficient use of biomass while encouraging switching from the use of biomass to alternative sources of energy. The policy also aims at engaging Ghanaian engineers and scientists to cooperate with international experts to bring down the cost of solar and wind energy technologies; and creating fiscal and pricing incentives to enhance the development and use of renewable energy. Ghana also has a sound waste-to-energy policy to convert most of the wastes generated in municipal activities, industrial operations and agricultural operations to energy to enable Ghana generate reasonable amount of energy from its wastes. Again, having realized that reduction in energy losses and wastage will lead to significant benefit for the national economy, the Ghana energy sector has also instituted policy measures to promote energy efficiency and conservation through fiscal incentives, awareness creation, institutional and human resource capacity development, and financial intermediation.

Gender issues are also of concern in the energy sector. The sub-sector has a policy to align the issue of frequent use and mismanagement of renewable energy sources, which in their very crude or primary form are used mostly by women, with proper health, safety and environmental standards to promote healthy and sustainable development. There are also policy actions that address future management issues in the energy sector. These policies cover regulations of the sector, mobilisation of investments for the sector, strengthening of human capacity, as well as research and development issues to ensure effective functioning of the sector (Ministry of Energy, 2010).

2.2.2 Power supply and energy consumption

Ghana has two major sources of power supply to the national grid; they are hydro power plants and thermal power plants. The latest update of energy supply and consumption was done in 2011. By the end of 2011 total Installed power capacity available for grid generation was about 2,170 Megawatt (MW). The details of the various sources of generation are shown in Table 2-2. The total electricity generated in 2011 was 11,200 GWh; as against 10,167 GWh in 2010. The 2011 generation comprised 7,561 GWh (67.5 %) hydropower and 3,134 GWh (32.5%) of thermal

power. 2011 recorded significant water inflows into the Akosombo and this accounted for the increased in electricity production over 2010. Out of the 11,200GWh of energy supplied in 2011, 7,976GWh were consumed. Total generation per capita was 452.5kWh/capita while 321.6kWh/capita was consumed per capita (Ghana Energy Commission, 2012).

Table 2-2 Installed Electricity Generation Capacity in 2011

GENERATION PLANT	FUEL TYPE	INSTALLED CAPACITY
		MW
Hydro Power Plants		
Akosombo	Hydro	1,020
Kpong	Hydro	160
<i>Sub-Total</i>		<i>1,180</i>
Thermal Power Plants¹⁴		
Takoradi Power Company (TAPCO)	LCO/NG/diesel	330
Takoradi International Company (TICO)	LCO/NG/diesel	220
Sunon–Asogli Power (SAPP)	NG	200
Tema Thermal Plant1 (TT1P)	LCO/NG/diesel	110
Mines Reserve Plant (MRP)	NG/diesel	80
Tema Thermal Plant2 (TT2P)	NG/diesel	49.5
<i>Sub – Total</i>		<i>989.5</i>
Total		2,169.5

Source: Ghana Energy Commission, 2012

2.2.3 Renewable energy resources and utilization

Apart from the Akosombo¹ and Kpong hydro-power sources, Ghana is well endowed in other renewable energy resources such as wind, solar and biomass that could add to generation mix. The exploitable potential of the renewable resource and associated costs implications are summarized in Table 2-3. Even though solar has the least exploitability (20MW) in Ghana's renewable exploitable potential, solar radiation is fairly distributed in all parts of the country. The monthly average solar irradiation in different parts of the country ranges between 4.4 and 5.6kWh/m²/day (16-20 MJ/m²/day) (Ghana Energy Commission, 2009). This makes solar technological solutions the most plausible for application in all parts of the country, especially, small scale technological solutions for rural applications.

¹ The Akosombo dam, referred in this study as Akosombo, is a hydroelectric dam constructed between 1961 and 1965 on the Volta River Basin in the southern part of Ghana. The dam is 366m wide, 111m high, and 660m long with a reservoir known as the Volta Lake, which is the largest man-made lake in the world (Center for Columbia River History website).

Table 2-3 Ghana's renewable resource potential

Energy Source	Exploitable Potential (MW)	Investment Requirement US\$ (million)
Medium – small Hydro	150-200	200-300
Wind	200-300	250-400
Solar	20	100-150
Modern Biomass /waste to energy	90	90-150
TOTAL	500-600MW	640-900

Source: Togobo, 2012²

Bioenergy resources that are available in Ghana include woodfuels, sawmill residues, agro-fuels and municipal waste. Biomass resources cover about 20.8 million hectares of the land mass of Ghana (23.8 million hectares) and is the source of supply of about 60% of total energy consumed in the country annually. Ghana has over 800 million tonnes stock of woodfuels whilst the potential annual production is estimated to be about 30 million tonnes. Actual logging cut ranges between 2.0 - 2.7 million m³ per annum, which contributes as much as 1.0 to 1.4 million m³ of logging residues on an annual basis. In addition to logging, there are several other sources of biomass reserves including trees of poor form, removed from plantations together with the residues from the harvesting of lumber grade trees. Diseased coconut trees as well as, over-matured coconut and oil palm trees are also good fuel sources for the production of energy. Wood processing residues such as slabs, edgings, off cuttings, sawdust, peeler cores and residues from plywood manufacturing and sawmills are also good potential for bioenergy in Ghana. Other sources includes wood residues from construction of roads and skidding trails in the forest for the haulage of harvested timber, wood from surface mining sites, and wood residues from forest clearings for agriculture (Ghana Energy Commission, 2009).

² Available statistics from literature concerning solar resources of Ghana show some level of ambiguity. For instance, according to OpenEI website publication, NREL in 2008 published 706,055,035MWh/year of solar potential for Ghana, while according to the director of RE of Ghana, Ghana's exploitable potential for solar energy is only 20MW. It is not also indicated if the 20MW is an annual exploitable potential or not. These figures and ambiguity, however, do not affect the results of this study because they are not employed in calculations of the study.

According to the Ghana Energy Commission (2009), agro-fuel potential of Ghana comes from two major sources: crop residues and animal waste. It has been estimated that there is 553,000³ tonnes of maize cob and stalk produced with a potential energy of 17.65 - 18.77 MJ/kg and 19 tonnes of paddy rice husks with a potential energy of 16.14 MJ/kg from agricultural residues. There are also 728,000 tonnes of residues from other farm product such as palm oil, sorghum stalks, millet stalk, and groundnut shell with an energy potential of about 133,870.2TJ/kg (Ghana Energy Commission, 2009) Municipal solid waste is another source of bioenergy in Ghana. Municipal waste is generated in large quantities in the cities, for instance, Kumasi and its suburbs generate up to 1,600 tonnes daily while Accra and its environs generate up to 2,500 tonnes. In general, municipal waste generation in the metropolitan centres varies from 600-800 tonnes per day. However, over the years, Ghana has not put in place specific measures and logistics for the exploitation of municipal waste for energy generation. Despite their prospect for bioenergy generation, municipal solid waste still remain a major problem as wastes in the municipalities in Ghana (Ghana Energy Commission, 2009).

Ghana also has rich resources of small-to-medium and mini hydro sites. Estimates show that there are 22 exploitable mini-hydro sites in the country (Table 2-4) with total potential between 5.6MW – 24.5MW. There are also 937MW of hydro potential from mini-hydro site, which supply 3.7GWh of energy annually.

Table 2-4 Total potential of mini-hydro resources by region

Region	Potential (kW)
Volta	3117 - 12,065
Eastern	226 - 1.150
Brong Ahafo	364 - 1,900
Central and Western	472 - 2,150
Ashanti	720
Northern	913 - 4,420
Upper East and West	499 - 2,100
TOTAL	5591 - 24,505

Source: Energy Commission, 2009

Wind is another rich renewable resource of Ghana. Ghana has about 2,000MW³ of raw potential for wind energy. The wind energy resource map of Ghana is shown in Figure 2-2.

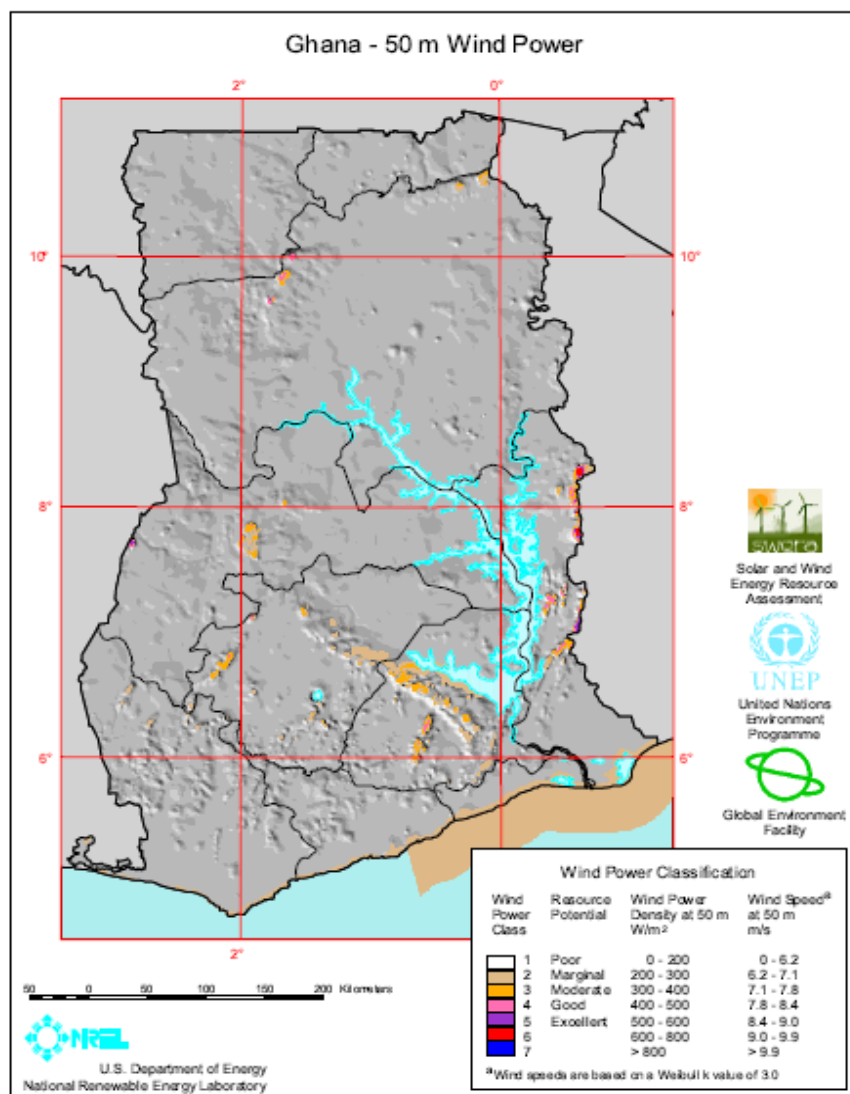


Figure 2-2 Wind energy resource map of Ghana

(Source: Schillings et al., 2004)

Data show that the annual average wind speed along the Ghana-Togo border is above 8 m/s. It is also projected that over 300 MW installed capacity of wind farm could be established at the coastal part to generate over 500 GWh to supplement

³ The wind energy resource potential estimates from literature also show some contradictions: Ghana Energy Commission (2009), for instance, estimates that there are about 2,000MW of raw potential for wind; estimates on MOEP website show about 5,600MW of gross wind electric potential; whiles Table 2-3 show 200-300MW exploitable potential. This study raises the concern about these contradictions; however, they do not affect results of the study because the values are not used in calculations.

the nation's energy supply. The wind direction in the country is predominately southwest. As depicted in Table 2-3, wind has far more resource potential than solar. However, Figure 2-2 portrays that commercial exploitation is mainly possible along the Ghana-Togo border, where the wind speed is high. The coastal areas and some parts of the north also have good wind speed for exploitation. Unlike solar, the uneven distribution of the wind speed in the country do not encourage small scale wind technological solutions, especially for rural applications (Ghana Energy Commission; 2009, Schllings et al., 2004).

