Human Resource Development for Disseminating PV Systems in The Republic of Ghana

Final Report

December 2011

Japan International Cooperation Agency

Ghana Office

Proact International Ltd.

Location of the Project

Area	230,535 km2
Population	Total: 23.42 million (2009 est. National statistic Service) Accra:　1,658,937 Kumasi:　1,468,609 Tamale:　360,579
GNI/capita	1,230USD (2010 est. World Bank)
Currency	Ghana cedi (GHC):　1USD=1.55GHC @2011 AUG.

Abbreviations/Terminology

AC	Alternating current
AGSI	Association of Ghana Solar Industry
Ah	Ampere hour
BCS	Battery Charge Station
CA	Community Agent
CC	Constant Current
CSS	Community Solar System
CV	Constant Voltage
DA	District Assembly
DSTC	Deng Solar Training Center
EC	Energy Commission
GEDAP	Ghana Energy Development Access Project
GHC	Ghana Cedi
GSB	Ghana Standard Board
HVD	High Voltage Disconnection
HVR	High Voltage Reconnection
IEC	International Energy Committee
JFY	Japanese Fiscal Year
JICA	Japan International Cooperation Agency
KNUST	Kwame Nkurmah University of Science and Technology
kWh	Kilo Watt Hour
LED	Light Emitting Diode
Lumen	Total integrated brightness of a lamp
Lux	Brightness
LVD	Low Voltage Disconnection
LVR	Low Voltage Reconnection

MOEd	Ministry of Education
MOEn	Ministry of Energy
MOU	Memorandum of Understanding
NES	National Electrification Scheme
NGO	Non-Government Organization
PDM	Project Design Matrix
PV	Photovoltaic
PVA	PV Agent
PV GAP	PV Global Approval Program
PWM	Pulse Width Modulation
RESPRO	Renewable Energy Service Project
RMS	Root Mean Square
SHS	Solar Home System
TOT	Training of Trainers
USD	United States Dollar

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Final Report

1. Outline of the Project

Ghana formulated National Electrification Scheme (NES) to promote rural electrification in 1989. The scheme targeted the electrification of communities with a population of more than 500 persons by 2020. However, because of population dispersion in rural areas and financial difficulty, rural electrification has not been promoted efficiently. On the other hand, the government of Ghana (hereinafter referred to as "Ghana") had a strong desire to utilize its abundant solar energy into a rural electrification plan.

In June 2003, the government requested JICA to conduct "the Master Plan Study on Rural Electrification using Renewable Energy Resource in the Northern Part of the Republic of Ghana." This study was conducted from February 2004 to May 2006 and a master plan was proposed. It was an action plan to establish an institutional framework for sustainable rural electrification with renewable energy resources by pointing out the need to improve institutional and structural challenges experienced in past projects. In addition, the Master Plan pointed out importance of introducing sustainable models in PV rural electrification.

Based on the proposal, Ghana requested JICA to conduct a project on sustainable PV rural electrification. In February 2008, the Project "Human Resource Development for Disseminating PV Systems in the Republic of Ghana" began for an initial duration of three years.

In JFY2008, the Project selected trainers from various institutions (KNUST, Tamale Polytechnic, Koforidua Polytechnic, hereinafter referred to as "Institutions") and started training of the trainers. Along with this, the Project and MOEn started discussion on how to set up an institutional structure for human resource development. However, start up of the Project did not run smoothly due to misunderstanding between the Project purpose to develop human resource development scheme and Ghana's request for the introduction of sustainable PV dissemination model. Ghana had a strongly desired to introduce a sustainable PV rural electrification model.

In JFY2009, the Project introduced 4 Community Solar Systems (CSS) in the southern

Ghana to demonstrate the potential of sustainability in response to a request from Ghana. The model utilized income from the charging service to improve sustainability of public PV systems. MOEn expressed interest in the potential and, at the end of JFY2009, the Project and MOEn decided to shift the project scope from human resource development to the construction of a sustainable PV dissemination model using CSS. The revised project plan was to conduct pilot projects for the construction of Community Solar business model to improve sustainable operation of PV systems and implement a human resource development scheme associated with the business model. Then, implementation of 20 pilot projects was planned around the country.

In July 2010, the Project Monitoring Team was dispatched from the JICA Headquarters. The team found that the project activities would require more time than initially expected, and the duration of the Project was extended for one year after consulting with the Ministries of Energy and Education. As a result, the total duration of this project has become four years which ends in December2011.

Although the project scope was shifted, the project purpose in PDM remained unchanged to avoid any confusion. The purpose of the project to "prepare the bases for human resource development for PV rural electrification," can be categorized into the following four components: (1) arranging a scheme to train PV technicians, who will engage in the operation and maintenance (O&M) of PV systems in rural areas, (2) training the trainers of educational institutions, (3) training engineers who will engage in PV product testing to improve user confidence, and (4) preparation and enhancement of public awareness of PV systems.

In JFY2011, the Project completed the CSS installation and set up a monitoring system. In the pilot projects, CA training was conducted by trainers and PV Agents. The monitoring system was established with Concessionaires, District Assemblies and MOEn. PV education in the form of weekend classes was attempted at the three Institutions as part of TOT (training of trainers). Lantern testing was conducted at GSB and the necessary technology was transferred to its engineers. Necessary materials to enhance public awareness such as posters, brochures, manuals, videos and web pages were developed. All these activity results were reported a the seminar held in November 2011 and the Project ended in December 2011.

2. Human resource development

2.1 Outline of the Human Resource Development

2.1.1 Background

Ghana has been implementing rural electrification based on grid extension since 1989. Rural electrification is an important subject in the national electrification plan. The greatest difficulty in rural electrification is the high cost of grid extension due to the extremely low population in rural areas and houses located far apart.

On the other hand, PV rural electrification has been expected to be a promising measure since Ghana has abundant solar energy around the country. Up to now, several PV rural electrification projects using Solar Home Systems, etc, have been conducted by donors. The most well known is RESPRO (Renewable Energy Service Project) based on a “fee-for-service” scheme.

A “fee-for-service” scheme is characterized by charging a fee for the use of the system to users instead of transferring ownership to them. In RESPRO, the fee was artificially kept low by politicians so that more people could enjoy PV electrification. However, the fee was set to so low level that the service provider could not maintain service. The provider could not afford transportation costs to visit users. As a result, service was no longer provided by the provider. Without a trained person to take care of the systems in the communities, many systems were left un-attended without proper maintenance.

According to a baseline survey conducted in 2008, more than 80% of the surveyed PV systems were not operational. Many users didn’t know who to ask for technical services and where to receive spare parts to repair their systems. On the other hand, only 10% of the respondents listed economic reasons for the lack of repairs. In other words, if the user can receive information regarding services and parts, the sustainability of PV system can be greatly improved. Financial difficulty is not the only factor that matters in sustainability. Strengthening local human resources and the network to provide PV users with relevant and accurate information on PV so that the systems can be maintained more easily must be considered.

Along with implementation of human resource development to overcome difficulties in keeping sustainability of PV systems, an effective PV dissemination model in rural areas was also needed by Ghana. As a result, Ghana requested JICA to implement a sustainable PV electrification project. In response, the project, "Human Resource Development for Disseminating PV Systems in the Republic of Ghana" was conducted from February 2008 to December 2011.

2.1.2 Human resources for PV dissemination

① Human resources for PV rural electrification

Human resources with good knowledge and skills regarding PV are very rare in rural areas. Few people know where they can buy the proper spare parts or receive technical services when problems in the system occur. Therefore, the first approach needed to improve the human resource problem is to train PV technicians in rural areas.

This approach has already been implemented by AGSI (Association of Ghana Solar Industry) in the form of PV training course. According to their report, more than 200 PV technicians were trained from 2003 to 2007. Difficulties were that most of the people trained were residents of urban areas and there was not good mechanism to train people in rural areas who could not afford the training fee. In addition, the training was held in Accra, far from rural people who actually needed it. At first, the Project targeted training PV technicians, but changed the plan after learning that AGSI already had a similar type of training course. The new plan directly targeted people living in rural areas who needed to understand how to maintain PV systems. PV systems cannot be maintained only by PV technicians but also by people in the community.

Based on this understanding, the Project first proposed to develop human resources at two levels: community-level knowledgeable leaders (Community Agents) who play a key role in disseminating the appropriate information regarding PV and its application in rural communities, and PV business promoters (PV Agents) who support Community Agents and expand PV business opportunities in rural areas.

With a good understating of PV and support from PV Agents, Community Agents can pioneer the use of PV systems and also help other people try PV products. Community Agents can contribute to the quick expansion of the PV market in remote areas by assisting in PV system sustainability and promoting potential users to be more confident in PV. Therefore, human resources required to disseminate PV systems can be categorized into two types; PV Agents and

Community Agents. Their roles and expected activities are summarized in the following table.

Table 1 Category of Human Resources

Human Resource	Role
PV Agent	PV market creator and service provider in rural areas
Community Agent	PV knowledge disseminator in remote communities

Table 2 Expected activities of PV Agent and Community Agent

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

The relationship between the PV Agent and the Community Agent is illustrated in the following figure. PV Agents support several communities and Community Agents. Community Agents support PV users in their communities.

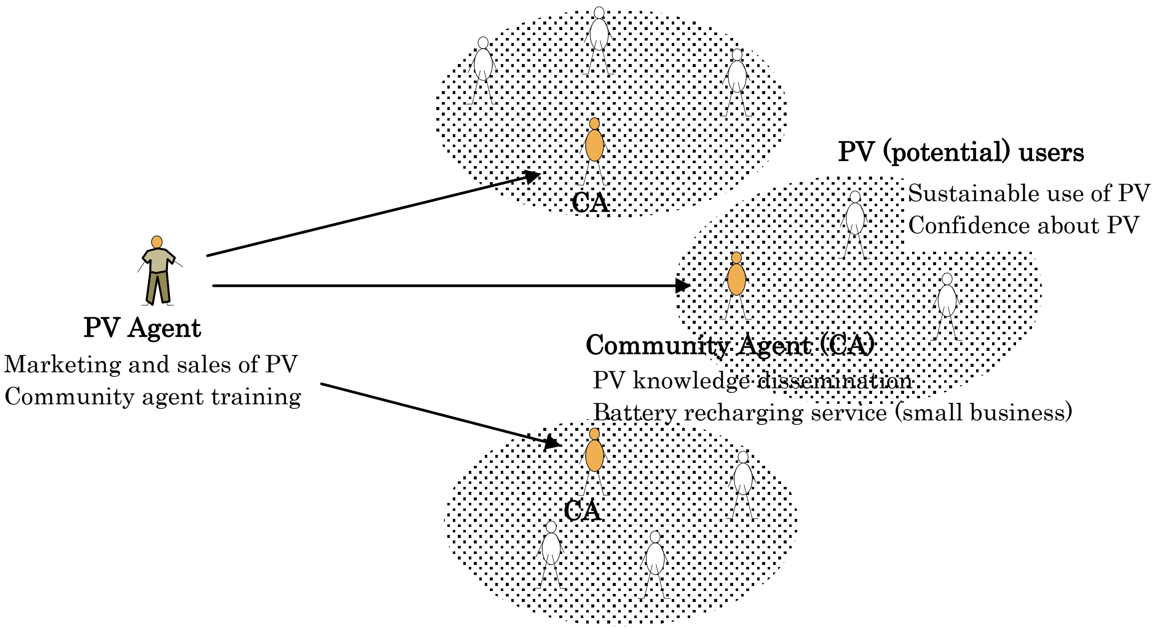


Fig. 1 Relationship between the PV Agent and the Community Agent

The Project also proposed the introduction of Community Solar System (CSS) as a sustainable model to disseminate PV systems in rural areas (details of CSS are explained in Chapter 3). This business model utilizes PV systems to charge mobile phones for a fee and using the income as the financial source to maintain the PV systems. In this case, business skills are also needed to manage the income efficiently. The Project introduced a Concessionaire as a business manager of CSS operation. Of course, the Community Agent can play the Concessionaire's role if he has business skills. The Community Agent and the Concessionaire operate the CSS and promote use of PV in the community.

② Human resources for PV quality control

Second, the Project supported human resource development for PV product quality control. Quality control is an important factor to promote PV market. If the quality of the product is poor, people's confidence in PV will diminish and hence, affect market expansion. To protect the PV market from low quality products, Ghana is introducing a PV technical standard based on the IEC (International Electric Committee) PV Technical Standard. One obstacle for Ghana is the lack of proper technology to test PV products. The Project provided necessary PV testing equipment and trained related people so that they can properly conduct PV testing.

③ Human resources in basic education

Finally, the Project supported basic human resource development in the educational system. It is important to train basic human resources so that more people can contribute to the installation, maintenance, promotion and quality control of PV. The project worked with the Institutions to develop a basic PV education course for their students.

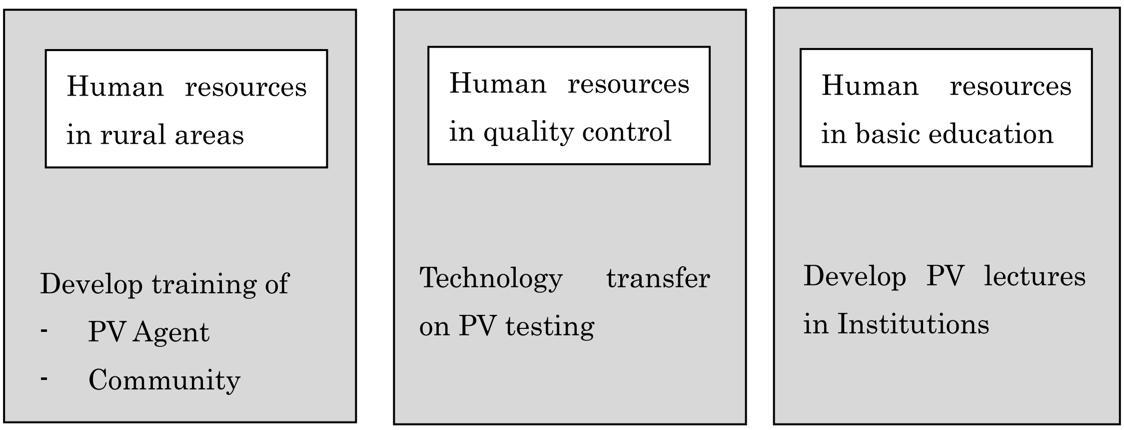


Fig. 2 **Targets of human resource development**

2.1.3 Human Resource Development in the Project

The Project aimed for market based PV dissemination which was considered to be a more appropriate way of promoting PV in rural areas. Developing human resources who can promote and maintain PV systems is very important in the building of a sound market. However, the PV market is still in its infant stage in Ghana. Those with interest in PV and could afford the PV training were limited. Although AGSI started PV training courses which targeted PV Agents, most trainees lived in urban cities. Therefore, the Project planned to reinforce the basis of PV training for rural people in cooperation with MOEn, MOEd, the Institutions and AGSI.