2.2.4 Rural energy supply and electrification

Energy utilization in rural Ghana has been based on local exploitation of biomass from ages and is still the major form of energy supply. However, the effort towards introduction and utilization of modern energy systems has also been on the increase. According to Kankam et al. (2009), the long-standing donor-driven initiatives that encourage dissemination and use of solar and biomass energy technologies, LPG, and kerosene in rural communities, as well as the commitment of successive governments toward continuous implementation of rural electrification programs using grid extension are some of the evidence of modern energy utilization efforts in rural Ghana (Kankam et al., 2009). In spite of these effort aimed at energy modernization in the rural areas, majority of the rural populates still rely on local/crude exploitation of biomass, especially the use of firewood for cooking and charcoal processing. However, the associated consequences, such as forest degradation and health implication, regarding this rural practices have been realized, as a result, there have been series of supportive initiatives that are geared towards the implementation of programs that particularly target household energy use. In most cases, these programs are targeted towards the enhancement and efficient utilization of biomass fuels and also encourage a switch from the use of traditional biomass to cleaner alternatives through the provision of subsidies. For instance, the Kerosene Distribution Improvement (KDI) and liquefied petroleum gas (LPG) programs being intensified in rural Ghana seek to, respectively, increase rural affordability of kerosene and encourage the adoption of LPG as the major cooking fuel at the household levels (Kankam et al., 2009; Kemausour et al., 2011;).

The issue of rural electrification in Ghana had been on policy agenda along with national electrification programs, but did not receive much attention in the past years

until recent times. One of the early rural electrification programs was developed in 1972, which had the objective of increasing electricity access to the rural people; however, the achievement of this program is not documented. Along the timeline of Ghana's electrification development, rural electrification programs were mainly envisaged through grid extension. However, in recent times, most of the rural electrification programs have focused on renewable energy technologies, especially solar PV systems thanks to technological advancement and the abundance of solar resource in the country. As indicated in the Ghana Energy Policy, the focus of rural electrification programs on renewables is in line with the national policy to increase the use of renewables for electricity use in rural areas to 30% by 2020. Implementation measures in line with this directive include the establishment of a Rural Electrification Agency (REA) with a Rural Electrification Fund (REF), as an autonomous institution outside the Ministry of Energy, to manage and coordinate efforts and to support local agencies to solicit funding from international donor facilities such as the Global Environment Facility (GEF) and the Clean Development Mechanism (CDM) However, according to Abavana, some of these programs, such as REA and REF were finally not adopted due to the creation of another level of bureaucracy.

The increased effort in rural electrification has introduced many technological solutions, particular, solar PV systems. For instance, the off-Grid Solar PV electrification Project supported by Spanish Government, the Renewable Energy Services Project (RESPRO) Supported by UNDP/GEF and recently the Community Solar Systems (CSS) supported by the Japanese International Cooperation Agency (JICA) are some of the major rural electrification programs aimed at rural development in Ghana The overall administration and implementation of rural electrification programs proceed through a well-organized administrative system and this system has been summarized by Abavana (Figure2-3) to ensure effective implementation of rural electrification programs in Ghana (Abavana, Ghana Energy Commission, 2009; Ministry of Energy, 2010).

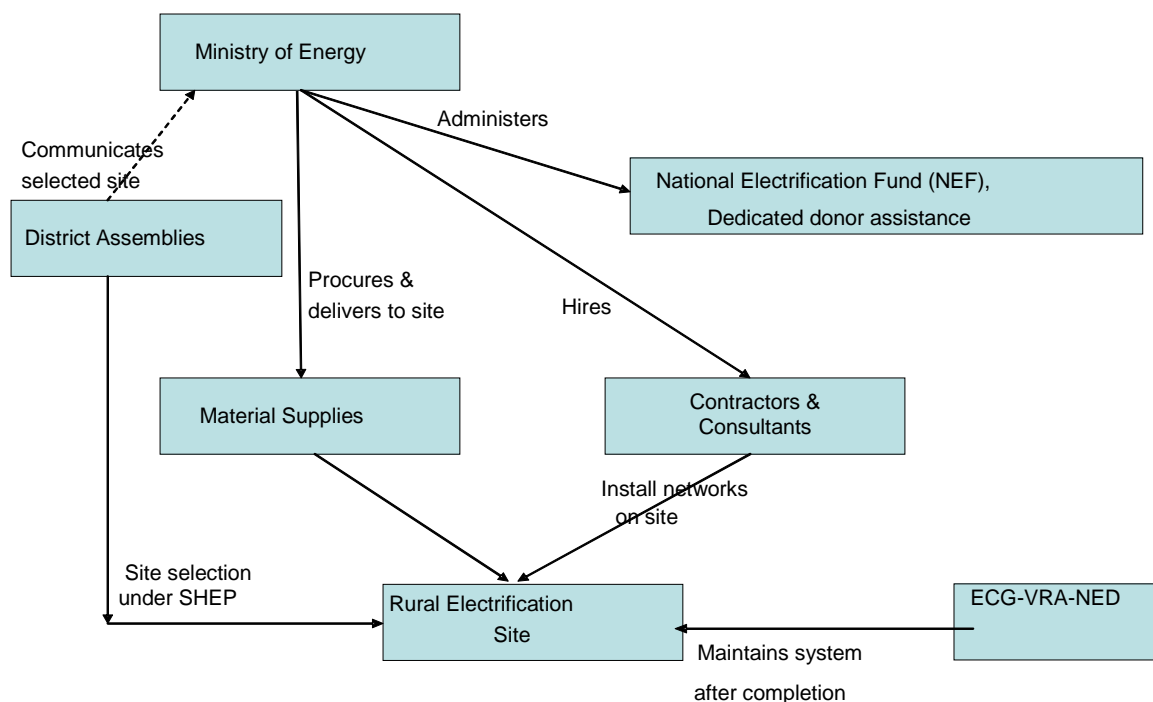


Figure 2-3 Institutional structure for implementation of rural electrification

Source: Abavana' website

3 Materials and research methodology

3.1 The study area

The Community Solar System (CSS) project is in its second pilot stage after confirmation of successful operation in first pilot stage conducted in 2009. Because the project is to be adopted as a national standard for solar PV systems in rural Ghana, the second pilot project is implemented in almost the whole country covering 20 rural communities from 13 districts across 7 regions in Ghana. The scope of this study, however, covers only the southern project area of Ghana consisting of 11 rural communities from 4 districts in 2 regions and 2 other communities (Bomigo, and Tomefa) from the first pilot project, which add up to a total of 13 rural communities from 6 districts in 3 regions in the southern part of Ghana (Figure 3-1). The division of the project area into northern and southern Ghana was necessary during the evaluation exercise and was based on ease of accessibility of the communities to cut down costs of transportation.

The respective names of the communities, districts and regions are presented in Table 3-1.

Table 3-1 Southern JICA CSS project sites

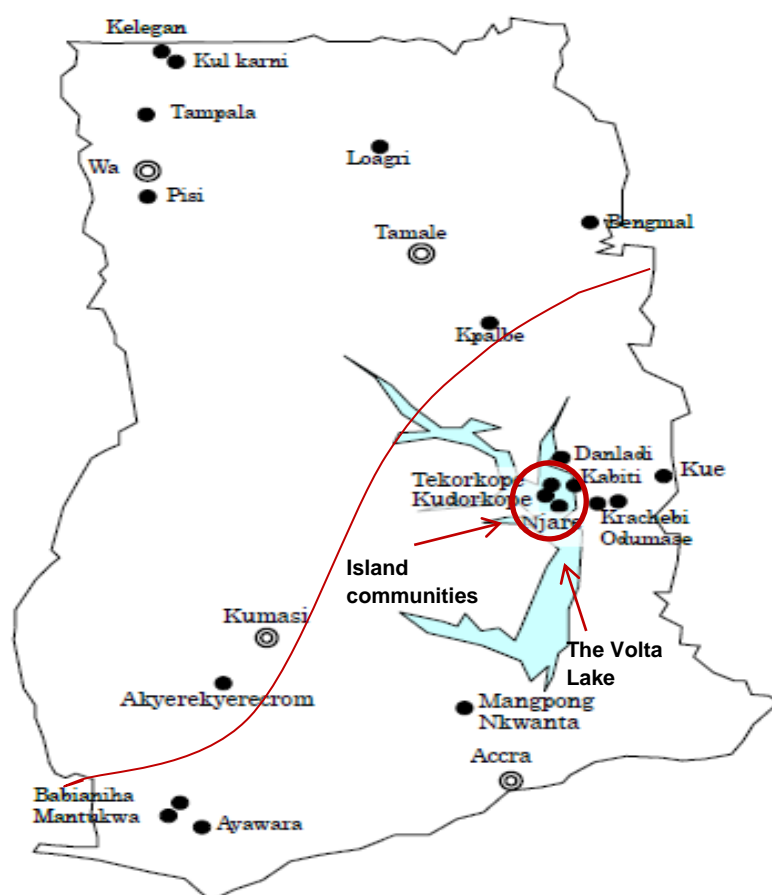
No.	Name of community	District	Region
1	Tomefa (1 st PP)	Ga South	Greater Accra
2	Ayawara	Ellembelle	Western
3	Mantukwa	Ellembelle	Western
4	Bibianiha	Ellembelle	Western
5	Danlaidi	Nkwanta North	Volta
6	Kabiti	Nkwanta South	Volta
7	Kracheibi	Nkwanta South	Volta
8	Kue (Nyambong)	Nkwanta South	Volta
9	Udumase	Nkwanta South	Volta
10	Dambai (1 st PP)	Krachi East	Volta
11	Njare	Krachi East	Volta
12	Tekporkope	Krachi East	Volta
13	Kodorkope	Krachi East	Volta
14	Bomigo (1 st PP)	Keta	Volta

Source: Adopted from JICA Report, 2011

Note: 1st PP refer to first pilot project

These 20 communities were selected from among 60 communities based on selection criteria, which are detailed in Appendix A. Some of the major criteria for selecting the communities, and for that matter, the project sites are; the population of the community, electrification status, distance to the nearest grid connection, and the availability of market. Regarding population, most of the communities' selected had more than 500 people while others had between 200-500 people (Appendix A and B). 'Electrification status' and 'Grid distance' are very important in the selection criteria. Although all of the communities were not electrified, few communities, Dambai, ayawara, and Tomefa, have high tension grid connection poles passing through them, which means grid connection is possible in the near future. However, respectively, some communities are extremely far from grid connection while others are restricted from possible grid extension in the foreseeable future. For instance, Bibianiha and Mantukwa have to be reach by about $1\frac{1}{2}$ hours of foot walk after driving about 1 hour from the district capital to a point where it is no more accessible by car. Again, Njare, Tekporkope, Kodorkope, and Bomigo (Figure 3-1) are island communities and could only be accessed by small boats. In this context, an off-grid electrification solution is very crucial for these and other communities with similar characteristics, hence sustainable implementation of the CSS project and or other off-grid technological solutions is critically important for the provision of electricity.

Figure 3-1 Map of Ghana showing 20 CSS pilot project sites



Source: Adopted from JICA, 2011

Note: Red border distinguishes north and southern part of evaluation demarcation

In rural Ghana, markets are very important; they are the place where the farmers' exhibit and sell their farm produce on a special day in the week. Some communities are market centres and attract other nearby communities, which do not have major market, during a market day, and such communities were very important during the selection of the project sites (JICA, 2011).

3.2 The Community Solar System Project

The Community Solar System (CSS) is a project, which resulted from long and continual studies since 2003. Due to institutional and structural challenges experienced in past renewable energy project, the government of Ghana tasked JICA to conduct a master plan study to address the challenges in June 2003. In addition to the master plan, which recommended the introduction of "Human Resource Development for Disseminating PV Systems in the Republic of Ghana"

project, JICA also proposed the need to introduce sustainable models in PV for rural electrification. Subsequently, the CSS project was adopted based on the merging of ideology of the two complementary projects: the PV models for rural electrification as one part and human resource development scheme as the other part. In JFY2009, the Project introduced 4 Community Solar Systems (CSS) in the southern Ghana to demonstrate the project's sustainability potential in accordance to request from Ghana. After successful demonstration of the project in the first pilot, the project was revised and second 20 pilot projects were planned around the country. This second pilot project, commenced from 2011, is still on-going and is pre-financed by JICA as a loan facility to the government of Ghana (JICA, 2011).

3.2.1 Component of CSS

Beside the human resource development scheme of the whole pilot project, the CSS itself has two components: a PV charging service system/community system and a public PV system.

The concept of the public system is to electrify public facilities such as clinics and schools in un-electrified communities. Due to the importance of such public facilities in rural life, the government of Ghana is very keen in providing electricity to such public facilities in communities which do not have electricity. Unfortunately, it was found difficult to maintain those PV systems because of lack of necessary funds for repairing the systems when troubles happened and for replacing components, especially, batteries when they came to an end of their life span. In order to overcome this challenge, the community charging system was introduced, which provides charging service to the community people to charge mobile phones and rechargeable lanterns. The income from the charging service is used to maintain both the public and the community charging systems and hence, the sustainability of the PV system is much improved. Both the charging PV system and the public PV system constitute the Community Solar System (CSS) (JICA, 2011).

3.2.2 The human resource development scheme

The human resource development scheme has been mentioned earlier to be an integral part of the CSS project. This aspect of the project has been the limitation to the implementation of many rural projects, especially in developing nations, where technology are transferred without adequate capacity development of the affected

and local people, which tend to affect the sustainability of the project after implementation. To improve the sustainability of the CSS project, the human resource development scheme is integrated in its implementation. The overall goal of the scheme is to train and build the capacity of all people related to the project, especially the local rural operators of the system, to confidently operate and offer repair services during operations of the CSS system. The scheme has three sub-components: the human resource for PV rural electrification, the human resource for PV quality control, and the human resource in basic education.

The human resource development sub-component of the scheme principally trained PV technicians (PV Agent and Community Agent) at the national level and in the affected rural areas respectively. The various roles and responsibilities of the PV and Community Agents are outlined in Table 3-2.

Table 3-2 Category of human resource and their expected roles

Human Resource	Role
PVA	PV market creator and service provider in rural areas
Community Agent	PV knowledge disseminator in remote communities
Expected roles of PV and community agents	
PV Agent	Community Agent
Marketing of PV in rural areas	Promoter of PV in the community
Supply chain development of PV components	Operation of PV systems Technical assistance for users of PV systems
Community Agent training PV user training	Support of PV users
Business networking into rural areas	Small business in PV component sales and battery charging

Source: JICA, 2011

The second sub-component supports human resource development for PV product quality control. This is in line with the fact that Ghana is introducing a PV technical standard based on the IEC (International Electric Committee) PV Technical Standard and as such related people need to be trained to equip them with requisite PV testing knowledge.

Finally, the Project supports basic human resource development in the educational system to educate more people who can contribute to the installation, maintenance, promotion and quality control of PV. This sub-component of the project also seeks to work with the Educational Institutions to develop a basic PV education course for their students as long term solutions (JICA, 2011).

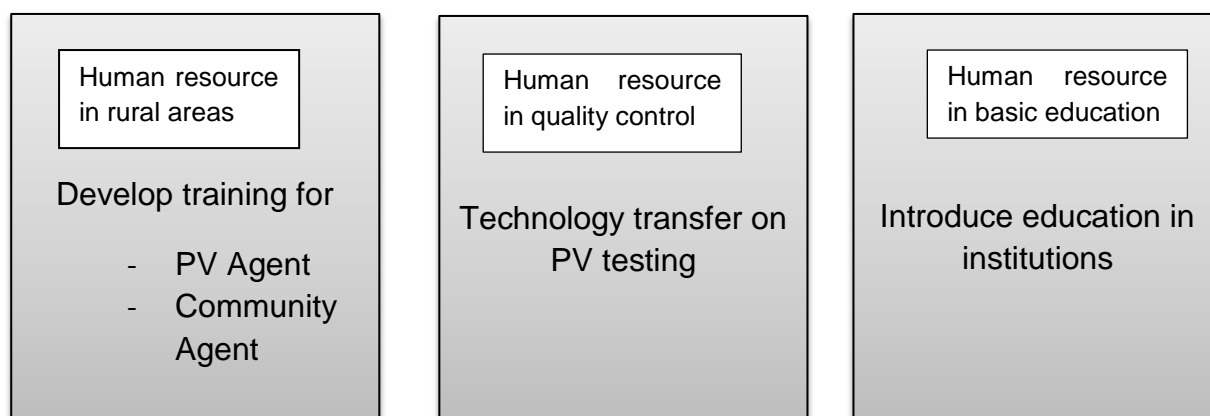


Figure 3-2 Target of human resource development

Source: Adopted from JICA, 2011

The overall human resource development component of the project is an integrated scheme involving all major and related stakeholders of the project. The major stakeholders are categorized into: the Institutions and the Association of Ghana Solar Industry (AGSI). The institutions consist of Ministry of Education (MOEd) and the then Ministry of Energy (MOEn), which is currently the Ministry of Energy and Petroleum (MOEP). Others are: Energy Commission (EC) and Ghana Standard Board (GSB). This integrated human resource development scheme is summarized in Figure 3-3, including the respective roles of the stakeholders.

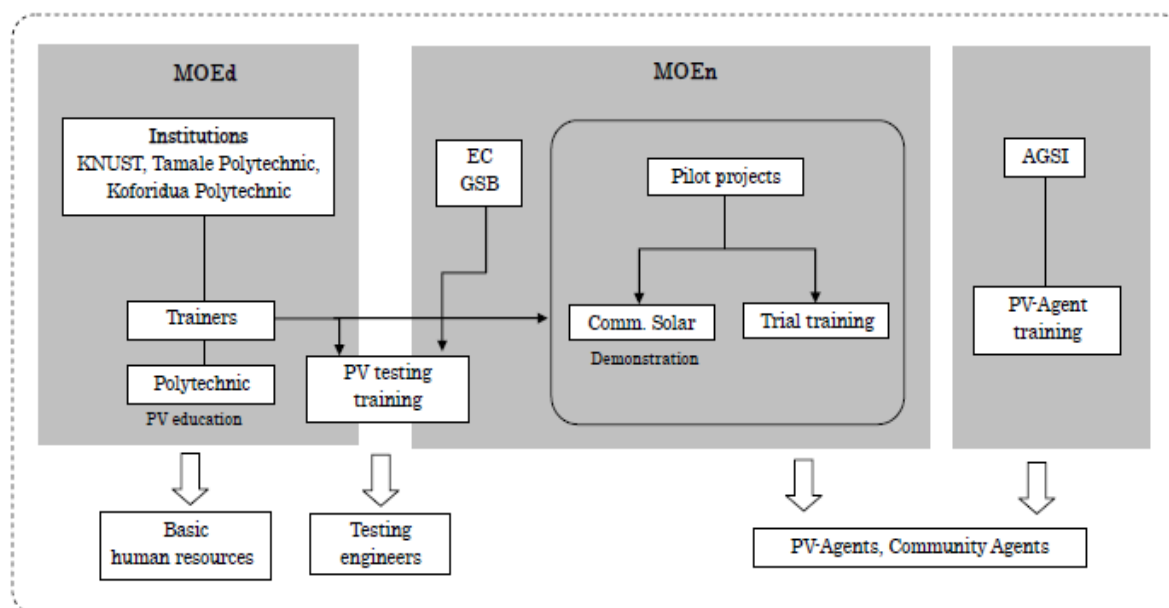


Figure 3-3 Integrated human resource development in the CSS project

Source: JICA, 2011

3.2.3 The CSS management structure

The CSS project also has an integrated management system that is responsible for ensuring effective performance of the CSS system through close monitoring of the system's operations, business operations, income distribution, and maintenance services towards sustainability of the entire project. At the top of the management structure is the MOEn, who play the overall supervisory role. The next level of management is positioned by the District Assembly (DA) who is to supervise the concessionaire⁴ in the rural communities and report to the MOEn. The concessionaire moderates the financial aspect of the business between the CA, the operator of the CSS in the rural areas, and the DA. The last level of the management chain is occupied by the PVA who promotes PV around and offer repair services for fee. This management system is supposed to constitute a chain of information flow about the status of the CSS during its operation to ensure effective management and sustainability of the system. This is called the Community Solar Management (CSM), which is presented in Figure 3-4 (JICA, 2011).

⁴ Concessionaire/Entrepreneur is a special person in the community with management skills to manage business operations and financial aspects of the CSS project.

3.3 Details of CSS system

3.3.1 Configurations of the CSS

The CSS project has two installations: (1) the public (school or clinic) PV installation, and (2) the community (charging service) PV installation. The principal components of the public installation are: panel for direct conversion of sunlight into electricity; a controller for stabilising the battery; battery for storage of energy produced by the PV array; and DC LED Lamps to light the public facility. The major configurational difference between the public system and the charging system is the inclusion of inverter and in some cases, the use of KOWA BOX⁵. The charging system configuration also includes plugs for charging of mobile phones and rechargeable lanterns.

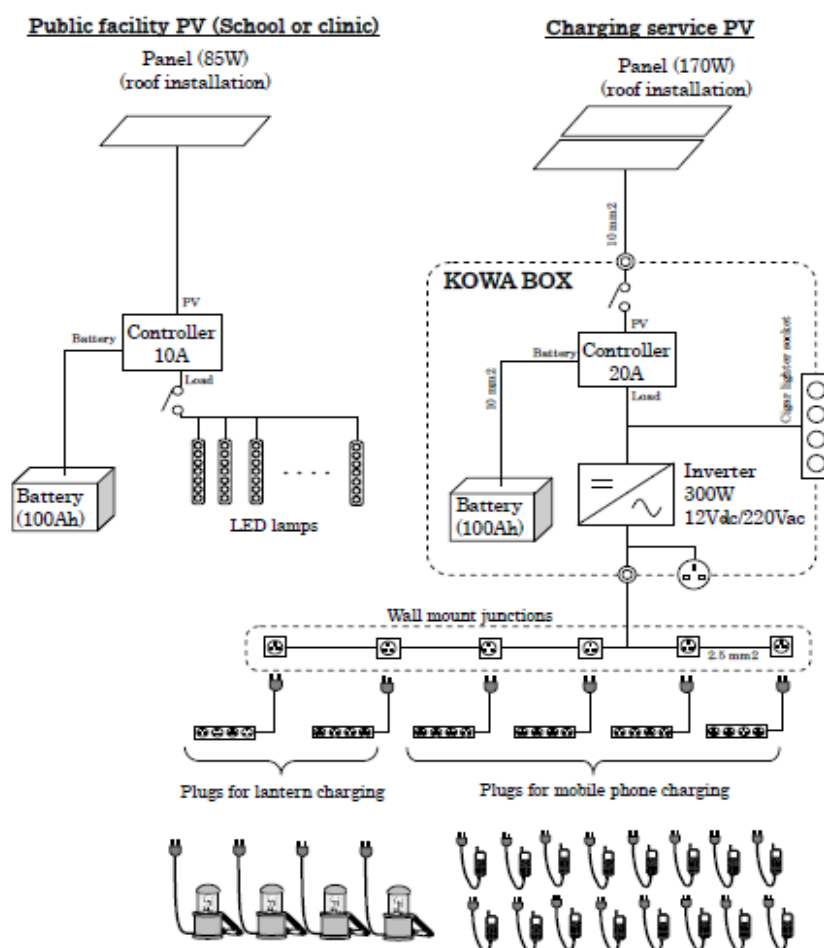


Figure 3-5 Configuration of CSS for public and charging systems

⁵ The KOWA BOX is a rectangular box (see Figure 3-6), which houses the assemblage (controller, battery, inverter, wirings) of the CSS system. It protects the components of the system from wiring abuse and also enhances pre-assembly and advance inspection of CSS installations.