The Project first addressed the needs to train PV Agents on the supply side and Community Agents on the demand side simultaneously. However, PV Agent training is considered to be better undertaken by AGSI, so the Project decided to transfer PV Agent training and support AGSI in their PV Agent training development. Then, the Project focused on developing a Community Agent training method in cooperation with the trainers selected for PV training at the three Institutions. The training method was developed so that it could be reflected in AGSI's PV Agent training and the PV Agent can train a Community Agent effectively.

Regarding PV testing, EC and GSB are in charge of planning and implementation of the quality control measures. The Project planned to transfer PV testing technology not only to EC and GSB but also MOEn and the Institutions. EC and GSB will use the technology in their plans for PV quality control. The Institutions will use the knowledge to train students, who will contribute to the formulation PV quality control in the future.

Furthermore, to secure enough qualified persons for the above-mentioned activities in the long term, it was necessary to start basic PV education and develop knowledge a base among the youth. It was expected that more talented young people would choose jobs related to PV, which would further accelerate PV dissemination in remote areas. The Project worked with three Institutions in implementing PV education into their educational system.

As a result, human resource development conducted in the Project targets trainers, PV Agents, Community Agents and testing engineers as illustrated in the following figure.

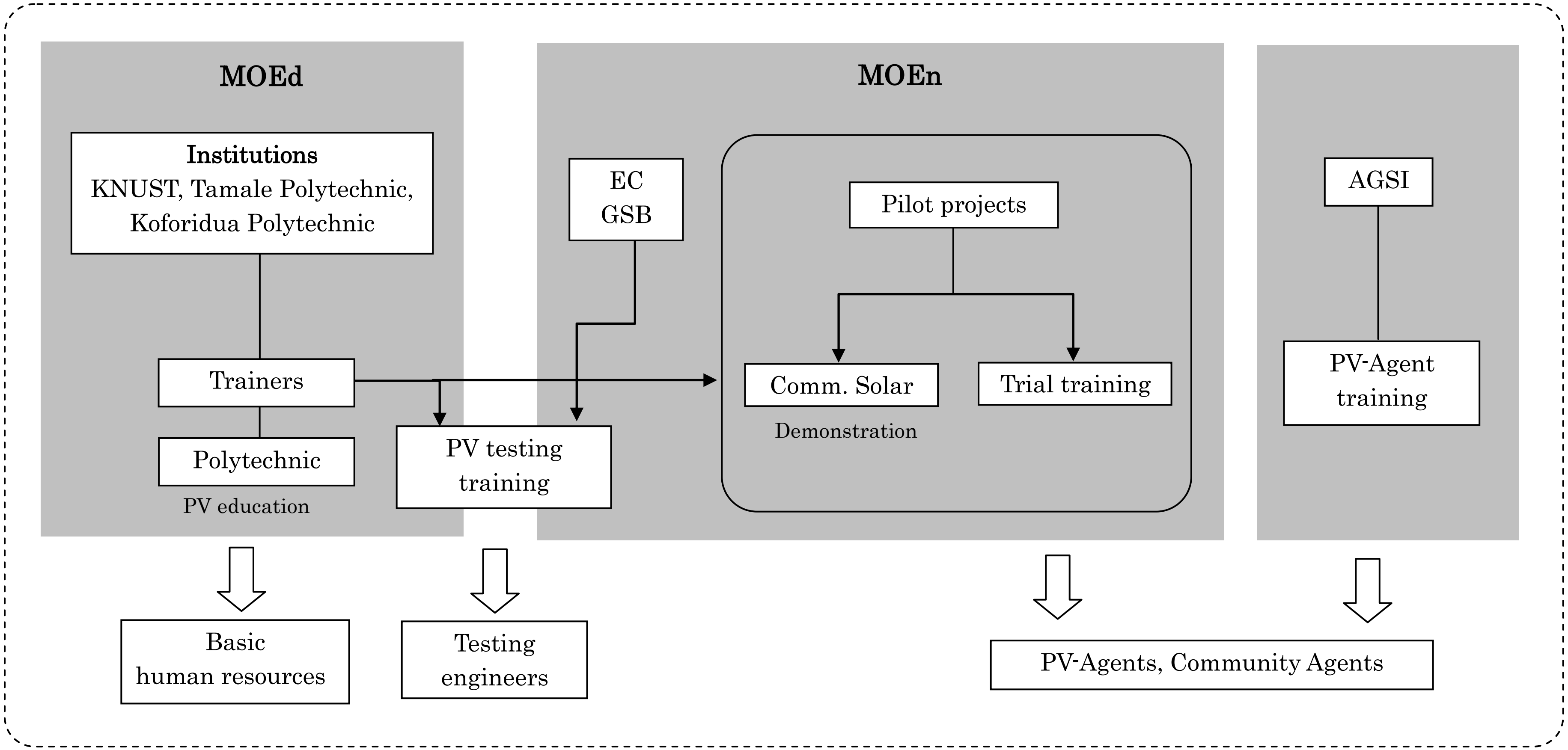


Fig. 3 Human resource development structure in the Project

2.2 Training of the Community Agent

Development of CA training is the most important part of the Project. The Project developed materials and training methods necessary for CA training with trainers through pilot projects. Training was to be implemented in an institutional system from the viewpoint of sustainability. However, implementing an institutional system for CA training was very difficult because the current PV market was too small and those targeted were too poor. Few people could afford the training fee. On the other hand, considering that most PV systems are introduced by the government or donor projects, CA training could be incorporated into those projects. Those developed materials and methods for CA training could be utilized if those projects were well designed. Raising awareness of CA training is also necessary so that the project designers could understand the importance of such training and implement it into their projects.

2.2.1 Role of the Community Agent

According to the results of a survey conducted to study the rural PV situation in 2008, in the use of PV systems, users needed information, such as how to conduct daily maintenance, where to buy spare parts and how to replace faulty parts, the most. If persons with appropriate knowledge were in the community, sustainability of PV systems could be greatly improved. Therefore, the main role of the Community Agent is daily maintenance, that is, to take care of and improve sustainability of the PV systems installed in the community.

Along with development of Community Agent training, the Project proposed the introduction of the Community Solar System (CSS) for rural PV electrification. In this case, operation of CSS is also an important role of the Community Agent because some knowledge and skills regarding PV are required for the operation of CSS. Operation is also a good job opportunity for the Community Agent.

Schools and clinics are very important public facilities even in un-electrified communities. PV is often used to provide needed electricity to those facilities. Since PV systems used in public facilities are larger than household PV systems, greater knowledge, and persons with such knowledge, are needed to operate them. The Community Agent can also be the person who operates such PV systems.

In the Project, PV for a public facility and PV for a charging station are considered as one Community Solar System (CSS) and operated by a Community Agent (CA). In this case, business skills are also required to financially control the operation. If the CA has insufficient business skills, then an entrepreneur should be selected to support the CA. In the Project, he is called as Concessionaire. The Concessionaire hires the CA to operate and maintain the system. If the CA has sufficient business skills, then he can also play the role of the Concessionaire at the same time.

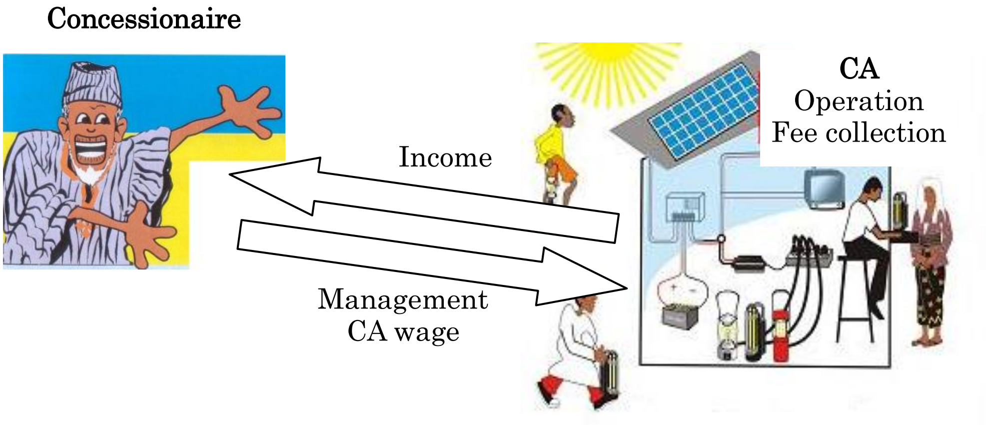


Fig. 4 Relation between Concessionaire and CA

The CA's role is to conduct easy daily work, such as operating PV systems, handling simple troubleshooting and consulting with users in the proper use of PV systems. The PV Agent supports the CA and deals with more difficult problems. He also conducts system expansion work, which needs greater skills and knowledge. When the CA acquires such skills and knowledge, then he can work as the PV Agent and train other CAs. As human resources increase, PV dissemination into rural areas becomes easier and can be promoted.

The following table is a summary of the CA's role and work.

Table 3 CA's role and work

CA's role	Operate and take care of the PV systems in the community. Consultation with PV users.
CA's work	Operation: Operation of CSS, public PV systems Maintenance: Cleaning of panels, water addition to batteries, replacement of batteries/ lamps, cleaning/re-tightening of wiring Guidance: Guidance of usable appliances, explanation how to save electricity, explanation of life span of appliances.
Candidate of CA	Persons with technical knowledge (such as teachers) Artisans with read/write/calculation ability

2.2.2 Training of Community Agent

<Persons to implement CA training>

The technical contents of CA training are not much difficult. Contents include basic understanding of photovoltaics, knowledge of PV systems and components, skills in electrical wiring and knowledge regarding of PV system maintenance. A junior high school education is enough to understand them. However, providing the opportunities to train people in rural areas with low income is difficult. Usually people in rural areas cannot afford the training fee. Training leads to social welfare, so the Government can be considered responsible to provide such opportunities to people in rural areas. The training work itself can be commissioned to either PV Agents or trainers, but securing a financial source is not easy, even for the Government, if there is no donor support. Therefore, CA training should be as simple as possible, with minimal cost. Then, the Government may be able to implement CA training with its own fund.

If PV systems are to be installed under a market mechanism, CA training must be carried out by the PV Agent as part of his market promotion. In this case, providing business incentive for CA training to the PV Agent is very important so that the PV Agent will be willing to carry it out. In the project, CSS is the source of this incentive. The CA is the operator of CSS which will expand the PV Agent's business opportunities. If the PV Agent conducts CA training effectively, the CA will be able to make a good profit. Then, CSS will expand around the area and, as a result, the PV Agent can also make a profit. By considering his future profit, the PV Agent is more likely to implement CA training effectively.

<Selection of the CA>

The CA's main role is operation and maintenance of the PV systems. Such work can be carried out by technician type of people within the community who can read, write and calculate. Before selecting CA, a businessman, the Concessionaire, is identified for CSS management. The concept of CSS is explained to the Concessionaire and the CA is appointed by the Concessionaire because they will be business partners in the CSS operation. In the Project, the CSS is installed as a public purpose and belongs to the District Assembly (DA), so the DA can appoint the Concessionaire and the CA. The appointment should be acknowledged by the community, which ensures the smooth operation of CSS business.

<Outline of CA training>

People in the community are targeted for CA training. For some, it is difficult to understand theoretical concepts. For others, even reading and writing is not easy. Therefore, the contents of training should be more practical than theoretical and the training material more pictorial than text. The Project developed practical and pictorial training materials. Practice using actual components is also recommended. In addition, being involved in the installation work is also effective for the CA to more thoroughly understand the system's configuration. Training for operation and maintenance should be conducted using actual systems.

After appointing the CA, lecture style training on PV basics should be provided by the PV Agent (or trainer) using the practical materials. Assembly practice using the training kit is included. Training is only for one or two days to reduce total cost. Samples of the curriculum are shown in the Attachment-2. Next, the CA is involved in the installation work. This helps the CA to review what he learnt in the lecture training and digest the actual configuration and wiring of the system. After installation, the PV Agent should provide operation and maintenance training to the CA using the actual system. Instructions on management are also provided at this time.

Overall procedures for the CA training are summarized in the following table.

Table 4 Procedure for CA training

Selection of CA	Appointed by the concessionaire and PVA (or DA) Acknowledged by the community
Materials	Pictorial handout/textbook Training kit
Training	Lecture/practice on PV ● Basics on PV ● PV components ● PV systems ● Assembly practice using training kit Involvement in installation O&M training on the actual system Instruction on management

<CA training in the Project>

In the Project, CA training was conducted two ways; one is by the trainers of the three Institutions and the other is by the PV Agent.

- CA training by trainers

CA training was conducted by the trainers at each Institution using the curriculum developed by each Institution. Duration of the training was 4 days, consisting of 3 days of classroom training including practice and one day of field training.

Since the training was held for the development of a CA training method, all training was observed by other trainers and PV Agents for peer review. After the training, a comprehension test (Attachment-6) was carried out so the CAs could evaluate their understanding. Trainees were tested on the names of PV components shown in drawings, asked to draw lines connecting components and to how to record CSS operations in the record books. The CAs could understand the configuration of the PV system, function of PV components and operation of the CSS very well.

Table 5 CA training by trainers

Day	Contents
Day 1, Day 2	Lecture on basics, assembly practice
Day3	Field practice
Day 4	Lecture on operation and management

- CA training by the PV Agent

CA training was conducted by the PV Agent at the time of CSS installation in pilot projects. In the training, introduction to PV basics and practicing assembly using the training kit were carried out on the first day. Explanation of PV basics took about 1-2 hours and practicing assembly was also about 1-2 hours. Installation work was carried out for 3 days, which helped the trainees to better understand the things learnt. Next, an explanation on operation/maintenance and management was carried out using the installed systems. The understanding of the CAs was also evaluated using the same test sheet used in the training by trainers. The CAs could understand the function of each component and system very well.

Table 6 CA training by the PVAgent

Day	Contents
Day 1	Lecture on basics, practicing assembly, management
Day2, Day 3, Day4	Field practice
Day5	Lecture on operation and management

<Follow up of CA training>

A follow up workshop was held for the trainers and PV Agents who observed the CA training. Contents of the training and a training duration of 4 days were accepted by the participants. None of the CAs had trouble in operating the CSS after training, but reinforcement of management was pointed out. As bookkeeping is the main part of management training CAs, the Project clarified the record books for management of CSS operation as below. (Record form and details are shown in Attachment-23). In addition, the Project developed an illustration describing CSS management structure, which is attached to the "Community Solar manual".

Table 7 Record books for CSS operation

Book	Keeper	Contents
Daily book	CA	● Date, weather ● Time of each charging ● Collected fee, total of the day ● Any remarks
Income/expenditure book	Concessionaire Institution	● Date ● Income of the day ● Every expenditure ● Balance of the month ● Any remarks
Summary book	DA Institution	● Monthly income/expenditure ● Balance of the month ● Any remarks

The difference between CA training by trainers and by PV Agents was also discussed. Since CAs can be better trained through practice, PVA type training is preferred. For training by PV Agents, several installation sites are needed for practice. Trainers agreed that more field work would be better, but they had only one installation site. As such, trainers requested the government to provide more installation sites for training.

2.2.3 CSS Operation by the Community Agent

CAs did not have much difficulty in operating the system when functioning. If a difficult technical problem occurs in the system, the CA only stops the system and notifies the Concessionaire. The Concessionaire calls the PV Agent for repairs. A problem in the Project was that this maintenance scheme was not well understood. This is not a technical issue but one of management. More time for management training is required.

Generally, CSSs of pilot projects were well operated by the CAs. The CA opens the CSS in the morning, receives mobile phones to charge from the customers, charges them and records each charging activity in the Daily Book. The CA collects a charging fee when the customer comes to pick up his phone. The CA records the collected fee and totals the one day turnout at the close of the day. He then submits the money to the Concessionaire. Operation was well recorded in the book although some information such as weather was missing. This should also be explained carefully during management training.

Business aspects of CSS operation are also important. This is described in Chapter-3.

2.2.4 Lessons learnt

How the training system for the Community Agent is set up is important. In the Project, two methods were attempted; training by PV Agents and training by the trainers. Although it is too early to evaluate the performance of training, some lessons could be gained from the performance of operations.

<CA training by PV Agents>

Since the CA is trained at the time of installation, CA training should be carried out by the PV Agent who installs the systems. One current problem is that most PV Agents do not know the merits of the CSS business and the importance of CA training. It should be taken into consideration that PV Agents will not want to spend their time and money on something they don’t know well. In the Project, installation work was commissioned to the PV Agents, and CA training was defined in their Terms of Reference. Still, PV Agents did not sufficiently carried out CA training. The Project proposes the following two measures to resolve this issue.

- Raise awareness

  Profitability of the CSS business and importance of CA training should be emphasized to the PV Agents in advance. The Project prepared a manual, a video and a website for this purpose. The Project also requested AGSI to raise awareness of CSS business among its members.

- Cost reduction

  It is better to reduce time and cost on the training as much as possible so that it is not become burden on the PV Agent. Classroom lectures and practice should be reduced to only one day. Components for assembly practice should be the ones for installation to further reduce any additional costs.

<CA training by the trainers>

- Training course

It is difficult to incorporate CA training into the official educational system. The technological level of CA training is at junior high school, which is not appropriate to the Polytechnic education. The most important thing in CA training is not the technical, but the non-technical issues, such as keeping daily routine and saving money for repairs and replacements. From the viewpoint of the national educational system, official Polytechnic education should focus more on the technical and theoretical aspects. CA training must be regarded as separate from the official educational course. Actually, both Polytechnic and the universities have a system of additional training course separate from their official course. CA training should be held as one such additional training course.

- Certification

People in Ghana often want to have some form of certification when they completing training. Certification of an additional training course as mentioned above does not necessarily need to be official. Since CA training takes only a few days, it does not qualify for official certification under the national education system. MOEn should consider this issue and prepare a “Recognition of Participation” instead of certification by the national education system.

Certificate

This is to certify that

has successfully completed a Community Agent Training
in

Solar PV Dissemination

Conducted at
The Energy Center, College of Engineering,
Kwame Nkrumah University of Science and Technology (KNUST)

From 19th to 23rd July, 2011

Mr Kunio Asai
JICA PV Expert

Prof Abeeku Brew-Hammond
Director, The Energy Center

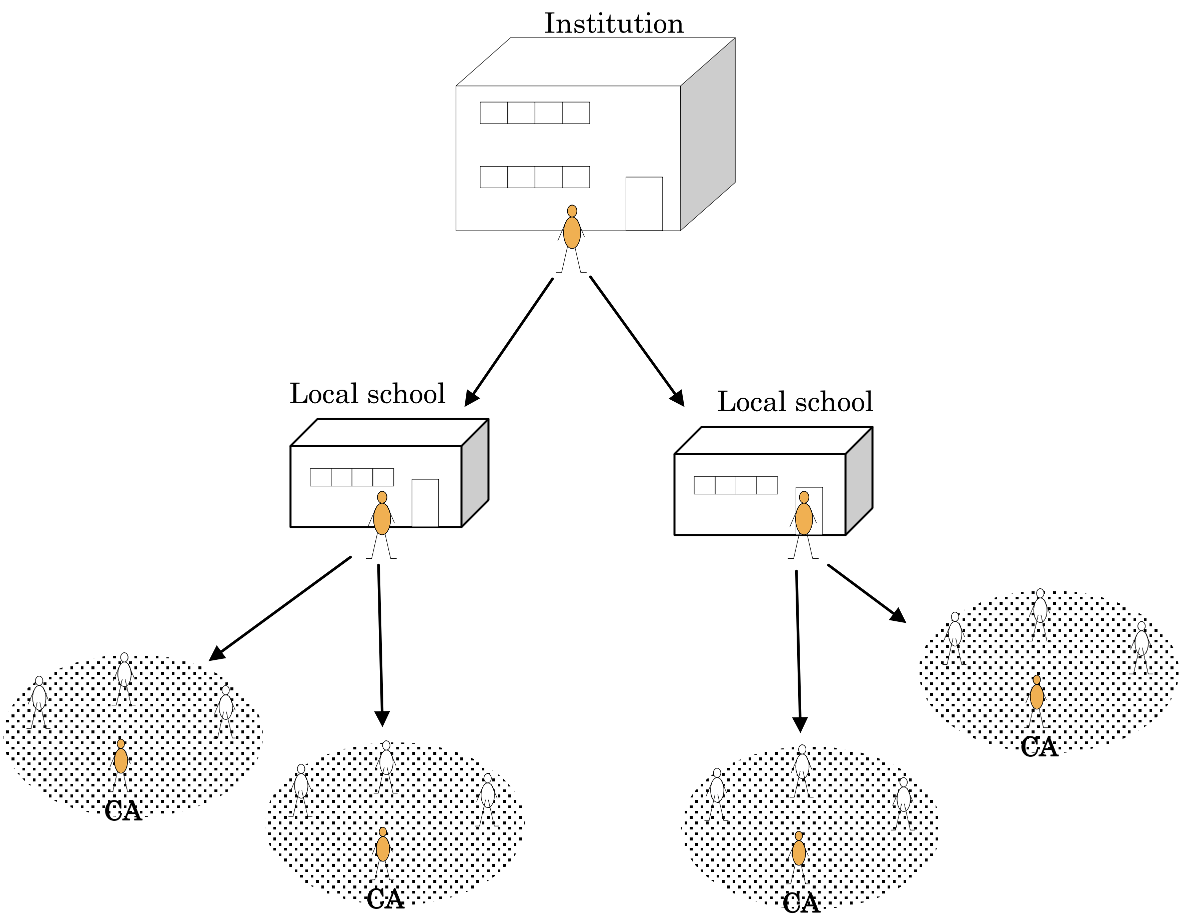
Fig. 5 Certificate issued in the Project

- Positioning of the trainers

Polytechnics and the universities should be the center of knowledge. Trainers in these Institutions must carry a variety range of knowledge. If they possess good PV knowledge, it will be disseminated to the surrounding areas through dealings with teachers and students. In consideration of this, the Project tried to involve the trainers in many activities. The trainers were trained in not only CA training but also in PV Agent training, CSS installation, LED lamp assembly and PV testing. Now, they have sufficient ability to lead PV industry.

Trainers should also be the knowledge center of the area. However, Polytechnic is the only one in each Region. The Project expects Polytechnic to communicate with other local schools such as high schools and technical schools and to establish knowledge network on PV in the Region so that support for people in rural areas can be provided by other schools close by. In this case, those people related to those schools can function like PV Agents in the area. This will improve sustainability of the PV systems installed in their areas.

Fig. 6 Expected knowledge network by Institutions



<Selection of the Concessionaire>

In the Project, a Concessionaire is selected as the business manager of CSS. He manages daily the business of the CSS. Therefore, a resident of the community is preferred. The Concessionaire can direct and hire a CA as his partner. The CA should also be a resident of the community. When introducing CSS to a community, the Concessionaire is selected first. If the Concessionaire can operate the PV system from technical viewpoint, he can also play the role of the Community Agent. A good candidate for the Concessionaire is a person who operates a shop in the community. Usually, a shop owner has good skills in operating business. In the Project, seven Concessionaires were shop owners. Other concessionaires were selected in consultation with the chief of the community. Two out of the seven Concessionaires appointed his son as the CA. Mutual trust between the Concessionaire and the CA is very important in CSS operations. Appointing his son as CA is a good method to build such trust. Community Solar Systems under such arrangements are operated well.

A difficulty in selecting Concessionaire in the Project was that these human resources should be selected through an official process since the CSS was to be installed for a public purpose. Therefore, the Project Team had to visit the chief of the community and ask for selection of the Concessionaire. In many cases, the chief, who did not always have good business skills, wanted to be the Concessionaire. One solution to avoid such inappropriate selection was to select the Concessionaire with the help of the District Coordinating officer in the District Assembly who was familiar with the community. He would know whether the chief has business ability and, if not, he had a power to direct the chief to select an appropriate person.

<Selection of the CA>

Persons who can read, write and carry out calculations are preferred as candidates for Community Agents. Such persons with technical skills are not difficult to find in a rural community. Teachers, if they permanently live in the communities and have time to operate the charging system, are also good candidates. Candidates should be determined by the Concessionaire. In some cases, selection is carried out with the chief, District Coordinating officer and PV Agent. They go to the community and hold hearing among resident of the community regarding the selection. Selection should be fair and transparent because the CSS is to be installed as a public purpose and will provide the CA with an income.

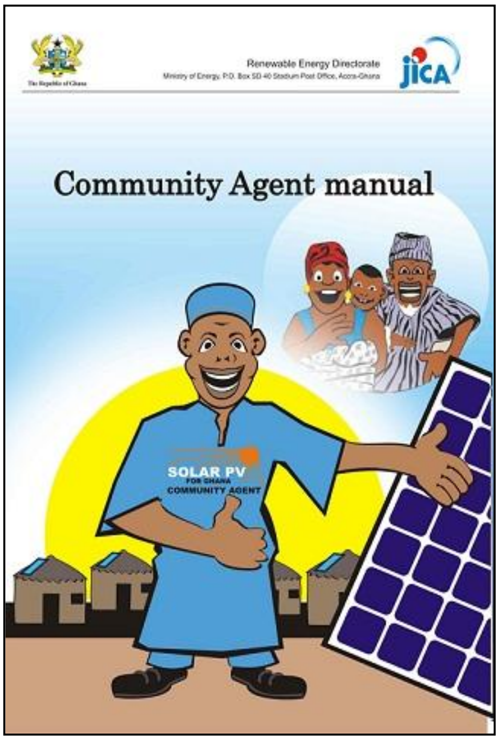
Training more than two Community Agents is advantageous in case the CA leaves the community. In this case, it is important to appoint one person as the “main” CA and the other as the “sub” CA during training.

In the pilot project in Tomefa, 4 Community Agents were trained without appointment of the "main" Community Agent, and led to un-necessary conflict among them. They take turns operating the CSS and share the wage.

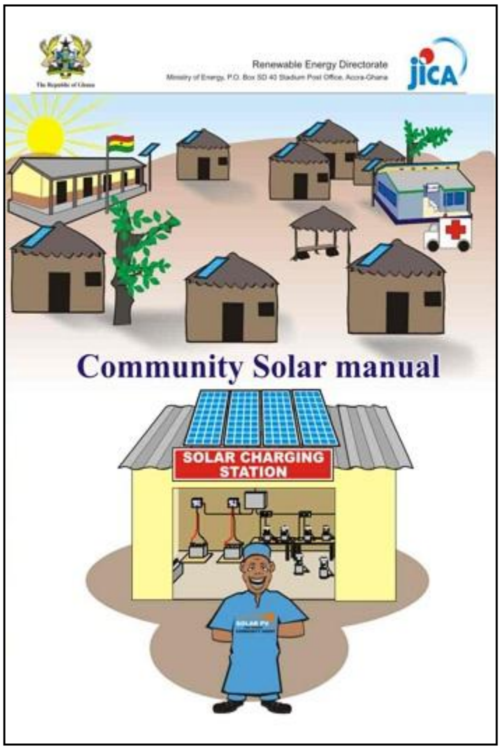
<Training materials>

The Project developed a "Community Agent manual" and a "Training Kit" for CA training. The Community Agent manual was initially contained a technical section and a Community Solar section, but was divided into two manuals- a revised "Community Agent manual" and the "Community Solar manual". The Community Agent manual is intended for Community Agents as a technical manual and the Community Solar manual is intended for Concessionaires, DAs and PV Agents as a business manual. When the original manual was divided, its contents were also revised to include more illustrations rather than text to improve familiarity for people in rural areas. This improvement was based on the experience gained by the Project Team when the old version was used in the field.

Fig. 7 Community Agent Manual and Community Solar Manual



Community Agent Manual



Community Solar Manual

The training kit is also effective. Basically, it is composed of the following.

- A wooden board

- A small PV panel
- A controller, an inverter and a lamp
- A small battery

The kit is used for the trainees to practice actual wiring between PV components to further understand system configuration and to experience actual wiring. Once the trainees complete this practice, they are more confident regarding PV systems and can carry out installation work.

The only problem is that it is very costly. If preparing the kit is too big burden for PV Agent, it is recommended to utilize the components that will be later used in installation.

Fig. 8 Photo of Community Agent training

2.3 Training of PVA and trainer

2.3.1 Role of trainer

<Trainers' role>

"Trainers" in the Project are not mere trainers but the persons who play a leading role in the field of PV. They have to carry a wide range of knowledge and skills.

Trainers do not necessarily train users directly. They will train instructors who will directly train users. Trainers should be able to provide proper knowledge to those who are working in PV field, such as government organizations and PV companies. Trainers' role is to train human resources in the field of education, industry and policy making. In the Project, the following persons were trained as PV trainers.