Source: JICA, 2011

The inverter is necessary in the configuration of the charging system to convert the variable direct (DC) output of the PV panel into a utility frequency alternating current (AC) to allow the use of AC appliances, which in this case are mobile phones and rechargeable lanterns. Most of the installations (the charging systems) are housed in KOWA BOX to protect the component due to charging activities and possibility of wiring abuse. The KOWA BOX is locked during operation and the key is kept only by the CA. However, the BOX has a glass window to check the functioning of the inside components, especially the indicators on the controller as depicted in Figure 3-6.



Figure 3-6 KOWA BOX

Source: JICA, 2011

3.3.2 Specifications of standard for CSS

Considering the fact that the CSS pilot projects will be referred as a standard in the future, its size is standardized as a typical one for rural solutions in Ghana. Based on previous studies, the following assumptions were made:

1. Population of around 500 people is common in un-electrified communities;
2. More than half of the population have mobile phones and need charging;
3. Minimum requirement of CSS is to charge more than 50 mobile phones in a day;
4. Charging of car batteries are possible; common battery size in rural areas is 50Ah;

5. Charging of lanterns are not yet common in rural Ghana, however, they can be charged when there is less mobile phone charging demand.

Based on these requirements, the size of the CSS is calculated as follows:

Mobile phone charging

Battery size of a mobile phone: 3.8V, 1.2Ah

Energy to charge 50 mobile phones: $3.8 * 1.2 * 50$ mobile phones = 228Wh

System efficiency:

Heat efficiency of panel = 0.8;

Inverter efficiency = 0.8;

Adaptor efficiency = 0.8;

Charger efficiency = 0.8).

Overall charging efficiency: $0.8 * 0.8 * 0.8 * 0.8 = 0.4$

Necessary energy to charge: $\frac{228Wh}{0.4} = 570Wh$

Average peak sun hours in Ghana: 5 hours

Necessary panel output: $\frac{570Wh}{5hours} = 114W$

Necessary number of panels: 3 * 50W class panels or 2 * 75W class panels

Since mobile phone charging is operated during daytime, not much electricity storage is needed. A battery is used in CSS for the purpose of stabilizing voltage to 12V; hence battery capacity can be 50Ah.

Controller current rating: more than 15A: that is; $\{\frac{150W}{12V} = 12.5A\}$

Battery Charging

Battery size: 12V, 50Ah

Typical current of 50W class panel: 3.3 A

Average peak sun hours in Ghana: 5 hours

Necessary number of 50W class panels: $\frac{50\text{Ah}}{3.3\text{A} \times 5\text{hour}} = 3$ (= 150W) or two of 75W class panels.

Controller current rating: more than 15A: that is; $\{\frac{150\text{W}}{12\text{V}} = 12.5\text{A}\}$

Based on the above calculations, the size of the CSS is specified as shown in Table 3-3.

Table 3-3 Specification of CSS standards

Facility	Specification	
	Components	Size
Charging station	PV Panel	150W
	Controller	15A—20A
	battery	100Ah
	Inverter	150W—300W
Public PV	PV panel	75W
	Controller	10A
	Battery	100Ah
	LED Lamp	10*1.5W

Source: Adopted from JICA, 2011

3.3.3 Business and financial details of CSS

Business feasibility can be evaluated by considering whether income can cover the necessary cost and the investment recovery. In this study, charging station is only 150W mobile-phone and lantern charging system. Battery charging system is not included because it is not profitable. The following is a feasibility study of the charging service in terms of cash flow.

Assumptions:

System size 150W; possible number of charging in a day: 15mobile phones/day⁶

Lantern: 4lanterns/day

⁶ Considering the population selection criteria for the project sites (Appendix A), most of the selected communities (Appendix B), have more than 500 people. The number of people with mobiles phones could not be estimated directly, however, 15mobile phones/day used in cash flow calculations is minimal enough to ensure high confidence level for the financial analysis of CSS business operations.

Charging fees:

Mobile phone: 50 pesewas/mobile phone

Lantern: 70 pesewas/lantern

Operation days in a year: 300 days/year

From the assumption, annual income from phone charging can be calculated as follows:

$$50p * \frac{15\text{phones}}{\text{day}} * 300\text{days} = \text{GH}\text{¢}2,250 \approx \$883.045^7$$

Likewise, annual income from lantern charging can be calculated as follows:

$$70p * \frac{4\text{lanterns}}{\text{day}} * 300\text{days} = \text{GH}\text{¢}840$$

Then, investment and annual income are summarized as in the following table.

Table 3-4 CSS investment and income

Initial investment		Annual income	
Component	Cost GH¢	Service	Income GH¢
Panel (150W)	1,000	Phone charge	2,250
Battery (100Ah)	350	Lantern charge	840
Controller (20A)	300		
Inverter (300W)	100		
Others	500		
Total	GH¢2,250	Total	GH¢3090
	≈ \$883.045		≈ \$1,212.72

Source: Adopted from JICA, 2011

In order to specify the annual cash flow, some operational costs have to be considered.

Assumptions:

⁷ Note: 1 GHS = 0.392465 USD; 1 USD = 2.54800 GHS. Mid-market rates: 2014.03.14.23.34.UTC (XE currency converter website)

1. Solar batteries which need replacement in every 5year; hence requires reserve of GH¢ 70/year;
2. Other purchases such as adapters and extension cords: GH¢ 100-200/year;
3. CA wage is \approx GH¢ 50/month \rightarrow GH¢ 600/year;
4. Management wage (care takers) \approx GH¢ 50/month \rightarrow GH¢ 600/year;
5. Average concession fee = GH¢ 600/year

From this analysis, the overall cash flow of the project is summarized as follows:

Table 3-5 Annual operational cash flow of CSS

Annual operations and services		Cash flow GH¢
Annual income	Business operations	3,090
Annual expenditure	Maintenance	300
	CA and other management fee	1,200
	Concessionaire fee	600
Net annual income		990 \approx \$388.54

Source: Adopted from JICA, 2011

The results show that annual income of GH¢990 \approx \$388.54 can be accrued from the business operation of the CSS charging system. The number of years to recover the investment cost is shown as follows:

Total investment costs = GH¢2,250;

Annual net income = GH¢990

Recovery year: $\frac{2250\text{Gh}\text{¢}}{990\text{Gh}\text{¢}} = 2.3\text{years} \approx 3\text{years}$.

This implies that the CSS has very high business feasibility potential. Since the business aspect is supposed to ensure maintenance of the complete CSS systems, it implies that the CSS project has very high prospect of being sustainable. In addition, unlike most rural electrification project, the CSS project also considers human resource development and a well-structured management system. The study advocates that if all of these component of the project should function and perform as expected, then the implementation, operation and the management of the CSS

project must be much improved and hence lead to a sustainable rural solution in Ghana. In order to ascertain this fact, the study undertakes an evaluation of the CSS system in three aspects:

- a. Technical aspect: evaluation of system and components performance;
- b. Economical aspect: evaluation of business performance; and evaluation of management structure performance and
- c. Social aspect: implied evaluation⁸ of effectiveness of human resource development at the local level; and evaluation of impacts of CSS project on the lives of the rural people.

3.4 CSS project evaluation

The evaluation of the CSS pilot project was carried out between 09.01.2014 and 25.01.2014 as part of the MOEP's annual monitoring exercise as the supervisor of the CSS pilot project. The scope of this study covers the evaluation of systems from 13 communities. On the average, one day was spent on each community for transportation and evaluation of both public and the charging systems. The evaluation team comprised of four members, namely: Project Manager (from MOEP); Project Monitoring Officer (from MOEP); a Research Assistant (the author from BTU-Cottbus); and a PA Agent (from MOEP). The team was further divided into team 'A' and team 'B' consisting of two members in each team for the north and southern part of Ghana respectively. As mentioned earlier, the scope of this study covers only the evaluation of team 'B', which covers the southern part of Ghana.

The tools used in the evaluation exercise are: Garmin etrex GPS tracker, a multi-meter, a voltage detector (electric tester), an evaluation guide question, and a camera (Samsung galaxy SII smart phone).

3.4.1 Evaluation process

The evaluation principally involved two forms of activities: first, interview with the community agent or the concessionaire using the evaluation guide questions. If both the CA and concessionaire were not available at the time of visit, a care taker involved in the business operation of the charging system was interviewed. After the

⁸ Implied evaluation of the human resource development aspect of the project means that the 'human resource development' is not evaluated directly during the evaluation, but its success and effectiveness on the project are analysed and deduced based on other evaluation results such as performance of CAs in the operation and use of the systems in the rural communities.

interview, the working status of each component of both systems were checked with the multi-meter and personal inspection to respectively identify which of the components were not working and which were mishandled. In this case, if a system was found to be working, and in full operation after inspection, then there was no need to test. In the case of the public system, the inspection was done by opening and closing of the circuit by turning the switch 'On' and 'Off' to see if the lamps illuminate (light-up). If the lamps do not light-up after turning the switch on, then there was the need for checking each component to identify which was not functioning. The same process was used to ascertain the charging status in the case of the charging system. The panels of each system were also thoroughly checked to ascertain if they were kept clean, and whether or not the cleaning exercise was done correctly. In addition, the Garmin etrex GPS tracker was used in each community to take the GPS coordinate separately for both charging and public systems

3.4.1.1 The interview process

Most of the interviews were conducted in the rural communities; however, the office of the DA was the first point of call upon arrival in each district to introduce the team and to enquire about the assembly's knowledge of the project status. The interview guide questions were structured into 5 thematic areas covering the working status of the system, system's component performance, management structure performance, business performance, and system's impacts on community. Details of the questions are shown in Appendix C. The questions were open-ended, which allowed respondents to express their own views and were recorded immediately onto the evaluation guide sheets. The same approach was used in all the communities, however, personal observation and experiences were also recorded and all lead to the collection of the needed qualitative data.

The interviews were conducted one-on-one with the respondent but in a more interactive and discussion form. In most cases, other community or relatives would join the respondent during the discussion but the focus was always on the respondent, which was either the CA, concessionaire or both or a care taker in the absence of the two.



Figure 3-7 Interview with a Community Agent during evaluation

Source: *Evaluation pictures, 2014*

The interview, discussion and inspection exercise in a community lasted for about 30-45 minutes for the charging system and about 15-30 for the public system and the major tool employed was the evaluation guide questions.

3.4.1.2 Component check for CSS

Normally, a system was preliminary inspected even before the interview started. If the system was not working, the components were then checked to identify which was not functioning. The electric tester and the multi-meter were used respectively to check the presence of voltage and the functioning of the system's components.

If a system was found not working after inspection, the solar panels were first checked followed by the other components. First, the connection between the solar panels and the regulator (controller) was disconnected (Figure 3-9). Then the multi-meter was turned to read DC voltage and set to 600v above the rating of the panels. The polarities of the panels were checked and the negative and positive contacts from the meter were connected to the negative and positive of the panels respectively, with the help of the alligator clip, to check if a panel was functioning. After checking the functioning of the panels, they were re-connected and the other components were checked as well. The focus of components check was to ascertain whether or not a component was functioning. After each check, the status was

recorded as working or not working. The results of the evaluation are summarized in the next section.



Figure 3-8 System components check at evaluation

Source: Evaluation pictures, 2014

4 Results and discussion

4.1 Evaluation results

This section entails the summary of results for the CSS project evaluation based on the technical, social and economic aspects. The results are presented in order of the systems performance, system's components performance, management structure performance, system's business performance, and system impacts assessment respectively.

Table 4-1 Results of system performance

Community		System Status							
		Working status		Usage period		Damage period		Repair/Services	
		CS	PS	CS	PS	CS	PS	CS	PS
1	Com.: Bibianiha Dist.: Ellembelle Reg.: Western	Not working	Not working	About 1year	About 1year	About 2years	About 2years	No Repair	No Repair
2	Com.: Mantukwa Dist.: Ellembelle Reg.: Western	Not working	Working	About 2years	About 3years	About 1year	No damage	No repair	No repair

3	Com.: Ayawara Dist.: Ellembelle Reg.: Western	Not working	Working	About 3years	About 3years	About 1month	No damage	No repair	No repair
4	Com.: Tomefa Dist.: Ga South Reg.: G. Accra	Working	Working	4years	4years	days	No damage	Yes	No repair
5	Com.: Danladi Dist.: N. North Reg.: Volta	Working	Working	2years	years	Some days	No damage	Yes	No reapi
6	Com. Kabiti Dist.: N. South Reg.: Volta	Working	Working	About 3years	About 3years	Some days	No damage	Yes	No repair
7	Com.: Kue Dist.: N. South Reg.: Volta	Not working	Working	1years	About 3years	2years	No damage	No Repair	No repair
8	Com.: Odumase Dist.: N. South Reg.: Volta	System was stolen	Working	Not specific	No evaluation	Not specific	No evaluation	Not specified	No evaluation
9	Com.: Kracheibi Dist.: N. South Reg.: Volta	Working	Working	About 3years	About 3years	Some days	No damage	Yes	No repair
10	Com.: Njare Dist.: K. East Reg.: Volta	Working	Working	About 3years	About 3years	No damage	No damage	No repair	No repair
11	Com.: Kudorkope Dist.: K. East Reg.: Volta	Working	Working	About 3years	About 3years	No damage	No damage	No repair	No repair
12	Com.: Tekporkope Dist.: K. East Reg.: Volta	Working	Working	About 3years	About 3years	No damage	No damage	No repair	No repair
13	Com.: Bomigo Dist.: Keta Reg.: Volta	Working	Working	4years	4years	Some days	No damage	Yes	No repair

Note: Com.-Community; Dist.-District; Reg.-Region; CS-Charging System; PS-Public System

Table 4-2 System components performance

	Community	System Components											
		Panels		Controller		Battery		Inverter		Lamps		KOWA BOX	
		CS	PS	CS	PS	CS	PS	CS	PS	CS	PS	CS	PS
1	Com.: Bibianiha Dist.: Ellembelle Reg.: Western	Working	Working	Removed	Working	Working	Working	Damaged	N/A	N/A	Removed	Damaged	Not provided
2	Com.: Mantukwa Dist.: Ellembelle Reg.: Western Res.:	Working	Working	Working	Working	Working	Working	Damaged	N/A	N/A	Working	Present	Not provide
3	Com.: Ayawara Dist.: Ellembelle Reg.: Western	Working	Working	Working	Working	Working	Working	Damaged	N/A	N/A	Working	Present	Not provide

4	Com.: Tomefa Dist.: Ga South Reg.: G. Accra	Working	Working	Changed once	Working	Changed once	Working	Changed thrice	N/A	N/A	Working	Not Provided	Not provided
5	Com.: Danladi Dist.: N. North Reg.: Volta	Working	Working	Working	Working	Working	Working	Working	N/A	N/A	Working	Present	Not provide
6	Com. Kabiti Dist.: N. South Reg.: Volta	Working	Working	Working	Working	Working	Working	Working	N/A	N/A	Working	Present	Not provided
7	Com.: Kue Dist.: N. South Reg.: Volta	Working	Working	Working	Working	Working	Working	Damage d	N/A	N/A	Working	Damage d	Not provided
8	Com.: Odumase Dist.: N. South Reg.: Volta Res.:	Stolen	No evaluation	Stolen	No evaluation	Stolen	No evaluation	Stolen	No evaluation	N/A	N/A	Stolen	No evaluation
9	Com.: Kracheibi Dist.: N. South Reg.: Volta Res.:	Working	Working	Working	Working	Working	Working	Frequent problems	N/A	N/A	Working	Present	Not provided
10	Com.: Njare Dist.: K. East Reg.: Volta Res.:	Working	Working	Working	Working	Working	Working	Working	N/A	N/A	Working	Present	Not provide
11	Com.: Kudorkope Dist.: K. East Reg.: Volta Res.:	Working	Working	Working	Working	Working	Working	Working	N/A	N/A	Working	Present	Not provide
12	Com.: Tekporkope Dist.: K. East Reg.: Volta Res.:	Working	Working	Not seen	Working	Not seen	Working	Not seen	N/A	N/A	Working	Not seen	Not provide
13	Com.: Bomigo Dist.: Keta Reg.: Volta Res.:	Working	Working	Working	Working	Working	Working	Change d once	N/A	N/A	Working	Present	Present

Table 4-3 Management structure performance

	Community	Project monitoring/ Reporting structure			Management records	
		CA reporting to Concessionaire	Concessionaire reporting to DA	DA reporting to MOEP	Type of Book	Status of Book Keeping
1	Com.: Bibianiha Dist.: Ellebelle Reg.: Western	CA do not report to concessionaire	No report to DA	DA not aware of project	Daily book	Daily book not seen
2	Com.: Mantukwa Dist.: Ellebelle Reg.: Western	CA do not report to concessionaire	No report to DA	DA not aware of project	Daily book	Daily book not seen
3	Com.: Ayawara Dist.: Ellebelle Reg.: Western	Yes-CA reports system status	No report to DA	DA not aware of project	Daily book	Bad records
4	Com.: Tomefa Dist.: Ga South Reg.: G. Accra	Yes-CA reports system status	No report to DA	Concessionaire and CA report to MOEP direct	Daily book	Good records
5	Com.: Danladi Dist.: N. North Reg.: Volta	Yes-CA reports system status	Yes-concessionaire report to Da	No-DA don't report to MOEP	Daily book	Good records
6	Com. Kabiti Dist.: N. South Reg.: Volta	Yes-CA reports system status	Yes-concessionaire report to Da	No-DA don't report to MOEP	Daily book	Good records
7	Com.: Kue Dist.: N. South Reg.: Volta	Yes-CA reports system status	Yes-concessionaire report to Da	No-DA don't report to MOEP	Daily book	Daily book not seen
8	Com.: Odumase Dist.: N. South Reg.: Volta	Yes-CA reports system status	No- system status not reported	No-system status not reported	Unknown	N/A
9	Com.: Kracheibi Dist.: N. South Reg.: Volta	Yes-CA reports system status	No- system status not reported	No- system status not reported	Daily book	Very good records
10	Com.: Njare Dist.: K.East Reg.: Volta	Yes-CA reports system status	Yes-concessionaire report to Da	No- system status not reported	Daily book	Good records
11	Com.: Kudorkope Dist.: K. East Reg.: Volta	No-CA don't report system status	No reports	No reports	Daily book	Book not made available
12	Com.: Tekporkope Dist.: K. East Reg.: Volta	No-CA don't report system status	No reports	No reports	Daily book	Book not made available
13	Com.: Bomigo Dist.: Keta Reg.: Volta	No-CA don't report system status	No reports	CA-report directly to MOEP	Daily book	Very good records

Table 4-4 System business performance

	Community	CSS Annual Cash Flow							
		No. of phones charged		Annual income GH¢		Annual expenditure GH¢		Net annual income GH¢	
		2012	2013	2012	2013	2012	2013	2012	2013
1	Com.: Bibianiha Dist.: Ellembelle Reg.: Western	No records	No records	No records	No records	No records	No records	-----	-----
2	Com.: Mantukwa Dist.: Ellembelle Reg.: Western	No records	No records	No records	No records	No records	No records	-----	-----
3	Com.: Ayawara Dist.: Ellembelle Reg.: Western	No records	No records	No records	No records	No records	No records	-----	-----
4	Com.: Tomefa Dist.: Ga South Reg.: G. Accra	No records	10130	No records	4,052	No records	No records	-----	4,052.00
5	Com.: Danladi Dist.: N. North Reg.: Volta	2110	850	631.20	342.00	2,140.48	105.00	-1,509.28	237.00
6	Com. Kabiti Dist.: N. South Reg.: Volta	No records	No records	1,040.00	443	1,365.00	605	-325.00	-162.00
7	Com.: Kue Dist.: N. South Reg.: Volta	No records	No records	No records	No records	No records	No records	-----	-----
8	Com.: Odumase Dist.: N. South Reg.: Volta	No records	No records	No records	No records	No records	No records	-----	-----
9	Com.: Kracheibi Dist.: N. South Reg.: Volta	No records	No records	1,817.00	1,316.00	861.60	499.00	955.40	187.00
10	Com.: Njare Dist.: K. East Reg.: Volta	No records	No records	1,026.00	555.00			1,026.00	555.00
11	Com.: Kudorkope Dist.: K. East Reg.: Volta	-----	-----	-----	-----	-----	-----	-----	-----
12	Com.: Tekporkope Dist.: K. East Reg.: Volta	---	-----	-----	-----	-----	-----	-----	-----
13	Com.: Bomigo Dist.: Keta Reg.: Volta	-----	-----	1,366.00	918.30			1,366.00	918.30