Table 8 PV trainers

Institution	Name
KNUST	Edwin Adjei
	Robert Okyere
Tamale Polytechnic	Baah Joseph Okyere
	Atiglah Henry
	Sankpi Linus
Koforidua Polytechnic	Augustine Ntiamoah
	Divine Atsu

<Candidate of trainers>

Trainers should carry a wide range of knowledge and skills such as basic theoretical ones, practical ones, economical aspects and management aspects. In addition, they have to know further applied technology, such as testing and regulation. In this sense, trainers should not only learn theory but also experience actual work including planning, management and evaluation. Basically, trainers should be electrical engineers. Technical staff in public organizations and persons in PV companies can be candidates, but since trainers are expected to train human resources, they had better to be persons in educational organizations.

Ghana already has a private PV training course in AGSI. Usually, staff working in such private training course only has technical knowledge. On the other hand, trainers in the Project need knowledge and skills in not only technical aspects but also financial aspects and manageable aspects. Persons with greater knowledge are more preferable as trainers.

Ghana also has renewable energy educational course in Koforidua Polytechnic. KNUST sometimes holds PV training courses. The Project selected persons in these schools as PV trainers, and worked with them. The Project also selected persons in Tamale Polytechnic because the North of Ghana is the area where PV rural electrification is mostly needed.

The following table shows the summary of requirements to be a trainer

Table 9 **Requirements for a PV trainer**

Role of trainers	Center of PV knowledge
Trainers' work	Education, planning, consultation and evaluation on PV
Candidates	Electrical engineers working in educational organizations

<Accreditation in the trainers' institutions>

All trainers belong to the national educational organizations; Polytechnics and a university. These organizations are accredited to issue public certification. Such certification is issued to those who study a specific field more than a year and mastered a wide range of knowledge on it. Unfortunately, photovoltaic is too narrow to be accredited by the national education system. Usually, only theoretical basics on photovoltaic are included in the curriculum of electrical engineering course in the national education system. Practical skills, such as installation, operation and maintenance, are not included in the curriculum although these skills are the most important in rural electrification. Revision of the curriculum is preferable to include practical photovoltaic in the official course. However, such revision should meet the national requirements for accreditation. This process is not easy and needs a long time. As a result, the Project recommended having PV educational course apart from official curriculum. Those institutions can have some special training course, such as after school lessons and week end lessons. PV training by trainers should be as one of such special courses.

2.3.2 Training of trainer (TOT)

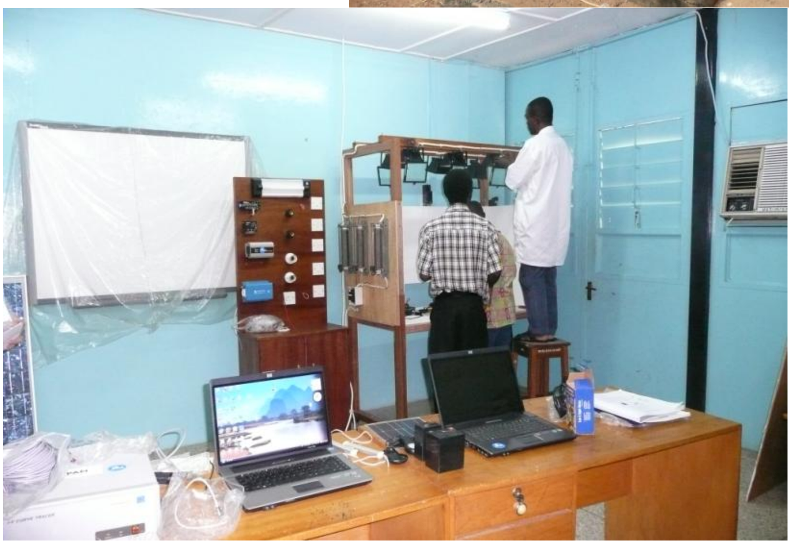
Trainers should master a wide range of PV knowledge and skills. In the Project, training of Trainers (TOT) was carried out for 4 years as shown in the following table. Details of the training are shown in Attachment-4.

Table 10 **TOT conducted in the Project**

Theory (Class room lesson)	1st time (2 days) PV basics, PV components 2nd time (3 days) PV systems, design, installation 3rd time (3 days) Community Solar System, management

Practice	Field practice in the practice sites (3 days) Installation, Operation, Maintenance, business Evaluation (4 days) Existing PV systems (Monitoring) PV testing (Panel, battery, controller, inverter, lamp) PV component (3 days) LED lamp assembly
Peer review	Practice lecture (2 days) Peer review among trainers CA training (4 days) Trainees (5-10 persons): CA candidates Observers (5-10 persons): Trainers, PV Agents, MOEn officers Week-end class (1 day) Trainees (5-10 persons): Students Observers (5-10 persons): Trainers, PV Agents, MOEn officers

Fig. 9 Photo of trainer training



2.3.3 Role of PVA

PV Agents usually deal with PV products in rural areas. They can also install PV systems. Role of PV Agents is to promote PV systems in rural areas.

In the Project, PV Agents are expected to promote PV market, especially Community Solar System, in rural areas. They go to communities, select Community Agent, carry out Community Agent training and install PV systems. They support the Community Agents in their operation and maintenance of PV systems. Daily maintenance and simple troubleshooting are carried by Community Agents. PV Agents will handle difficult problems that Community Agents can't do with. They also supply some PV spare parts to Community Agents.

PV Agents should be able to conduct CA training. They should prepare materials for CA training with their own investment. If PV systems are disseminated under pure market mechanism, CA training itself should be conducted by PVA's own investment. When appropriate training is provided to CAs, sustainability of the PV systems in the community will be improved, and hence, the PVA's business opportunity in the community will expand. As a result, the PVA recover his investment. If Community Solar System is introduced into the community, investment recovery becomes much easier through the income of the charging service. PVA is in the position to disseminate CSS and train CAs in rural areas.

Table 11 PV Agent's role

Role of PVA	Promotion of PV in rural areas
PVA's' work	Sales of PV products Training and support of Community Agents Dissemination of CSS
Candidates	Staff of local PV dealer

2.3.4 Training of PV Agents

PV Agents need not only technical but also business knowledge and skills because they must run PV business in rural areas. Theoretical knowledge is not so important for them but practical skills are more important. Currently, AGSI is operating training courses to train PV technicians for PV dealers. The training can be regarded as a PV Agent training, but a problem is that AGSI's training does not have business training. Therefore, the Project decided to develop business training so that AGSI can use it in its training.

From practical viewpoint, contents of business training should be based on actual PV business. The Project found that Community Solar System was a good sample for studying PV business. Necessary knowledge on business, such cost study, investment recovery, pricing, bookkeeping and management, can be found in several samples of Community Solar operation. Therefore, the Project summarized these data and developed "Community Solar Manual" as a textbook for business training. This textbook can be used not only for PV Agents training but also raising awareness of Concessionaires, DAs and government staff. The following is the contents of the manual (Details are in Attachment-27).

Table 12 Contents of Community Solar Manual

Chapter	Contents
1. Community Solar System	Basic concept of CSS
2. Sustainability	Financial and technical sustainability of CSS
3. Charging method	DC charging, AC charging
4. Charging capacity	Possible number of charging
5. Business mode	Sales mode, rental mode Pricing
6. Management	Role of concessionaire Management structure
7. Monetary control	Maintenance cost Bookkeeping
8. Business feasibility	Cash flow Investment recovery
9 Tips for Community Solar operation	Consideration on night operation and lantern use Maintenance tools Business expansion Record of troubles

The Project planned to develop business training for PV Agent with AGSI. The contents should be harmonized with AGSI's PVA training. As a result, Joint training was held by the Project and AGSI. AGSI took charge of technical part and the Project took charge of business part. Technical part was for 4 days and business part was for 1 day, in total the duration was 5 days. The following table shows the summary of the curriculum (Detail curriculum is shown in Attachment-3).

Table 13 **Contents of Joint Training**

Day	Contents
Day 1	● Safety ● Basics on photovoltaic ● PV components ● Introduction of Solar Home System ● Measurement of PV panels (practice)
Day 2	● Measurement of batteries (practice) ● Connection of PV panels (practice) ● Connection of batteries (practice) ● Irradiation and peak sun hours ● Drawing exercise
Day 3	● System sizing ● System assembly practice
Day 4	● Concept of Community Solar System ● Operation and maintenance ● Pricing, investment recovery ● CA training ● Management of Community Solar System
Day 5	● Installation practice ● Questions and answers

Community Agent training method using “Community Agent Manual”, the brochure and “Training Kit” is also explained in the joint training. Relation among PV Agents, Community Agents and Concessionaires is explained using the MOU that was developed in the Project to define their roles clearly.

Fig. 10 **Photo of joint PVA training**

2.3.5 Lessons learnt

There are not many special subjects to learn in PV technology. Most of PV technology is included in general electrical technology. Electrical technicians can become good PV technicians with small additional training concerning photovoltaic basics and panel setting. Setting up such technical training is not difficult in Ghana.

Ghana already has many good electrical technicians and they can be good candidates of PV technician. A problem is that the current PV market is too small for them to start business as PV technicians. As a result, most electrical technicians are working in normal electrical field and do not pay much attention to PV business. Before considering training scheme, more efforts should be paid to expand PV market.

Against this background, the Project shifted its project purpose from development of PV training system to expand PV market by introducing Community Solar business model.

For disseminating Community Solar business model, there still some issues remain concerning human resource development. The following is lessons and learnt for PV Agent training.

<PV Agent candidates>

PV market in Ghana is very small. Most of PV systems in Ghana were installed directly by donors without going through market. Most of PV dealers are in Accra which is better place for them to have a chance to participate in donor projects. Most of the trainees of AGSI training are also in urban areas. The Project held PV Agent training jointly with AGSI. At first, the Project called for trainees among DSTC training graduates. Those who applied were all from urban areas. The Project tried to find candidates in rural areas through MOEn’s network and secured only two persons. If calling for PV Agent candidates is organized through such public announcement, it is very difficult to find candidates in rural areas. In the Project, PV Agent candidates were called for through the human network of MOEn and AGSI. Calling for trainees through such specific network is better way to find suitable candidates.

Another way of securing PV Agent candidates is to target technicians in District Assemblies or local schools. District Assembly is in a good position to have close contact with communities. Schools are also able to have good relation with people in the areas through their students. In most cases, these organizations have electrical engineers. They are also good candidates for PV Agents.

Table 14 Candidates PV Agents

Local PV dealers
Technicians of the District Assembly
Technicians of schools

<Business training>

The Project held two times of joint training for the PV Agent with AGSI. The feature of the training was that it had business training. The duration of the training was 5 days. AGSI took charge of technical training for 4 days and the Project took charge of business training for one day. The business part was sample study on CSS operation. The training was very successful. The trainees understood the merits of CSS and showed strong interest in operating its business.

Although trainees showed their interest in CSS business, a difficulty was that all the trainees did not have enough fund sources to start CSS business. In such a case, Ghanaians are likely to rely on the government help or donor’s aid. However, from the point of sustainability, they have to invest their own money and take full responsibility on their business. If they don’t have enough sources, they must apply to bank loans. In the joint training, there was no component to train skills to apply to bank loan. Training on such skills should also be one of important subjects for business training.

<Community Agent training by PV Agent>

Currently, the possibility for PV Agent to carry out CA training is still very low. PV Agent does not want to lose his time and money on CA training because he does not know the business possibility of CSS and importance of training CA for the CSS operation. Even if he knows the importance of CA training, PV Agents want to reduce time and money losses on CA training. Therefore, time and cost needed for CA training must be minimized. The duration of lecture type training will be for a half day. Assembly practice also should be for a half day. PV components needed in assembly practice should be the ones to be used for installation. Most practical training should be carried out through involvement in installation work. Three time of installation practice is enough for trainees to understand PV systems.

<Development of human network>

Building up human resource network is very important to keep sustainability of PV systems in rural areas. In the Project, Community Agent, Concessionaire, PV Agent and District

Coordinating officer (or other appropriate staff) are key persons to form the human resource network. When holding CA training, inviting these people is a good way to form the human resource network. They can become familiar with each other during the training. They can mutually understand and confirm each role. It will facilitate later communication and help forming good trust among them.

<Accreditation/qualification>

At first, the Project planned to implement accreditation and qualification system for PV technicians. However, it was found that the scope of capability as being PV technicians or PV Agents is too narrow to be qualified in the official accreditation system. Official qualification is issued only for those who have sufficient knowledge and skills concerning the technology. Usually, 2-3 years are needed to acquire an official qualification. The training course that the Project planned to implement is only one or two weeks. Official schools do not issue any certification for such short term training. Certification for those who master such short term trainings had better to be handled by private systems. Issuing “Recognition of participation” is enough for such type of training.

2.4 Human Resource Development for PV testing

2.4.1 PV testing

<Background>

Ghana has already introduced the national PV standard. PV testing technology and methods are defined in it. Once a product meets the standard, its performance is certified by the government. Therefore, test for the certification must be very strict because the government must bear the responsibility in place of the manufacturers when any problem is found with the product. To meet such strict requirements, Ghana has introduced the national PV standard from the one defined by International Electric Committee (IEC), which is an internationally authorized organization.

There is Ghana Standard Board (GSB), which is in charge of standardization and testing of products in Ghana. Quality of all products sold in Ghana must meet the National Standard. GSB is responsible to test whether products meet the Standard, and GSB is the only organization that can issue any certificate of products performance. Therefore, as long as official certification is concerned, testing must be conducted by GSB using the National Standard.

The Project tried to develop an official certification system for PV products at first. The process for such national standard is very sophisticated. Necessary equipment for testing and its maintenance are very costly. On the other hand, the current PV market is very small. All PV products are imported. Imported PV products are usually certificated by the manufacturing companies. Need to establish certification testing for PV products is not high. As a result, the purpose of PV testing in the Project was shifted from development of certification testing system to technology transfer on PV testing as part of human resource development.

<Target of PV testing>

Technology transfer on PV testing in the Project is summarized as the following table.