Table 4-5 System impacts assessment

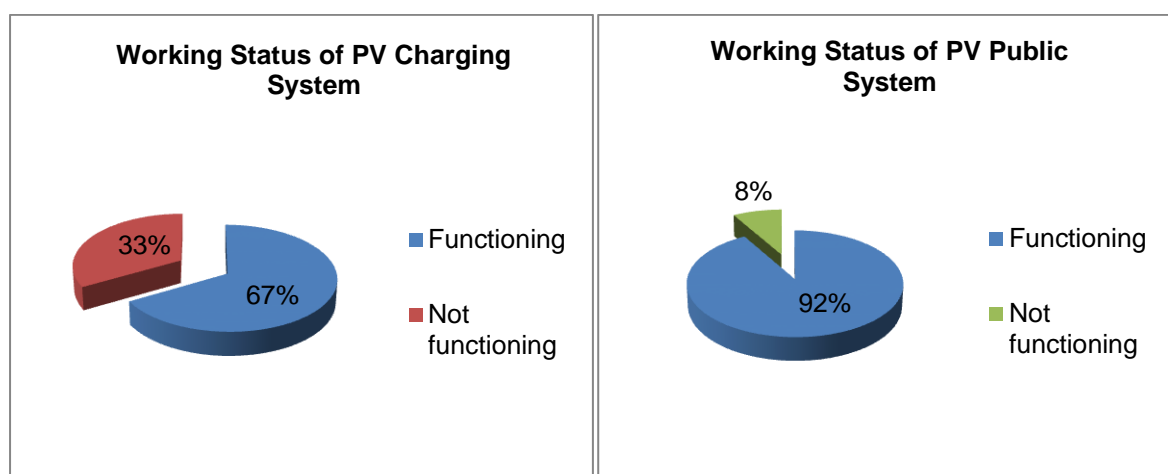
	Community	System Impacts Assessment			
		System Acceptance	System Performance	Electricity Provision	System Recommendation
1	Com.: Bibianiha Dist.: Ellembelle Reg.: Western	Well accepted	Not very sure due to early damage	System not enough to watch television	Recommendable for provision in un-electrified communities
2	Com.: Mantukwa Dist.: Ellembelle Reg.: Western Res.:	Well accepted	Satisfied with system performance	Very satisfied with system	Recommendable for provision in un-electrified communities
3	Com.: Ayawara Dist.: Ellembelle Reg.: Western	Well accepted	Very satisfied with system performance but problem with frequent inverter damage	Satisfied, community has different street electrification system (Spanish Project)	Recommendable for provision in un-electrified communities
4	Com.: Tomefa Dist.: Ga South Reg.: G. Accra	Well accepted, but need more charging system	Highly satisfied, additional system has been provided, but inverter problem	Satisfied, but extra electrification needed	Recommendable for provision in un-electrified communities
5	Com.: Danladi Dist.: N. North Reg.: Volta	Well accepted	Very satisfied with system performance, but inverter problem	Satisfied, but extra electrification needed	Recommendable for provision in un-electrified communities
6	Com. Kabiti Dist.: N. South Reg.: Volta	Well accepted	Very satisfied with system performance, but inverter problem	Satisfied, but extra electrification needed	Recommendable for provision in un-electrified communities
7	Com.: Kue Dist.: N. South Reg.: Volta	Well accepted	Satisfied with initial system performance, but inverter problem	Satisfied, but extra electrification needed	Recommendable for provision in un-electrified communities
8	Com.: Odumase Dist.: N. South Reg.: Volta	System stolen	No evaluation	No evaluation	No evaluation
9	Com.: Kracheibi Dist.: N. South Reg.: Volta	Well accepted	Highly satisfied, additional system has been provided	Satisfied, but extra electrification needed	Recommendable for provision in un-electrified communities
10	Com.: Njare Dist.: K. East Reg.: Volta	Well accepted	Satisfied with system performance	Satisfied, but extra electrification needed	Recommendable for provision in un-electrified communities
11	Com.: Kudorkope Dist.: K. East Reg.: Volta	Well accepted	Satisfied with system performance	Well satisfied with system	Recommendable for provision in un-electrified communities
12	Com.: Tekporkope Dist.: K. East Reg.: Volta	Well accepted	Satisfied with system performance	Well satisfied with system	Recommendable for provision in un-electrified communities
13	Com.: Bomigo Dist.: Keta Reg.: Volta	Well accepted	Highly satisfied with system performance	Highly satisfied with system	Recommendable for provision in un-electrified communities

4.2 Discussions

4.2.1 Technical evaluation

Broad overview of the working status of the CSS project in the 12 communities evaluated is presented in Figure 4-1. There are three communities (Bibianiha, Mantukwa and Kue) whose charging systems were completely out of use, while Ayawara had temporal problem with the inverter. The 4 communities represent 33% as those with non-functioning systems whereas 8 communities represent 67% as those whose systems were functioning. Unfortunately, 1 community (Odumase) had its entire PV charging system stolen, but the public system could also not be assessed as well for evaluation. Regarding the public systems, only 1 community, Bibianiha, had its system out of use. This represents 8% while the remaining 11 communities represent 92% respectively.

Figure 4-1 Performance of charging and public systems of CSS

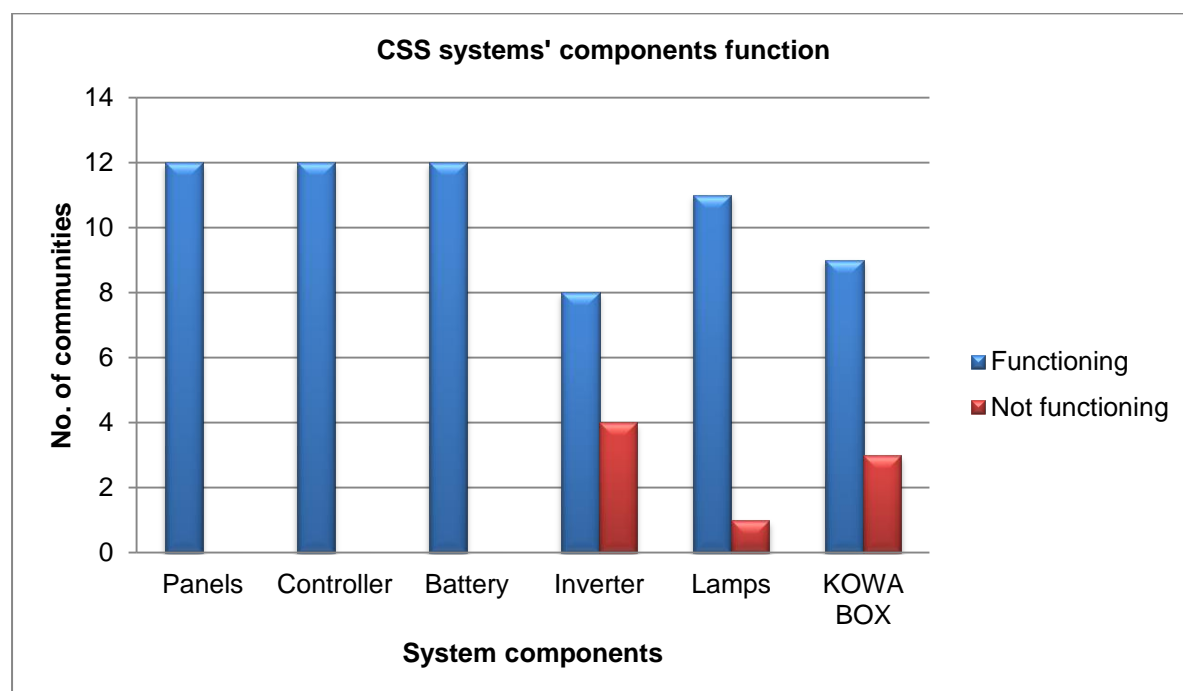


The broad aspect of the technical evaluation in this study focuses on the performance of the CSS project as well as the functioning of its components. These are critical considerations to ascertain whether or not the CSS project is capable of meeting its operational and design life span of 20 years in the Ghanaian rural settings. Since the pilot project was initiated in 2011, it implies the maximum operational time of the project up-to-date is 3 years. The question is if a project which is supposed to last for 20 years could record 33% damages in 3 years, as in the case of the charging systems, then how sustainable could the project be in 20 years? There are no direct answers to this question because there are many contributing factors such as technology integration and effectiveness of the human resource development component of the project, which could affect the operation of the project. Regarding

technology integration, Gómez et al (2010), have identified some technological issues such as misuse of material, sophisticated components and assumption of neutrality⁹ as some characteristic issues that hinder renewable energy electrification programs. However, it can be assumed that these issues are well addressed in the CSS project, especially, in the human resource development aspects of the project. The project design is also relatively simple with simple components and connections. In addition, the operations of the systems do not require much interaction or input from the users and the use of the KOWA BOX, which houses the rests of the components of the system, prevents or reduces the extent of misuse by users.

The analysis of the technical evaluation results in this study identifies that the functioning of the CSS components is a major contributing factor to its operational performance. The inverter, lamps and KOWA BOX were the three components, which recorded damages in some of the communities, Figure 4-2. The KOWA BOX purposefully houses the components of the systems and do not have much effects on the system's performance. Only one community (Bibianiha) also had the lamps of the public system removed, causing the damage of one public system.

Figure 4-2 Performance of CSS system components



⁹ Assumption of neutrality, as explained by Gómez et al. (2010), is an assumption that technology is neutral and therefore allows automatic performance independence of users.

The inverters are important components of the charging system; this is realized in all four communities whose charging systems were not functioning, all the four communities also recorded damages of inverters. The effect of the inverters is also reflected in the relatively lower performance of the charging system, which recorded four damages as against one of the public system, which do not have inverters in their designs. Apart from the four communities, there are other communities who had changed their inverters due to damages. For instance, in Bomigo, the inverter had been changed once; Tomefa had also changed their inverter on three occasions, while Krechaibi complained of frequent damages of their inverter.

The inverter problem identified in this study is likely associated with misuse of the charging system or the quality of the inverters. Misuse of the system could be charging of more mobile phones and lanterns at a time. Overcharging of gadgets during the day can cause excessive discharging of the battery and higher current flow to the inverter, which could subsequently affect the functioning of the inverter. This overcharging problem is illustrated in Figure 4-5. Another misuse is likely to stem from charging of gadgets in the night. Since the charging system is designed for charging only in the day time, charging of gadgets at night could cause over-discharging of the battery, although there were no records of damage batteries, there is the high prospect that the lifespan of over-used batteries will be shortened.

Figure 4-3 Evidence of over-charging gadgets in a community



Revisiting the issue of technological integration, assumption of neutrality and misuse of materials as a major issue confronting renewable energy programmes, as lamented by Gómez et al (2010), this study emphasizes that misuse of technology is the underlying factor regarding technology integration in rural Ghana. In this study, the major technological barriers identified have to do with operational performance of the system components and misuse of the technology. Even though, the inverter is identified with frequent operational problems, the operational capacity of batteries in the whole system design is crucial to stabilize voltage and the entire system even in the case of misuse of the system; however, this is not a major technological problem since such problems can be avoided with appropriate operation and use of the system by the rural people. In the Ghanaian context, the successful integration of the CSS technology in the rural settings largely depends on the operation and use of the system by the local users in the rural areas, which intend, depends on the effectiveness of the human resource development components of the whole project. It is also important that the quality of inverters and other system component are not compromised in future development to ensure that components of high quality are purchased and used to avoid or reduce frequent damages.

4.2.2 Socio-Economic evaluation

4.2.2.1 Management structure performance

The management of the CSS project has been perceived through a well prescribed framework of management system called the Community Solar Management (CSM). The hierarchy of authority and their respective responsibilities and roles in the CSM framework have been outlined in section 3.2.3. This CSM system describes a chain of integrated close monitoring roles among the stakeholders to ensure effective management of the CSS project. The prescribed monitoring roles of the CSM mandate that the CA, who is the operator of the system at the rural level, keeps a 'Daily Book' in which daily records of the number of charged services and money paid is supposed to be recorded. The income from the charging services are kept and managed by a concessionaire who has business skills. The concessionaire also keeps 'Income and Expenditure Book' in which all expenditure and monthly income are recorded. The concessionaire is also responsible for paying the CA upon an agreed percentage from the monthly income; take a percentage to the DA; pay himself; and reserve a percentage in a bank for

maintenance of the two systems. In the same way, the DA is responsible for paying quarterly monitoring visit to the project sites in the various beneficiary communities in the district to ensure effective operation of the system and to be kept up-dated of the systems' status. In this role of the DA, they are also responsible for keeping a 'Summary Book' containing the summary of all activities and report annually to the MOEP, the overall supervisor of the project. The MOEP is also responsible for paying annual visit to the DA and project site for monitoring and evaluation of the system, and hence the individual roles of the stake holders of the CSM system is supposed to collectively ensure effective management and sustainability of the CSS projects.

The evaluation results, however, reveal that the perceived effect of the CSM system has not fully impacted on the CSS project. The results show that majority of the CAs do not report to the concessionaires while others are not even aware of the concept of the management system. In such communities, the income is entirely managed and used by the community members in which the chief of the community are often involved. The roles of the concessionaires have also not been effective. The few concessionaires who are active in the project do not report to the DAs most of the times after collecting the money from the CA and are also unable to keep progressive records of the income distribution. Out of the six districts of the thirteen community project sites, only three DAs are aware of the on-going CSS projects in their districts. However, none of the DAs have ever visited the project in the communities; only one DA receives money from the concessionaire while none of the DAs has ever reported to the MOEP. It is also identified that the two communities (Tomefa and Bomigo) of the first pilot projects have performed better in management of the system than the remaining communities. Tomefa for instance, although does not report to the DA, has been able to raise money in the bank from its business operations. Bomigo also report directly to the MOEP because the CA is also the concessionaire and does not report to the DA (Table 4-3).

The broad implication of the above observations is that the ineffectiveness of the CSM system is likely to cause the sustainability of the CSS project in the medium-to-long term. First and foremost, the monitoring and information dissemination chain among the management stake holders is totally broken. This is as a result of the long chain of stake holders involved in the CSM system, which involves reporting from CA

→concessionaire →DA →MOEP (Figure 3-4). The long chain has undoubtedly created some level of bureaucracy in the CSM system resulting in the ineffectiveness of monitoring and information flow. The information flow between the MOEP and the two communities, Bomigo and Tomefa, who, respectively, do not report to concessionaire or DA and DA are evidence of the effect of the long chain bureaucratic management system of the other communities. Another facet of the problem has to do with effective management and distribution of the income from the project's business operations.

The overall conception of the business operation in line with the charging system is to generate income, which will be used to maintain the CSS project towards sustainability and maximal benefit to the rural populates. However, from the financial performance evaluation results, some of the income is distributed among concessionaire and DA, even so, the long bureaucratic chain do not permit the successful distribution of the income. As a result, most of the communities could not provide records of the income generated since the 3years of business operation of the system, Table 4-5. The total damage of inverters and subsequently non-functioning of the charging systems in the three communities are evidence that service and maintenance income for the system could not be kept during the operation of the systems. There is one other major problem which the evaluation results do not explicitly show, but it was realized from the evaluation that most of the communities have different charging fees, CA fees, concessionaire allowances and differences in the DA percentage. As a result, some communities charged very little fee for charging services; others paid as high as 30% of income from charging services as CA fees and others with as high as 60% allocation for DA. This problem, which is appropriately classified in this study as 'inconsistency in income allocation' in the CSM system can also have a profound effect on the CSM system and also defeat the concept of standardization of the CSS project. Since the pilot project serve as a standard system, all aspects must be standard to ensure consistency.

4.2.2.2 Business performance

According to the financial feasibility analysis of the CSS business operations, the project is supposed to generate an annual net income of about GH¢ 1000.00 ≈ US\$390.00. The results of the financial performance evaluation show that the annual net income estimate is relatively higher, however, the annual expenditure, which was

estimated at GH¢300.00, is extremely low due to evidence of frequent inverter damages and subsequent services fees. This shows that the overall cash flow estimate of the project has significant inconsistencies and need to be reconsidered.

Regarding the evaluation results, it is found that of the 12 communities evaluated, only six communities could show financial records of which other details regarding charging services and expenditure could not be provided. The business and financial performance aspect of the project is very important because it is the key factor determining the capacity of the system to sustain itself through maintenance and replacement of damaged components. However, the cash flow records of the six communities do not reflect a sustainable financial image of the project. The annual net income recorded by Njare (GH¢1,026.00) and Bomigo (GH¢1,366.00) in 2012 (Figure 4-4) cannot be realistic since they fail to provide expenditure for that year. On the other hand, Danlaidi and Kabiti recorded higher expenditure than income generated, resulting in a net annual loss of GH¢1,509.28 and ¢325.00 respectively. This implies that financially, such systems in Danlaidi and Kabiti cannot be self-sustainable with regards to any future eventualities. In addition, Kracheibi had a sound annual benefit of GH¢ 861.60. However, this is below the expected annual benefit from the operation of the project, nevertheless, the effort of Kracheibi is enough evidence that the CSS business operation is highly profitable with good management efforts.

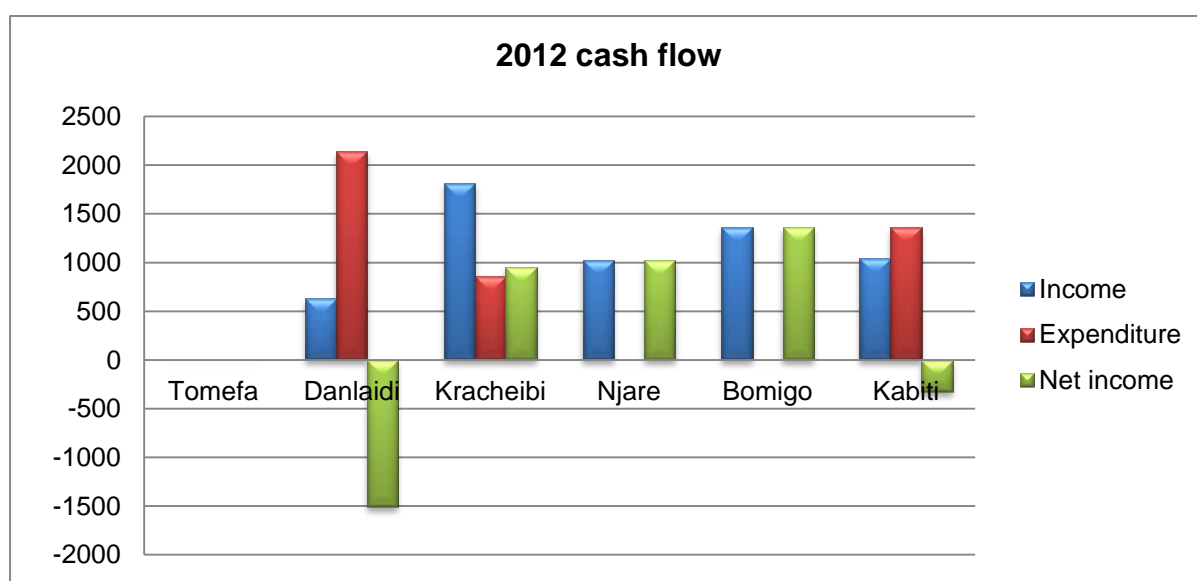


Figure 4-4 Cash flow of CSS operation in 2012

Another critical concern realized about the financial feasibility of the project is the large gap in the financial performance between the 2012 and 2013 years of operation. As depicted in figure 4-4 and figure 4-5, averagely, the year 2013 business operations recorded relatively lower cash flow than 2012. This implies depreciation in the business operations of the project. Although the actual cause of this seemingly operational depreciation cannot be detected directly, it can be deduced to be contributed from lower managerial efforts and lower operational and or patronization efforts. If the project exhibits similar trend in the next two to three years, then the CSS project is likely to be characterized by the same problem of 'project value depreciation', which has already been described by the Director of Renewable Energy in Ghana, as the major cause that lead to the abandonment of rural electrification project due to loss of interest and subsequent back out by donor agencies.

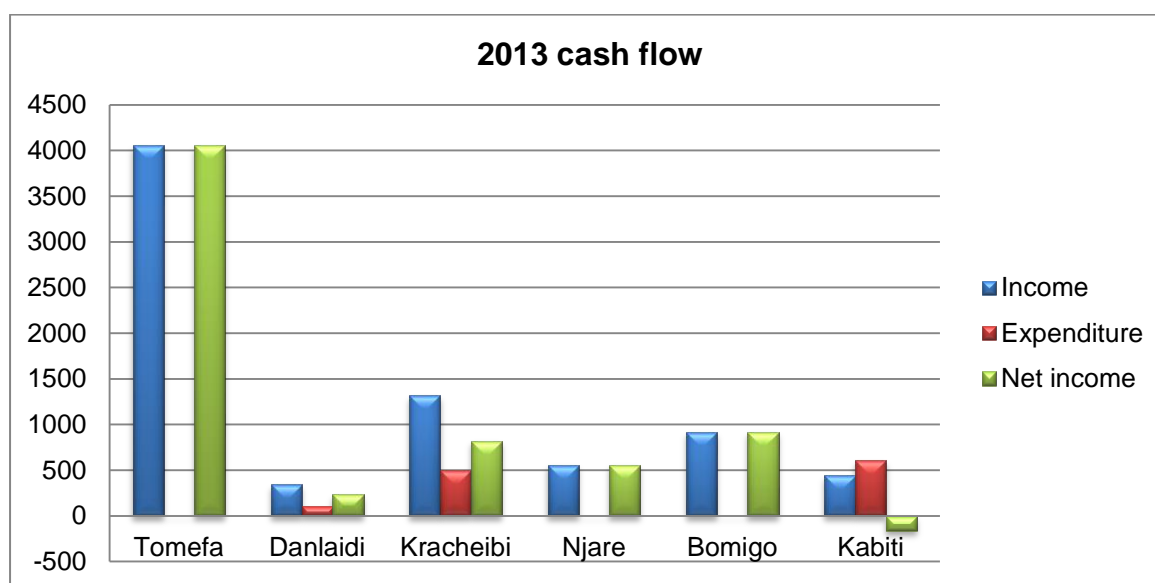


Figure 4-5 Cash flow of CSS operation in 2013

4.2.2.3 Impacts of CSS project in rural Ghana

In order to assess the significance of small scale renewable energy project in rural development, the CSS project was also subjected to community impact assessment in the evaluation exercise. There were additional interviews with some community members; the DA and the director of renewable energy from the MOEP to retrieve enough information regarding the aforementioned objective.

The responds of the project's impacts on the rural people is shown in Figure4-6. Regarding the preference of the CSS project, all the communities accept the project and the CAs from some of the communities even raised concerns for the provision of more of the charging systems to expand the business operations. All the CAs in the twelve communities showed satisfaction with the performance of the system, but there were six communities who raised concerns regarding the frequent damages of the inverters. Regarding the peoples expectation from the CSS project, the respondent indicated that the rural people are really satisfied with the system; however, respondents from seven communities emphasized that the people normally complain about the absence of street light and asked of more electricity capable system which would enable them use television and radio in the communities. Nevertheless, the respondent from all the communities readily recommended the continuation of the CSS project and possible extension to other un-electrified rural communities. The DAs also indicated that the project is important for such island and isolated communities but also raised the concern that implementation of such rural project must well include and respect the role of the DAs to ensure their full participation and support. The director of renewable energy, when interviewed, also emphasized on the importance of the CSS project, especially for the provision of electricity in the public facilities to promote safe health delivery and education in the very remote areas of Ghana. On a more important note, the director lamented that it is difficult to actually meet all the electricity needs, such as the required electricity to support cooking and other social and business activities of the rural populates without grid extension, however, these small scale PV systems offer some level of solution, especially, in this era where grid-extension is not possible into some of the isolated and island communities.

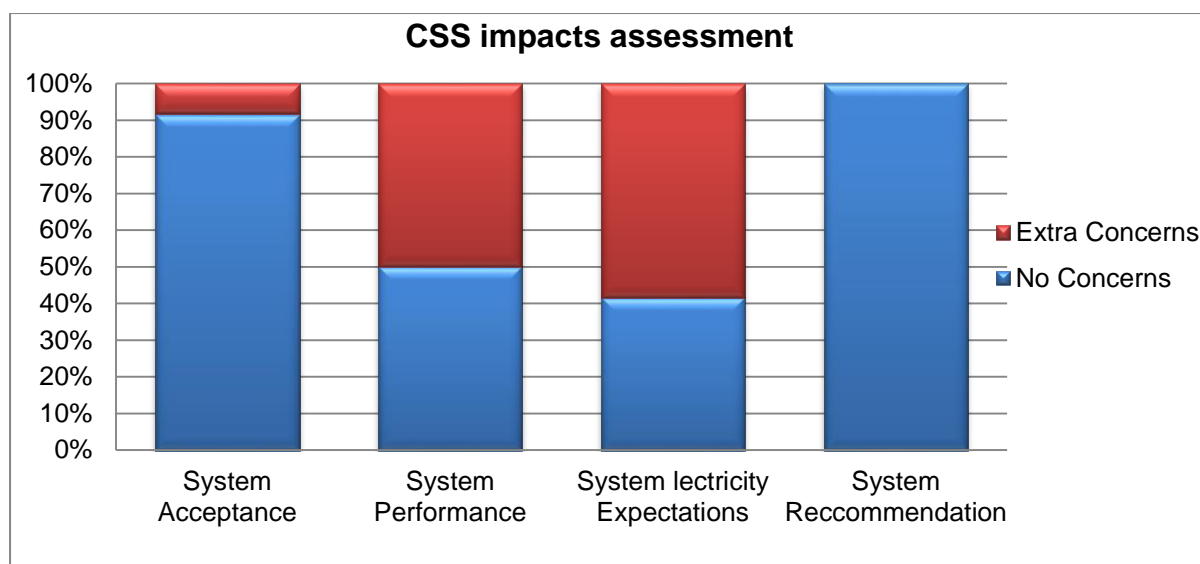


Figure 4-6 Community impacts assessment of CSS project

The content of the above results readily indicate that the CSS project and other similar small scale renewable energy solutions are important for enhancing the social life of the rural people, particularly for improved health delivery and quality of education. However, the major problem is that they do not provide total rural electrification solutions. Nevertheless, the CSS project and similar small scale renewable rural electrification solutions are highly recommendable because they have significant impacts in rural development.