Table 15 Target PV testing technology in the Project

Products	Testing technology	Target organization
Panel	● IV curve measurement based on IEC procedure ● Manual IV curve measurement	KNUST Tamale Polytechnic Koforidua Polytechnic
Battery	● Capacity test ● Charge-discharge cycle test	KNUST Tamale Polytechnic Koforidua Polytechnic
Charge controller	● Set point test	KNUST

		Tamale Polytechnic Koforidua Polytechnic
Inverter	● Output wave form measurement	KNUST Tamale Polytechnic Koforidua Polytechnic
Lamp	● Lux measurement	KNUST Tamale Polytechnic Koforidua Polytechnic
Lantern	● Quality test based on PV GAP procedure	KNUST GSB

2.4.2 Training on PV testing

2.4.2.1 Panel test

- IV curve measurement based on IEC

The most common evaluation of PV panel is IV curve measurement, which is to measure basic voltage-current characteristic of PV panels. The Project introduced MP-160 (EKO) which is designed to automatically carry out panel measurement suitable to IEC procedure. A difficulty of panel measurement is to set up a light source whose light is stable, uniform and strong enough to measure panels. The following table shows IEC's requirements for the light source when measuring PV panels.

Table 16 Light source requirement by IEC

Item	Requirement
Uniformity	±5%
Intensity	more than 0.6kW/m^2

In the Project, natural sun was used as the light source because setting up an artificial light source is too difficult. The Project tried to develop a lamp house for panel measurement. Unfortunately, the light of the lamp house is not uniform, and not strong enough for IEC requirement. It can only be used as a rough estimation tool of panel evaluation.

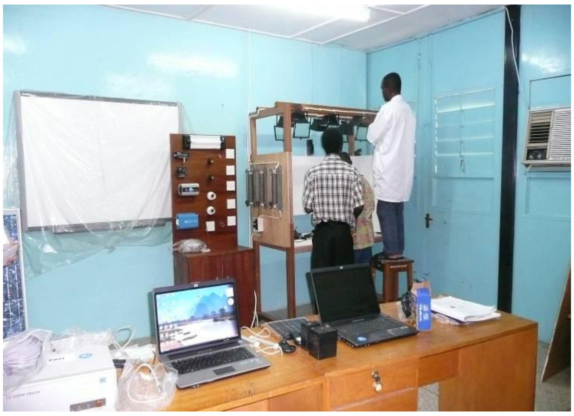
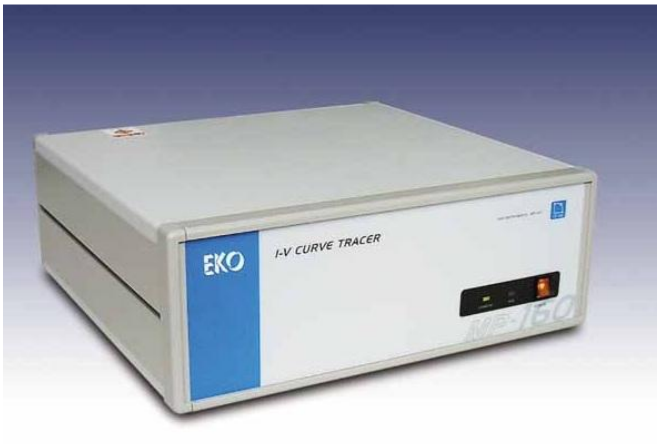


Fig. 11 Lamp house in KNUST

The feature of MP-160 is that it takes only 2 seconds to measure panels, enabling to avoid any temperature and light intensity disturbance caused by sunshine fluctuation. The equipment can be used as panel test in accordance to IEC procedure when used with natural sun of more than 0.6kW/m^2 intensity as its light source.

Fig. 12 EIKO MP160



- Manual IV curve measurement

Method of manual measurement is shown in Attachment-8. Natural sun is also used as light source in this method. Since this method is very primitive and uses only two multi-meters, a sunshine meter and a thermometer, it is very suitable for students to learn the electrical characteristics PV panels.

On the other hand, this method is not recommended for official panel test. The measurement takes several minutes to evaluate one panel. There might be light and temperature disturbance caused by sunshine fluctuation.

2.4.2.2 Battery test

Kikusui Battery Testers are provided for battery testing. It is composed of a programmable DC power supply and a programmable charge/discharge controller. The Tester can perform CV charge/discharge, CC charge/discharge, CV/CC charge/discharge, CP charge/discharge and pulse charge/discharge. The programmable controller enables any combination and repetition of these charge/discharge modes and as a result, it can perform battery test defined by IEC procedure.

(CC: Constant Current, CV: Constant Voltage, CP: Constant Power, refer Attachment-9.)

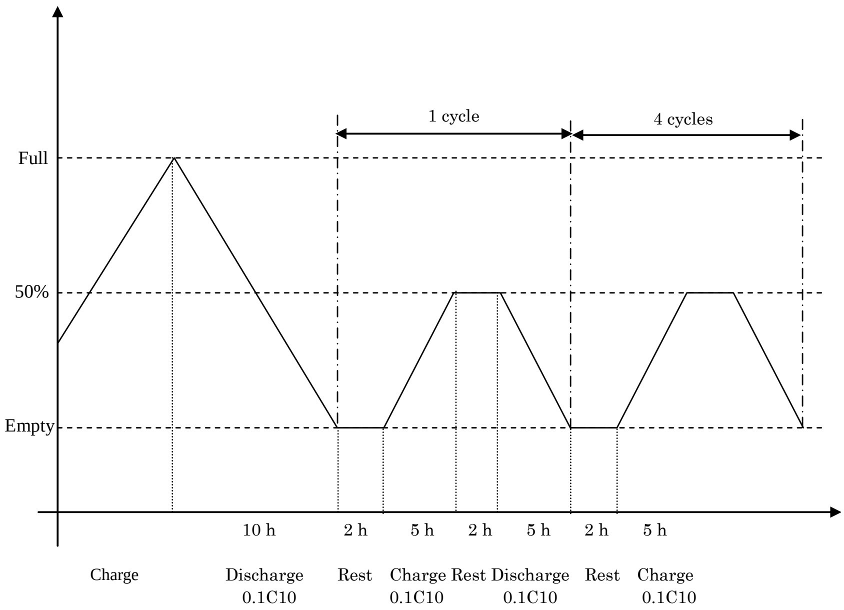
Fig. 13 Kikusui Battery Tester

- Cycle test

Cycle test is the most common test to evaluate batteries. Usually, CC/CV mode is applied to cycle test. The procedure for cycle test defined in IEC requires 100 days; 3 hours of discharge at 2*C10 current and 21 hours of charge to 14.4 V with less than 2*C10 current. This evaluation takes very long time.

Another evaluation is Ah-cycling efficiency. Although this evaluation also takes a time, it is up to 5 cycles with one cycle 14 hours. Initially, a battery is fully charged and it is fully discharged. Then, it is charged to 50% with C10 current. It is fully discharged again with C10 current. 2 hours of rest is inserted between each action. Charge/discharge efficiency of the 4th and 5th cycle are averaged. 90% of efficiency is the criterion..

Fig. 14 Ah-cycling efficiency test



- Internal impedance

A feature of Kikusui Battery tester is that it has a function of internal impedance measurement. Although internal impedance measurement is not defined in IEC test procedure, it is very useful to evaluate battery deterioration. The following table shows typical value of initial internal impedance of 12V 50Ah lead acid battery. Internal impedance of other rating batteries can be estimated in proportion to the voltage and inverse-proportion to the capacity. When batteries get deteriorated, their internal impedance increases. For example, if a 12V 50Ah solar battery shows more than 50 mΩ of internal impedance, it is much deteriorated.

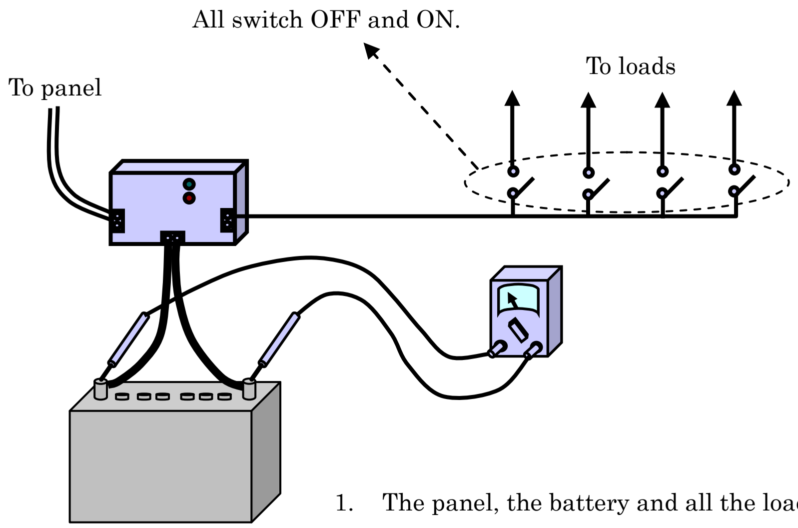
Table 17 Typical internal impedance of batteries

Battery type	Internal impedance
Car battery	Around 10mΩ
Deep cycle battery	20-30 mΩ

- Simple impedance evaluation

Battery voltage drops by internal impedance when it drives appliances. If the battery is old, internal impedance increases and the voltage drop also increases. The following drawing shows the practical method to know whether the battery is old by measuring the voltage drop in the field when there is no impedance meter available.

Fig. 15 Manual impedance evaluation



1. The panel, the battery and all the loads are connected.
2. Switch OFF all loads and measure the battery voltage.
3. Switch ON all loads and measure the battery voltage.
1. If the all load ON voltage is more than 0.5V lower than all loads OFF voltage, then the battery is deteriorated.

2.4.2.3 Charge controller test

There are two types of charge controllers. One is set point type and the other is PWM type. In IEC test procedures, only evaluation of set point is defined. The Project conducted the set point evaluation in the training. This test can be performed using two DC power supplies. By-directional DC power supply is recommended to use in this measurement. In the training, only one-directional type was available. In this case, a protection circuit is necessary to protect the power supplies from current contention by the other power supply. A sample circuit diagram is shown in Attachment-11, which was explained and used in the training.

IEC standard indicates recommended value for set point type charge controllers. The following table shows the value.

Table 18 Recommended set point for lead acid batteries by IEC

Set point	Value
HVD	13.8V -
HVR	12.9 – 14.1 V
LVD	10.8 – 11.4 V
LVR	12.3 – 12.9 V

HVD is higher than HVR by around 0.5 V. Usually, HVD of sealed batteries is set a bit lower than that of flooded batteries. Typical combination of HVD and HVR is as follows. LVD and LVR are not much different among lead acid batteries.

Table 19 Typical HVD and HDR

Set point	Flooded batteries	Sealed batteries
HVD	14.1 V	14.0 V
HVR	13.5 V	13.5 V

2.4.2.4 Inverter test

Inverter tests defined in IEC procedure were for electrical and mechanical endurance and efficiency. Electrical and mechanical endurance test is not much different from the ones for other electrical appliance test. Efficiency measurement differs depending on output wave form. If output wave form is pure sine wave, efficiency measurement is not difficult. Output power can be calculated by simply multiplying current, voltage and power factor. However, there are many inverters in PV application whose output wave form is not pure sine wave. In this case, voltage and current should be recorded and output power is calculated using RMS (Root Mean Square) method.

The Project provided LABview as a platform of universal testing. It can record any electrical signals, and calculation of them can be programmed using "G", a graphic language for LABview. Programs of output wave form observation and calculation of RMS were developed by the project Team (the program is shown in Attachment-12), and explained to the trainers.

2.4.2.5 Lamp test

There is not any specific test method for PV in IEC test procedures. General electrical test methods for lamps can be applied to PV lamp evaluation. The Project conducted lamp efficiency test in terms of LUX/power, which is considered useful when evaluating PV lamps. Basically, efficiency should be evaluated in terms of LUMEN/power for lamps. LUMEN is integrated value of all the light from the lamp, which is difficult to measure. LUX represents brightness at specific direction. In the Project, LUX was used for evaluation instead of LUMEN from practical point of view. Efficiency comparison between LED lamp and fluorescent lamp was conducted in the Project. The results are shown in the following table.

Table 20 Results of lamp evaluation

	Fluorescent lamp	LED lamp
Brightness at 1m distance	25 lux	56 lux
Consumption power	15 W	2.2 W
Energy efficiency	1.7 lux/W	22.5 lux/W
Cost	2 cedi	30 cedi
Cost performance	0.85 lux/W*cedi	0.8 lux/W*cedi

2.4.2.6 Lantern test

PV lanterns are becoming very popular in the world especially in developing countries because they are much cheaper than any other PV systems and very useful in the areas where power is unreliable or unavailable. Evaluation of their reliability is very important for PV lanterns to expand their market. The Project found that some PV dealers were going to introduce PV lanterns into Ghana market. Unfortunately, no information concerning reliability is available with those products. It is very useful to establish an evaluation procedure of lanterns in Ghana.

IEC has evaluation procedures for PV lanterns. They are very strict and need about three months to complete. Such costly and lengthy procedures are not practical in developing countries. PV GAP is an organization that provides testing services to the countries that do not have facilities for testing. PV GAP has a more moderate evaluation procedure for PV lanterns than IEC. The necessary duration for the test is around 30 days.

The Project considered that the PV GAP procedure is suitable to Ghana to evaluate PV lantern reliability, and decided to transfer the technology. The Project also developed rechargeable lantern test procedure based on the PV lantern test because rechargeable lanterns are very important in the pilot projects. The test procedure for PV lanterns and rechargeable lanterns are shown in Attachment-13.

As a practice, 8 lanterns were evaluated following PV GAP procedure. Out of them, three were failed in document inspection. The following table shows the test results of the remaining lanterns.

Table 21 Results of lantern test

Type	Manufacturer	Result
PV lantern	Philips	Failed
	Suntransfer	Passed
	D lights	Passed
Rechargeable lantern	Q-link	Passed
	Akai	Failed

2.4.3 Developed materials

The Project developed "PV Testing Manual" which contains test procedures for panels, batteries, inverters, controllers and lamps based on IEC procedures. It also contains performance references.

IEC test procedures define several procedures for testing depending on the test environment. The Project selected the most appropriate procedures considering Ghana's natural environment and available materials to use. The selected procedure can be conducted with the equipment that the Project provided.

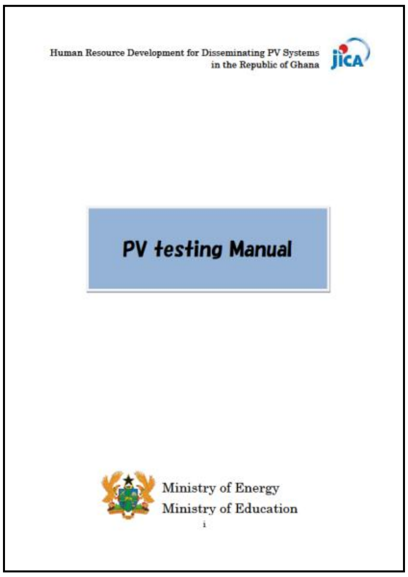


Fig. 16PV testing manual

The Project also developed training board in KNUST and Tamale Polytechnic. It was developed for students to learn practical knowledge on PV components and systems. Basic configuration of PV system, performance comparisons among several products, voltage loss along cables and current test technique can be studied with this board. Configuration of the board is shown in Attachment-7.

Fig. 17Training board

2.4.4 Lessons learnt

<Panel test>

- Light source

IEC testing method of PV panels is very well known around the world. Many industrialized countries provide panel test/certification service based on IEC test procedures. Most panels produced in industrialized countries are tested and certificated in their countries. It is not difficult to know panel reliability by checking whether it has IEC certificate or equivalent. Since Ghana does not produce PV panels, the first approach of PV panel quality control is to check the certificate at the time of import and it is enough to keep the panel quality in Ghana. Panel test is necessary only when there is a need to confirm panel output caused by such as users' claim that their panels do not generate the rated output.

When conducting panel test, users have to decide what type of light source to use. The Project recommends using the natural sun as light source. Natural sun is the most preferable light source if measurement is conducted on a clear sunny day (light power is more than 0.6kW/m^2). There are several types of artificial light sources dedicated for panel measuring. They are very stable, but the cost of the equipment itself and its maintenance is too high. Using natural sun for panel evaluation is the most practical solution.

On the other hand, a lamp house was developed in the Project. However, it was very difficult to find stable lamps in Ghana. The Project used some halogen lamps although their light output was not strong enough and uniformity was not satisfactory. It should be used only for rough estimation when weather is not good for panel evaluation.

- Temperature coefficient

MP160 that the Project provided for panel testing can easily measure IV curve of panels. It can produce IV curve graph, raw data and calibrated data in a report form to be used for evaluation. For the calibration, some coefficient is necessary. The relation between IV curve data and coefficient is shown in Attachment-14. The following table shows the necessary coefficient for calibration.

Table 22 Coefficient needed for calibration

Coefficient		Value
Temperature coefficient of Isc (α)	1/K	0.000346
Temperature coefficient of Voc (β)	1/K	-0.00250
Irradiation correction factor		0.0340
Series resistance	mΩ	624
Temperature coefficient of Rs	mΩ/K	2.4

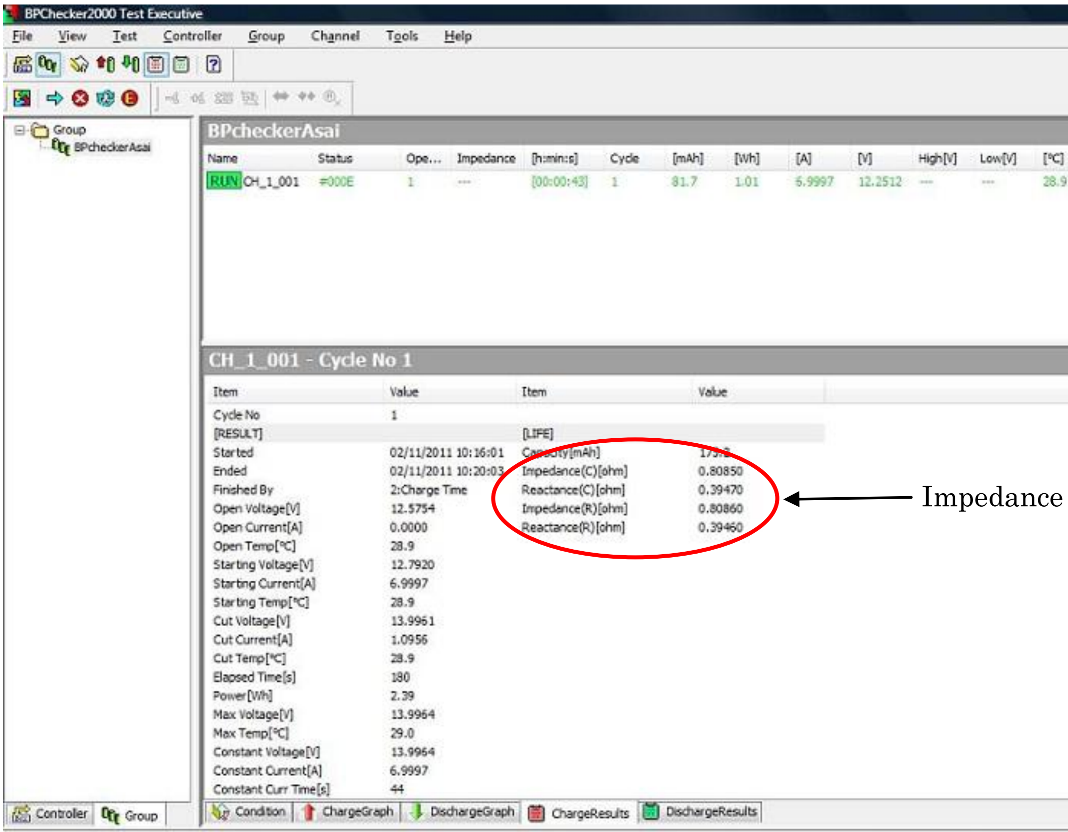
<Battery test>

One of difficulties in battery test is that most battery manufacturers do not disclose enough data for users to conduct test. Sometimes, only ampere-hour capacity without indicating C-rate is known to users. In the training, C10 is recommended to evaluate battery capacity. C20 is the most preferable considering that most PV systems are designed based on around 20 hours of discharge. However, if C20 is used in cycle test, one cycle needs almost 2 days and 100 cycle test needs 200 days. It is not practical and C20 capacity and C10 capacity is not much different among batteries of 12V 50-100Ah that are commonly used in rural PV systems. Therefore, using C10 is the most practical.

The most important factor in evaluating batteries is life span, which is usually evaluated by cycle test. A difficulty of the test is that it takes a very long time, that is, 100 days with C10 rate, and it is a destructive test. The test has to be well planned and backup power supply is necessary to avoid fruitless failure caused by power failure.

The battery tester that the Project provided has a function of evaluating internal impedance. It can evaluate internal impedance after every charge and discharge step. If the internal impedance increases more than double of its initial value, the battery is deteriorating. This method of evaluation is convenient when there is not enough time to perform cycle test.

Fig. 18 **Output of Battery Tester**



Although measurement of internal impedance is very useful to evaluate battery deterioration, it is difficult to bring the tester to the field. The simple evaluation method that is shown in Chapter 2.4.2.2. is very useful as field technique.

<Controller test>

Although controller test procedure is defined in IEC, no manufacturer follows the procedure. Manufacturers use their own test methods and certify by themselves. It is hard for users to know controllers' performance. Set point of controllers can be evaluated with the methods used in the Project. However, set point itself does not differ among products. Although the most important factor for users is reliability, it is not easy to evaluate. The simplest way to identify reliable controller is to find the most commonly used controllers.

<Inverter test>

From the viewpoint of output wave form, inverters are categorized in to two types; one is sine wave and the other is non-sine wave. Output wave form was only evaluated by visual observation using an oscilloscope. Sine wave inverters are preferable but their cost is high. Non-sine wave sometimes makes noise and, in worst case, damages appliances with its spike noise. However, most appliances will run with non-sine wave inverters and they are very cost effective. In addition, their availability in the market is very high. Therefore, the Project uses non-sine wave inverters.

Efficiency evaluation of non-sine wave inverters is very difficult as is explained in Chapter 2.4.2.4. Instead of evaluating efficiency, the Project recommends measurement of stand-by power consumption and overall power consumption with load connected. Those can be evaluated by measuring only input side of inverters. Since input side is DC, it is easy to calculate power. Obtained values can be used as references when estimating power consumption.

Evaluation of input voltage range is also important because some inverters' input range is too narrow for PV use. At least, input range must be wider than 11.5 - 13.5V because this is normal voltage range of 12V battery.

<Lamp test>

Only efficiency test was conducted in the Project. The test is not specific to PV systems but can be applied to all lamp systems. The only difference is that the Project evaluated LUX instead of LUMEN. It is because the Project considered that information of brightness at necessary spot is much more practical than that of integrated value.

Reliability of lamp was not evaluated because LED, which is much more reliable than the old tube type lamps, is now prevailing in PV systems. Reliability is not a problem with LED lamps.

<Lantern test>

Since PV lantern can be regarded as a miniature size PV system, its testing technique can be applied to not only PV lanterns but also other PV systems. The Project conducted PV lantern testing and transferred the technology to both KNUST as educational purpose and GSB as official testing purpose.

PV GAP procedure is used for this testing. Even so, about 30 days are necessary to complete whole the procedure. Most of the time is used for battery charge/discharge cycle test. This technique is based on the same concept with battery cycle test. Once they understand battery test technique, understanding this part of the lantern test was not difficult. Other parts are mechanical vibration endurance test, switch ON/OFF test and over-voltage endurance test. The training in the Project focused more on battery-test part with explanation of the general battery test as a background.

A difficulty of lantern test was vibration test. In PV GAP procedure, 10Hz to 150Hz vibration with amplitude of 3.5mm and acceleration of 1 octave/min for 2 hours has to be applied to the lantern. Implementation of this test condition is too difficult. The Project recommended developing a different type of vibration test such as loading the lantern on a vibrating machine such as engines.

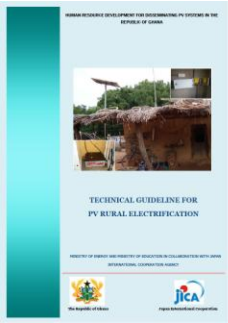
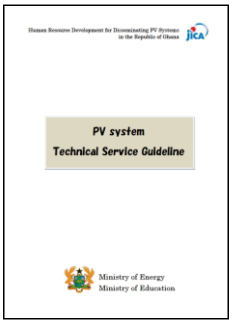
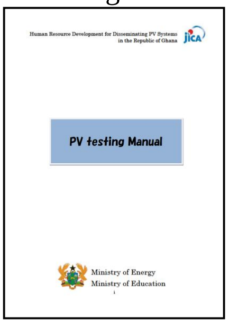
Test procedure for rechargeable lanterns is implemented based on PV lantern test procedure. Difference between PV lantern test and rechargeable lantern test is only how to charge batteries. PV lanterns are charged be PV panels with designated hours of designated light power. Therefore, the proportion of the charging energy to the rated energy for full charge in PV lantern testing is calculated. The proportion is recalculated to the charging time of rechargeable lantern testing. The detailed procedure is shown in Attachment-13.

2.5 PV Education

2.5.1 Developed materials

The Project developed the following materials for PV education.

Table 23 Developed materials

Name	Contents
Practical guide for PV rural electrification  	Developed for students who study basic PV technology Contents: ● Solar power ● Electricity theory ● Solar cell ● Solar panel ● PV components ● PV testing ● PV systems ● Installation ● Management ● Operation and maintenance ● Community Solar System
Technical service guideline  	Developed for engineers who manage PV installation Contents: ● Introduction ● PV components ● System design ● Installation ● Inspection ● User manual ● management
PV testing manual  	Developed for engineers who conduct PV product test Contents: ● Panel testing ● Battery testing ● Charge controller testing ● Lamp testing ● Lantern testing ● Normative reference

Those materials were developed intending that they were to be used for Polytechnic level education. “Practical guide for PV rural electrification” can be used as a textbook. The other two can be used as reference manuals. The training board that is explained in Chapter 2.4.3 can also be used as practice of PV system testing for Polytechnic students.

In addition, the Project developed many presentation materials in the trainings. They are also very useful to use in PV education. The Project printed all the presentation materials, filed them in a binder and delivered them to each Institution. The following is the materials that are filed.

- Presentation materials in trainer trainings
- Trainer’s note
- Community Agent handout
- MOU of the CSS system for Institutions
- MOU of the Concession contract
- Community Solar drawing
- Manual PV panel test
- Manual battery test
- KOWA Box
- Training board

2.5.2 Special PV course

Half day PV classes were held by each Institution. They were held on Saturdays apart from the official curriculum. Their contents were developed by the trainers of each Institution. Basically, the contents were for providing attendants with basic concept of photovoltaic through lectures and practice. KNUST and Koforidua Polytechnic focused on introduction on PV. They taught basic concept on PV and conducted practice on PV panel voltage measurement. It stimulated attendants’ interest on PV. Tamale Polytechnic conducted more theoretical lecture and practice. The lecture was introduction of PV system design and installation basic, and the practice was PV panel current measurement. Because the contents was a bit high level, attendants of the class was limited only for grade 3.

The classes were successful and attendants showed their strong interest to learn more on PV. The three institutions plan to hold more such classes. The only problem to consider is that all the classes were held for free although the attendants were provided with drinks and snacks. It is traditional culture of Ghana. However, it will spoil not only the participants' seriousness but also sustainability of the classes. The Project pointed out this issue and the institutions are planning to introduce fee collection from the participants from next time.

3. Pilot projects

3.1 Outline

3.1.1 Objective of pilot system

The most difficult factor in sustainable use of PV systems is replacement of batteries. Batteries are expensive and need replacement every several years. Considering the affordability of rural people, securing money to replace battery is very difficult.

The next difficult factor is that most users are too much dependent on government aid saying that the government will repair their system when problem occurs. Actually, it is very difficult for the government to support all users' troubles. As a result, users don't prepare the money for repair and troubled systems are left un-attended.

To overcome these difficulties, the Project introduced Community Solar System (CSS), where users gain profit with charging service and use it for the expenditure on maintenance. Along with this business model development, the Project trains Community Agent as the operator of the CSS. The Community Agent is expected to operate the CSS and provide maintenance service to other PV systems in the community.

In the Project, CSS is composed of a charging service station and a public PV system such as school PV system or a clinic PV system. The income from the charging station is used for the maintenance of the station and the public PV system. If the charging station is operated efficiently, the income can cover the maintenance cost with enough profit. In order to operate the CSS efficiently, Community Agent (CA) who knows PV system and can operate the system is necessary. The CA is selected in the community and trained in the pilot project. Therefore, training of CA is a necessary part in the pilot project.

Since charging service generates income, a manager with business skills is necessary for keeping its business operation financially in good condition. If the CA has good business skills, he can manage the business operation. If he doesn't have them, a person called Concessionaire is selected for the management. The CA and the Concessionaire are trained and they together operate the CSS.