5 Conclusions and recommendations

5.1 Conclusions

The CSS project, together with the 'Human Resource Development for Disseminating PV Systems in the Republic of Ghana and a well-structured management system; 'The Community Solar Management' provide strategic solutions to the problems of rural electrification in Ghana. However, the evaluation results of the project indicate that there are important factors that can significantly hinder the sustainable implementation of the CSS project and other similar small scale rural electrification solutions if they are not adequately addressed.

First and foremost, the technical evaluation results show that the CSS project has relatively simple design with simple components and operations. This makes the

project design user friendly with high integration potential. This fact is justified by the respondents' high level of confidence and satisfaction with the system performance as well as the communities' appreciation of the system. However, the frequent damaging of inverters is alarming. As it was seen in the case of four communities, the inverter problem ceased four charging systems in four communities from operation. This problem is appropriately classified in this study as 'frequent system component failure' and is closely linked to quality of system components or misuse of technology. Despite the linearity of technology misuse with system failure, misuse of technology in itself has also been broadly identified as a major technical characteristic issue of the CSS project, which can significantly offset the purpose and successful implementation of the project. This technology misuse problem is defined as overcharging of gadgets (mobile phones and lanterns) during the day and possible charging of gadgets during the night and is closely linked to the effectiveness of the human resource development component of the project.

Regarding the socio-economic aspect of the project, the results of both management structure performance and business performance reveal that there is more documentative managerial effort than what is actually executed on the ground. This is because the concept of the CSM as documented is not executed as expected. As a result, the overall management structure is not functioning effectively. This ineffectiveness in the CSM system has been identified to be as a result of inadequate monitoring; lack of information flow among the CSM stakeholders; and inconsistency in income allocation. The long chain of management structure is also realized to contribute some level of bureaucracy leading to the ineffectiveness of the whole CSM system. There are also signs of poor financial management of the project; however, this is not classified as a major problem that can significantly hinder the sustainability of the project. This is due to the fact that first; the business aspect of the project is only a complementary objective to raise income to support and maintain the systems; and secondly, the inconsistency in the income allocation is not a characteristic of the system itself but only due to long chain of management levels; inconsistent and inadequate monitoring and supervision, especially at the local level. Hence, this issue can duly be dealt with if managerial efforts are raised.

Lastly, the community impacts assessment of the CSS project reveals that the project has profound positive impacts on the lives of the rural population. However,

there are two contending issues: first, the CSS project has not been efficient enough to provide the needed electricity by the rural populace. The current electricity supply of the project is only limited to schools, health delivery facilities and charging of mobile phones as well as rechargeable lanterns, but does not cater for other socio-economic needs of the people. This problem is a major consequence for gradual decline of users' interest for such small scale renewable energy solutions, which eventually leads to project abandonment. Secondary, the project implementation and operations have not adequately included the DAs who are the key administrators of rural development. Nevertheless, the CSS project is contributing to safe health delivery and improved education in the rural communities as well as making the use of mobile phones and for that matter, communication between the rural people and their relatives in cities possible and effective.

In the context of the above analysis and observations, this study emphasize that the CSS pilot project is credible and recommendable for further implementation as a standard for rural electrification solutions in Ghana, however, the issues identified as potential hindrance to the sustainability of the system have to be adequately addressed. More importantly, the study concludes that the solar PV systems of the CSS project and other similar small scale renewable energy rural electrifications do not necessarily abridge the energy poverty gap between the cities and the rural communities or as against grid-extensions solutions. Meanwhile, they are necessary as intervening solutions and play key role in rural development.

5.2 Recommendations

In the context of the issues identified in this study as issues of potential significant hindrance to the sustainability of the CSS project and other similar small scale renewable energy projects, this section recommends some steps that should be considered in order to overcome those potential barriers.

Regarding the technical issues of 'frequent system component failure' and 'misuse of technology', it is recommended that the quality of system components and source of manufacturing be duly considered to ensure that materials and components of good quality and source are purchased in future developments to ensure durability of the components and sustainability of the entire system. If it is possible, it is necessary that manufacturing of components be customized in future

development to produce components with greater resilience and self-protection capacities to meet the hash and possible eventualities in the rural settings. It is also recommended that the design operational capacities of the systems' components be adjusted or reconsidered to increase the overall voltage flow and storage by the battery to buffer any eventualities of overcharging of gadgets or even possible recharging at nights. This is necessary to stabilize the system in the event of misuse and to also cater for population expansion since the design was based on 2010 population statistics. The issue of misuse of technology can duly be addressed with regular monitoring and supervision of the system. Continual training and support for the CAs and local users will increasingly broaden the knowledge of the rural users and contribute to responsible operations of the system towards sustainability.

In order to ensure effective functioning of the CSM system and sustainable management of the CSS project, it is important that the various stakeholders take up their responsibilities. Taking up responsibilities means that MOEP has to raise project awareness among DAs by duly acknowledging and addressing DAs in further and future development of CSS and other similar projects to up-date them of the project and to clearly define their responsibilities to ensure their participation and effective contributions. DAs also have to pay at least quarterly visit to the project sites (communities) to regularly up-date themselves of the project status and also ensure regular monitoring and supervision of CAs. If DAs are able to pay quarterly visit to the various project sites and report to MOEP, then an annual supervisory visit by MOEP to the DAs and project sites for evaluations will be adequate to achieve sustainability of the project. In order to also address the long bureaucratic chain of management, as depicted in the CSM system, it is further recommended that the concessionaire and their roles are a totally avoided in the CSM system. It is possible to avoid concessionaires in the CSS management to enable direct communication and monitoring between the DAs and CAs and also reduce the stakeholders to only three managerial levels, including the CAs at the community level, the DAs at the district level and MOEP at the national level. Avoiding concessionaire roles in the CSM system will also lead to high financial output because concessionaire fee will reduce the annual expenditure and increase the overall annual net income and hence higher financial security for the project since more income will be allocated for services and repair of the system.

Regarding the effectiveness of the human resource development components of the project, it is clearly demonstrated in the CSS project that one-time training of local users at the rural level is just not enough to ensure effective operation. Hence continuous training and education of local users regarding technology usage is critical to improve technology utilization at the rural level to contribute to improved and sustainable renewable solutions in rural settings.

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Appendix A

Criteria for selection of communities

1 Electrification	5	Not electrified Only the center is electrified but far
2 Grid distance	5	More than 5km
	3	2-5km
3 Population	3	More than 500
	2	200-500
4 School	3	Building in good condition
5 Clinic	3	Building in good condition, delivery
	2	Building in good condition
6 Charging house	5	Identified, building in good condition
	3	Identified, building needs improvement
7 Market place	5	In the community
	3	Near the community, within 5km
8 Possible PVA	5	Identified, less than 2 hours by car
	3	Identified
9 Entrepreneur	3	Identified, with business skills
	2	Identified
10 Possible CA	5	Identified, with electric knowledge
	3	Identified
11 Islands	3	Yes
	0	No
12 Others	1-5	MOEn's rural electrification policy aspect Security

Source: JICA, 2011

Appendix B

Selected communities

Site No.	Community	Criteria	Electrification	Grid distance	Population	School	Clinic	Charging House	Market Place	PVA	Entrepreneur	CA	Island	Others	Total (50)
1	Kpalbe	Salaga	5	5	3	3	3	5	5	5	0	0	0	5	39
3	Akyerekrekrom	Amansie West	5	5	3	3	3	5	5	5	0	0	0	5	39
2	Manpong Nkwanta	Koforidua	5	0	2	3	3	3	3	5	0	3	0	5	32
13	Bengmal	Yendi	5	5	2	3	3	3	3	0	0	3	0	5	32
24	Pisi	Wa	5	3	3	3	3	0	3	5	2	3	0	0	30
20	Tampala	Jirapa	5	3	3	3	2	3	0	5	2	3	0	0	29
42	Kabiti	Nkwanta South	5	5	3	3	2	5	3	0	0	3	0	0	29
43	Kracheibi	Nkwanta South	5	5	3	3	2	5	3	0	0	3	0	0	29
48	Odumase	Nkwanta South	5	5	3	3	2	5	3	0	0	3	0	0	29
4	Loagri	West Mamprusi	5	5	3	3	0	0	0	5	3	3	0	0	27
5	Wakiuri	Nkwanta	5	5	3	3	3	0	0	5	3	0	0	0	27
15	Babianiha	Ellembelle	5	5	3	3	0	0	0	3	5	3	0	0	27
46	Keri	Nkwanta South	5	5	3	3	2	3	3	0	0	3	0	0	27
50	Techorkope	Krachi East	5	5	3	3	0	5	0	0	0	3	3	0	27
51	Kudorkpoe	Krachi East	5	5	3	3	0	5	0	0	0	3	3	0	27
18	Ayawara	Ellembelle	5	5	2	3	0	0	0	3	5	3	0	0	26
22	Liero	Sissala West	5	5	3	3	0	0	3	5	2	0	0	0	26
23	Kelegan	Sissala West	5	5	3	3	2	0	3	5	0	0	0	0	26
28	Njare	Krachi East	5	5	3	3	2	3	0	0	2	3	0	0	26
45	Kwe	Nkwanta South	5	5	3	3	2	5	0	0	0	3	0	0	26

JICA, 2011

Appendix C

CSS evaluation guide questions

Site Details	Community	District	Region	GPS Coordinate	Respondent	
Working Status of Community Solar System (CSS)						
Type of PV System			PV Community Charging System		PV Public System	
Status of PV System	Working Status					
	Time in use					
	Time of damage					
	Repairs/Serviceing					
	No. of times repaired					
Management Structure Performance						
CSS Performance Reporting	CA reporting to concessionaire					
	Concessionaire reporting to DA					
	DA reporting to MOEP					
	Reporting Frequency					
	Status of Reporting					
Book Keeping Records	Type of Records					
	Status of Record Keeping					
Status of CSS Component Performance						
CSS System Component	Panels					
	Cable					
	Controller					
	Battery					
	Inverter					
	Switch					
	Lamps/Lamps holder					
KOWA BOX						
CSS Impact Assessment						
Is CSS performing as expected?						
Is the community satisfied with the system?						
Is the CSS helpful to the rural community members?						
If yes, how?						
Is the system recommendable to other rural communities without electricity?						

CSS Financial Performance 2012

Month	No. of phones/Lanterns charged	Total Income	Expenditure
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
Total			

CSS Financial Performance 2013

Month	No. of phones/Lanterns charged	Total Income	Expenditure
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
Total			