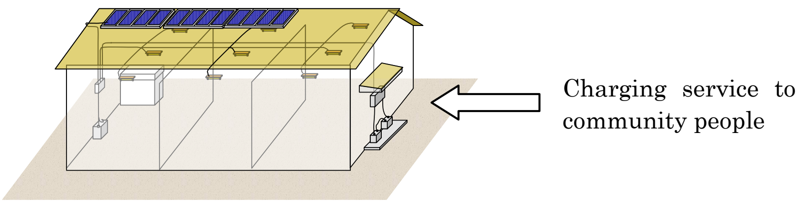
This is the basic structure of human resource in the Pilot Project. It is conducted for development of effective CA training method and effective operation system of CSS.

3.1.2 Concept of Community Solar System

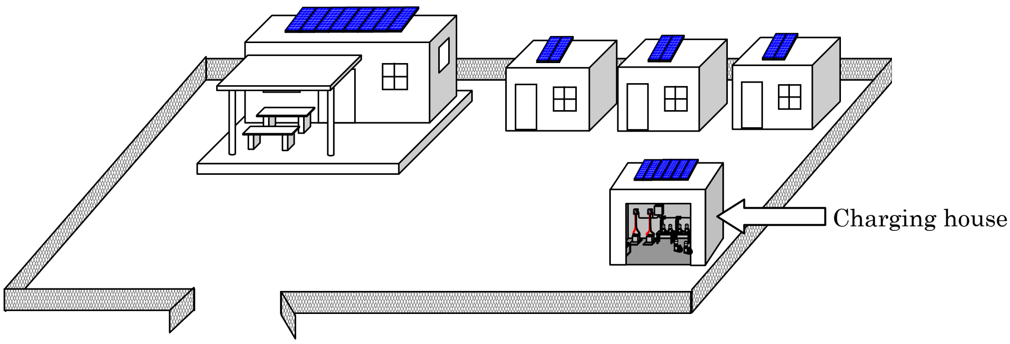
Public facilities such as clinics and schools are very important in rural areas. Therefore, the Government has been very keen in electrifying those facilities. PV systems were often used as an alternative measure when electrifying the facilities in un-electrified communities. Unfortunately, it was found difficult to keep sustainability of those PV systems because of lacking in necessary fund for repairing the systems when troubles happened and for replacing components when they came to an end of their life span. The concept of Community Solar System came up to overcome such difficulties.

As mentioned earlier, a charging system is attached to a public facility PV system. The charging system provides charging service to the community people. Currently, the demand to charge mobile phones is very high even in rural areas. It can also provide charging service to other appliances such as rechargeable lanterns. The income from the charging service is used to maintain all the PV system and hence, the sustainability of the PV system is much improved.

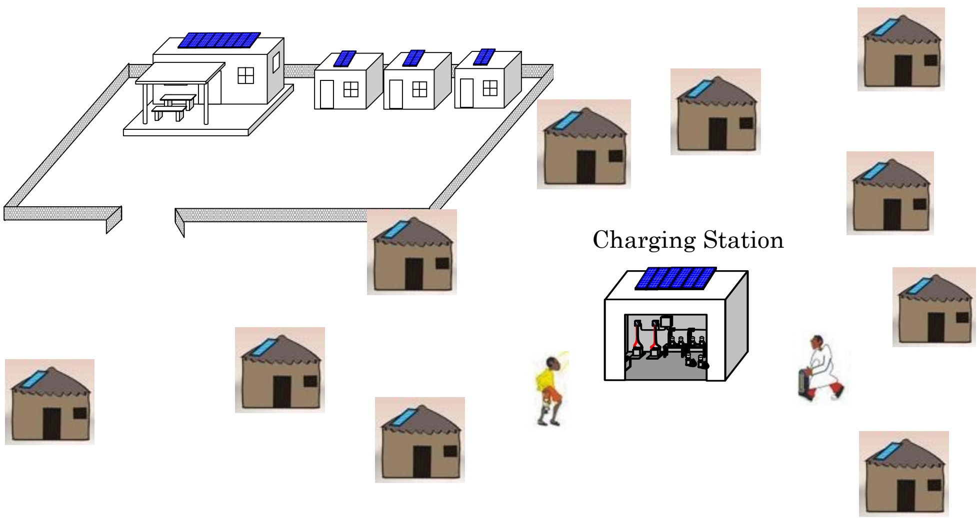
Initially, the charging system was part of a public PV system (a). In this case, it was not convenient for the public facility to operate completely different system from their original mission in the same building. Then, the charging system is separately installed in the facility and dedicated person was assigned to operate the system. Still, it sometimes caused inconvenience in the facility because so many people who do not have any business with the facility came and charge their appliances. Finally, the charging station came to be installed at completely different place from the public facility, where it was more convenient for many people in the community to come and charge their appliances. The income from the charging service is used for maintaining both the public PV and the charging system, and whole the systems are considered as one Community Solar system.



(a)



(b)



(c)

Fig. 19 Types of Community Solar System

3.1.3 Structure of CSS management

In the Project, two types of CSS operation mode were implemented. One is controlled by District Assembly (DA model). The other is controlled by Institutions (Institution model). The role, rights and responsibilities of concerning organizations/persons are summarized as follows.

Table 24 Roles on CSS management

- DA model

Person	Role
MOEn	Overall supervision
DA	Owner of the system Having rights to collect fee from the Concessionaire and to confiscate the system when any abuse found Bearing responsibility to monitor the Concessionaire.
Concessionaire	Business manager of the CSS Baring responsibilities to manage operation and to pay fee to the DA and the CA
CA	Operator of the CSS
PVA	PV promoter around the area, training CA, supporting maintenance for a fee

- Institution model

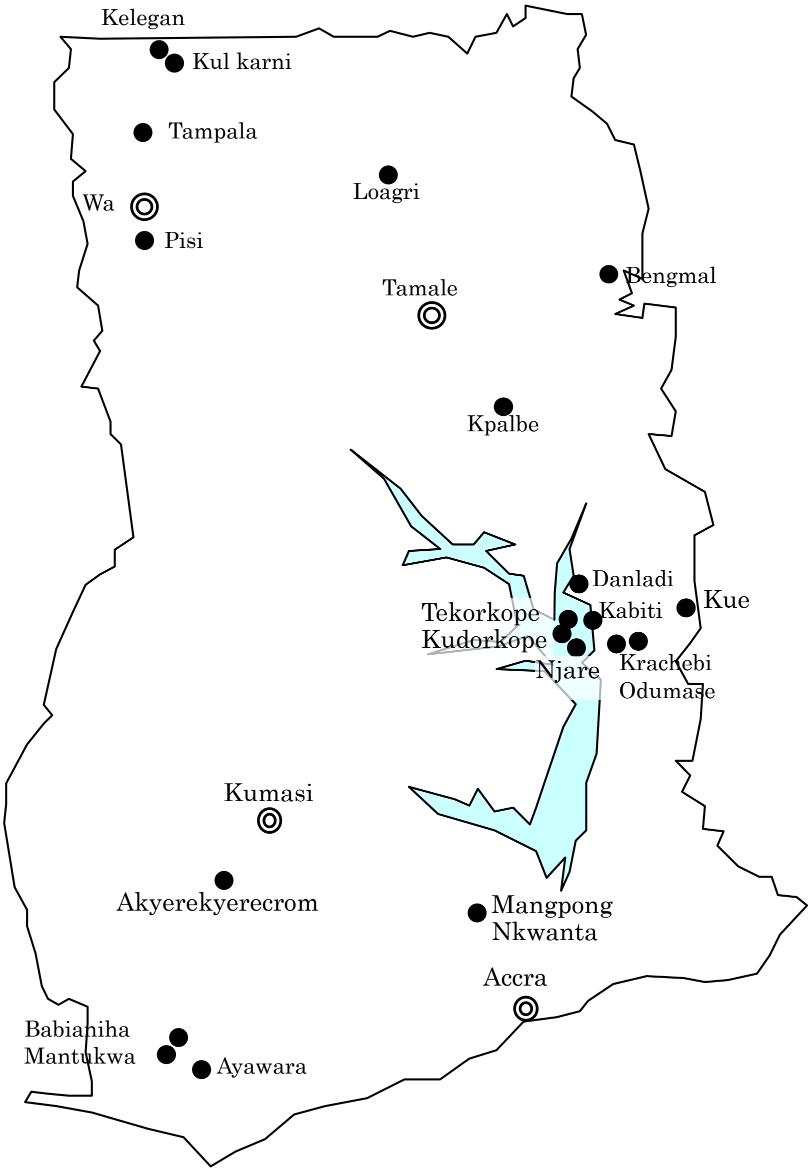
Person	Role
MOEn	Overall supervision
Institution	Owner of the system. Having the roles, responsibilities and rights of DA, Concessionaire and PVA in DA model
CA	Operator of the CSS

The management structure, roles, responsibilities and right of each organization is clarified in the Memorandum of Understanding (MOU). Two types of MOU (DA model and Institution model) were developed. The MOUs were to be signed from MOEn, DA and Concessionaire of each pilot project site.

3.1.4 Selection of pilot project site

In 2009, Community Solar Systems were installed at 4 sites in the South of Ghana (Tomefa and Keta). The objective of the installation was to test preliminarily whether Community Solar System could be operated in communities. After confirmation of operation, the Project decided to conduct another 20 pilot projects. Then, MOEn and the Project Team surveyed around the country and listed around 60 candidate sites. 20 pilot project sites were selected following the criteria determined by the Project. The criteria and selected communities are shown in Attachment-17. The location of the pilot project sites is shown below.

Fig. 20 Pilot project sites



3.2 Installation of CSS

3.2.1Specification of CSS

Considering that the CSS of the pilot projects will be referred as a standard in the future, its size should be typical one in Ghana. In un-electrified communities, population of around 500 is very common. In many cases, more than half of them have mobiles phones and need charging in every several days. Based on this observation, minimum requirement of CSS is regarded as charging more than 50 mobile phones in a day.

Other possible charging is car batteries and lanterns. Considering the affordability of rural people, possible size of batteries is around 50Ah, which costs around 150 – 200 GHC. It should be charged in a day. On the other hand, charging of lantern is not common in Ghana yet. Lantern charging can be performed when there is not much demand of mobile phone charging or battery charging.

Based on the requirement mentioned above, the size of the CSS can be calculated as follows.

- Mobile phone charging
  - Battery size of a mobile phone: 3.8V, 1.2Ah
  - Necessary energy to charge 50 mobile phones:
    3.8V x 1.2Ah x 50 mobile phones = 228 Wh
  - Overall charging efficiency: 0.4
    (Heat efficiency of panel: 0.8, inverter efficiency: 0.8, adaptor efficiency: 0.8, charger efficiency: 0.8)
  - Necessary energy to charge: 228 Wh / 0.4 = 570 Wh
  - Average peak sun hours in Ghana: 5 hours
  - Necessary panel output: 570 Wh / 5 hours = 114 W
  - Necessary number of panels: three of 50W class panels or two of 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. Its capacity can be 50Ah.
  - Controller current rating: more than 15A (150W / 12V = 12.5A)

- Battery charging
  - Battery size: 12V, 50Ah
  - Necessary current to charge battery: 50Ah
  - Typical current of 50W class panel: 3.3 A
  - Average peak sun hours in Ghana: 5 hours
  - Necessary number of 50W class panels: 50Ah / 3.3A / 5 hours = 3 (=150W)
    (or two of 75W class panels)
  - No battery is needed

➢ Controller current rating: more than 15A (150W / 12V = 12.5A)

The configuration of CSS for the pilot project is shown in Attachment-18.

3.2.2 KOWA BOX

CSS in the pilot project used KOWA BOX that housed a controller, a battery, an inverter and wirings between them. The merits of using KOWA BOX are as follows.

- Wiring of most of the components can be pre-assembled and inspected in advance, which can reduce field work.
- Wiring around controller and battery is protected in the box, which reduces any wiring abuse by users.

In the field, installers only installed panels and placed a KOWA BOX. Wiring from panels and extension cords were connected to the KOWA BOX. There is a window in the front door of KOWA BOX for users to see indicators on the controller, but they can't change wiring of it. The front door is locked and Community Agent holds its key. He only opens the door when maintenance is necessary.

Fig. 21 **KOWA Box**

3.2.3 Installation

Installation of CSS was carried out in two stages. 1st stage was preliminary trials at Tomefa and Keta. (At this time, rehabilitation of existing PV systems was also conducted in Tengzuk and Appolonia without installation of CSS.) After confirmation of successful installation and operation, another 20 installations were planned around the country. Installations of the 2nd stage were conducted by new PV Agents supervised by the PV Agents who undertook installations of the 1st stage as a part of human resource development. The following is the summary of installations.

Table 25 Installation of each site

1st stage

Community	District	Region	PVA
Appolonia*	Dangme	Greater Accra	Askn Electric
Tomefa	Ga West		
Blemazado	Keta	Volta	Rural Energy
Azanu			Rural Energy
Bomigo			Rural Energy
Tengzuk*	Bong	Upper East	Jak Solar
Pishegu		Northern	Jak Solar
Kpabia			New Energy

*: Rehabilitation site

2nd Stage

Piisi	Wa	Upper West	Wa Polytechnic
Tampala	Jirapa		
Kul Karni	Lambussi		Festus Mwinkom
Kelegan	Sissala West		
Loagri	West Mamprusi	Upper East	Isaac Yamdogo
Kpalbe	East Gonja	North	Tamale Polytechnic
Bengmal	Saboba Chereponi		
Akyerekyerecrom	Amansie West	Ashanti	KNUST
Mampong Nkwanta	Koforidua	Central	Koforidua Polytechnic
Danladi	Nkwanta North	Volta	Kpasa Tech. School
Kabiti	Nkwanta South		Aikins
Kue			
Odumase			
Kacheibi			
Njare	Krachi East		Olu
Tekokope			

Kudorkope			
Ayawara	Ellembelle	Western	Technician of Ellembelle DA
Babianihha			
Manktuwa			

The PV Agents of the 1st stage were selected among PV installers based on their experiences. They experienced CA training under direction of the Project Team and did good work. They conducted supervisory work in the 2nd stage and directed work to the new PVAs.

The CSS in the 2nd stage was standardized based on the experience of the 1st stage. Specification of BCS is mentioned in Chapter 3.2.1. The following table shows the summary specification of CSS for 2nd stage.

Table 26 Specification of standard CSS

Facility	Specification
Charging station	Charging for mobile phones and lanterns PV: 150W, Controller: 15A or 20A, Battery: 100Ah AC charging system (inverter 300W) (Kpalbe, Akyerekyerecrom and Mampong Nkwanta have 150W of battery charge system.)
Public PV	Lighting system PV: 75W, Controller: 10A, Battery: 100Ah, LED lamp: 1.5W×10

Materials for the installation of the 2nd stage were also standardized. It was not only the materials for CSS installation but also ones for CA training and public awareness raise. The standardized material list for installation is shown in Attachment-20.

Although installation work was supervised by well experienced PVA, some installations of the 2nd stage were not well done. These inappropriate works were not caused by lacking in technology but by insufficient management. The most serious problem was that CA training was not done properly. The supervisor knew PV technology and CA training well, but they did not have enough incentive to manage and train new PV Agents and CAs. The Project explained the importance of CA training again and did it with the PV Agents. Enough time and explanation are needed to get consensus with PV Agents on CA training.

3.3 Training of CA in pilot projects

In the Project, CSS was introduced by the Government as a public welfare. If CSS is to be disseminated under market mechanism, government will not be involved in any activity on CA training, and PV Agent will have to carry it out at the time of CSS installation. This is the most preferable CSS dissemination style in the future. The Project considered this and requested PV Agents to conduct CA training.

The training conducted by PV Agents was as the following table.

Table 27 Contents of CA training conducted by PV Agent

Day	Contents
1st day	Lecture on PV basics, PV components and PV systems for a half day
	PV system assembly practice using training kit for around 1 hours Explanation on management and bookkeeping for around 1 hour
2nd-4th day	Involvement in installation
Final day	Operation guidance for around 1 hour

This style of training is very practical. Classroom style training is only half a day on the 1st day, followed by assembly practice in the later half of the day. Management and bookkeeping are also explained on the 1st day. At the end of the day, most trainees basically understood the concept of PV systems. This understanding is reinforced by installation work from 2nd day. Trainees experienced around three installations and they got instructions on operation and management using actual system they were going to operate. Most of the training was carried out practically.

The important point of this training is that trainees should experience installations of several sites. Therefore, this training is only possible when there are some installations in an area. In the Project, there are 3 installation sites in Nkwanta North and Nkwanta South. Nkwanta North and Nkwanta South are located very closely. Training of the 1st day was conducted at Kpasa Technical School in Nkwanta North calling for the CAs of the 3 installation sites.

Operation guidance was successful because it was conducted using actual systems the trainees were going to operate. Bookkeeping is also important part of management. It was explained on the 1st day and explained again on the final day.

3.4 Operation of CSS

3.4.1 Pricing of charging service

Pricing is an important factor in business. Currently, 50 pesewas is the most common fee of charging mobile phone by diesel generator in un-electrified communities around the country. Considering necessary electricity to charge (Attachment-22), the following proportion has to be considered as one of charging fee samples for lanterns and car batteries.

Table 28 Charging fee ratio

Item	Fee level
Lanterns	two times of mobiles phone charging
Car (Solar) batteries	two times of rechargeable lantern charging

For example, if mobile phone charging fee is 50 pesewas, then lantern charging is 1 cedi and battery charging is 2 cedi. However, the prices should be adjusted considering affordability of the community people and other market prices. In some cases, there are cheaper charging service stations, especially if the station is in electrified communities. If such community is near the PV charging site, the fee at PV charging station is forced to come down to survive in market competition. In the Project, CSSs at Keta are forced to decrease their charging fee.

In the case of lantern charging, two types of business mode are possible for charging service. One is sales mode and the other is rental mode.

Table 29 Business mode of lantern charging

Mode	Contents
Sales mode	Lanterns are sold to users. Users buy them and bring them to Community Solar for charging. Charging fee has to be paid to the operator.
Rental mode	Community Solar prepares fully charged lanterns. They are rented to users. The rental fee includes investment recovery and charging cost. So, it is a bit higher than sales mode charging fee.

The use of rechargeable lantern is not common in rural areas. Therefore, CSS had better to prepare rechargeable lanterns and rent them to the community people for the moment. Once the use of rechargeable lantern is known to the people, people will buy lanterns for themselves and prefer to use sales mode.

The following table shows the current CSS pricing in the pilot projects.

Table 30 Price of charging

Site	Mobile phone (pesewas)	Lantern (pesewas)	Battery (cedi)
Tomefa	40	50	1
Bomigo	30	40	-
Blemazado	20	30	-
Azanu	30	50	-
Mampong Nkwanta	40	50	1
Akyerekyerekrom	30	30	1
Kpalbe	20	50	1
Bengmal			-
Piisi	50	1 cedi/week 3 cedi/month	-
Tampala	50	1 cedi/week 3 cedi/month	-
Kur Karni	50	50	-
Kelegan			-
Loagri	50	50	-
Danladi	40		-
Kabiti	50	100	-
Kue	50		-
Odumase	50		-
Kacheibi	50		-
Njare	50		-
Ayawara	50		-
Babianihha			-
Manktuwa	50		-

Most of mobile phone charge by diesel generator can be found around the country is 50 pesewas. There are also mobile-phone charging services at some electrified communities to un-electrified community people. Sometimes their price is lower than 50 pesewas. In such cases, PV charging fee is set to lower than 50 pesewas. Mobile phone charging fee depends on such environment. Lantern charging fee is set in relation to mobile phone charging.

Piisi and Tampala are under the control of Wa Polytechnic. It already operates another lantern project of "Social Light". Lantern charge fee of them are set to equal level with the project.

3.4.2 Management structure

Under the current management scheme of DA model, DA will take a concession fee from the Concessionaire. The Concessionaire will take all the income from the charging service and pay wage to CA. He should pay necessary cost for maintenance from the income. The concession fee and CA wage are decided by each site. The following table shows the current status of those fee and wage.

Table 31 Concession fee and CA wage (cedi/month)

Site	Concession fee	CA wage
Tomefa	-	20 cedi
Bomigo	-	-
Blemazado	-	-
Azanu	-	-
Mampong Nkwanta	75%	25%
Akyerekyerekrom	Not decided	Not decided
Kpalbe	Not decided	Not decided
Bengmal	Not decided	Not decided
Piisi	-	32%
Tampala	-	20 cedi
Kur Karni	-	Not decided
Kelegan	-	-
Loagri	30%	Not decided
Danladi	30%	Not decided
Kabiti	40%	30%
Kue	40%	30%
Odumase	40%	30%
Kacheibi	40%	30%
Njare	30%	
Ayawara		
Babianihha		
Manktuwa		

Koforidua Polytechnic site (Mampong Nkwanta) sets concession fee in proportion to the turnout. It also pay CA wage in proportion to the turnout. This scheme is effective because both Polytechnic and the CA will try to increase the turnout to increase their income. It works as incentive for them. Nkwanta South sites (Kabiti, Kue, Odumase, Kacheibi) also takes concession fee using similar incentive scheme (40% of the turnout).

3.4.3 Bookkeeping

The following table shows the book that have to be kept for CSS operation. CA, Concessionaire, DA and MOEn have to keep their books. Detail forms of the books are shown in Attachment-23, 24.

Table 32 **Books to be kept**

Person in charge	Book	Contents
MOEn	Monitoring sheet (Recorded once/month)	Year/month Income/expenditure summary of the month Reserved money by the concessionaire Reserved money by the DA
DA	Summary book (Recorded once/month)	Year/month Income/expenditure summary of the month Reserved money by the concessionaire Reserved money by the DA
Concessionaire	Income/expenditure book (Recorded everyday)	Date One day turnout Expenditure (Item, quantity, amount) Total turnout of the month, Reserved money Troubles and remarks
CA	Daily book (Recorded everyday)	Date, weather Charging time, customer name Phone/lantern, fee Troubles and remarks Total turnout of the day

CA records every charging operation. Concessionaire records income and expenditure every day. Income record can be one day total but expenditure record should be every details. DA should record monthly summary of income/expenditure. It also has to record the reserved money at DA side and the Concessionaire side.

Bookkeeping is very important in CSS operation. It is not only for accounting purpose but also for avoiding any troubles in business. In some cases, senior customers may force the CA to charge for free. Some phones might be difficult to charge. Such happenings have to be recorded and reported to the Concessionaire. It will be useful to avoid any further oppression and ineffective operation.

3.4.4 CSS business operation

The following table shows the average turnout of each project site.

Table 33 Turnout of CSS

Site	Monthly average (cedi)	Total (cedi)	Operation start
Tomefa	272	6291	2009.12
Bomigo	153	2505	2010.3
Blemazado	68	1888	Stopped
Azanu	79	1397	Stopped
Mampong Nkwanta	140	1007	2011.5
Akyerekyerekrom	230		2011.6
Kpalbe	222	310	2011.7
Bengmal	60	72	2011.9
Piisi	180	720	2011.5
Tampala	150	505	2011.5
Kur Karni	12	62	
Kelegan			
Loagri	200	617	2011.5
Danladi			2011.9
Kabiti	300	1225	2011.6
Kue	-	-	2011.9
Odumase	235	634	2011.9
Kacheibi	223	606	2011.9
Njare	83	232	2011.6
Ayawara	33	128	2011.6
Babianihha	15	15	2011.9
Manktuwa	22	111	2011.9

Since Blemazado and Azanu are being electrified, they stopped charging operation. The systems will be transferred.

All charging station is 150W PV system for mobile-phone and lantern charging. Tomefa, Kpalbe, Akyerekyerekrom and Mampong Nkwanta have 150W battery charging in addition. Income from battery charge is small because only one battery can be charged and its charge fee is only 1 cedi. This is the reason why other sites do not have battery charge system. Technically, CSS operation is well and mobile-phone/lantern charging is cost effective.

3.4.5 Business feasibility

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

- Assumption
  - System size 150W
  - Possible number of charging in a day
    - Mobile phone 15
    - Lantern 4
  - Charging fee
    - Mobile phone 50 pesewas
    - Lantern 70 pesewas
  - Operation days in a year 300days

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

50 pesewas ×15 phones/day ×300 days = 2,250 GHc

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

70 pesewas × 4 lanterns/day × 300 days = 840 GHc

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

Table 34 **Investment and income**

Initial investment			Annual income	
Panel	(150W)	1,000GHc	Phone charge	2,250 GHc
Battery	(100Ah)	350GHc	Lantern charge	840 GHc
Controller (20A)		300GHc		
Inverter	(300W)	100GHc		
Others		500GHc		
Total		2,250 GHC	Total	3,090 GHc

Solar batteries which need replacement in every 5 years cost 350 GHc. For simplification, let's consider battery replacement reserve as 70 GHc per year (350 GHc divided by 5 years). Other maintenance cost (such as purchase of adaptors and extension cords) can be 100 - 200 GHc a year. In total, maintenance cost of 300 GHc per year is enough for sustainable operation.

Community Agent wage is around 50 GHc/month from the data collected in the pilot projects and management wage will be also the same level. In total, 1,200 GHc (50 + 50 = 100 GHc a month, multiplied by 12) per year will be considered as human cost.

Average concession fee is estimated as 600 cedi per year based on the data collected in the pilot projects.

The overall cash flow is summarized as follows.

Table 35 **Cash flow of CSS operation**

Annual cash flow			
Income	Annual income		3,090 GHc
Expenditure	Maintenance	300GHc	Total 2,100 GHc
	Community Agent and management fee	1,200GHc	
	Concession fee	600GHc	
Surplus			990 GHc

All prices are 2010 level

The result shows that 990 GHc annual surplus can be left in the Concessionaire's hands. It also implies that the initial investment will be recovered in around 3 years, which means that business possibility of CSS is very high.

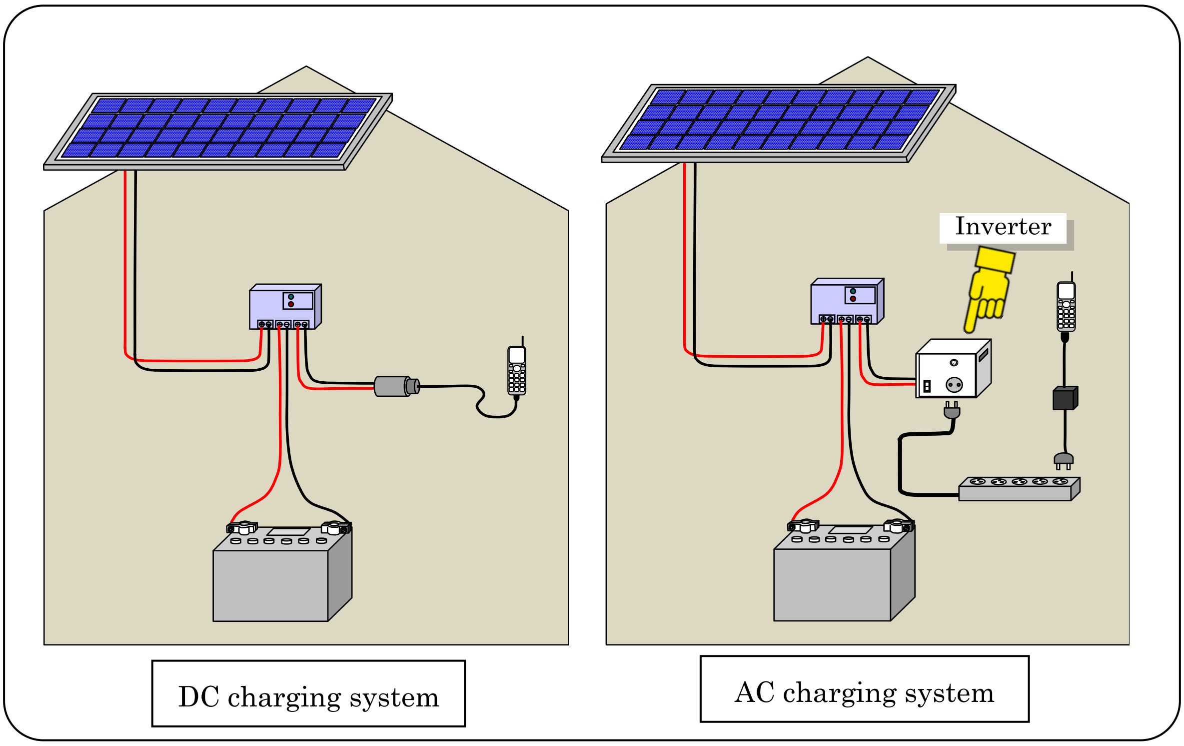
3.5 Lessons learnt

3.5.1 Technical issues on CSS

<AC system, DC system>

There are two types in charging systems. One is DC charging system and the other is AC charging system. AC system is easily implemented by inserting an inverter between DC output of DC system and charger. DC system is more efficient than AC system because power loss is caused by the inverter in AC system. However, AC system is more recommended because, in rural areas, it is hard to find DC charging adaptors which are necessary in DC charging system.

Fig. 22 AC system, DC system



<Charging efficiency>

When calculating overall energy efficiency in AC system, one has to take panel heat efficiency, inverter efficiency, adaptor efficiency and charger (in the phone) efficiency into consideration. Usually, overall efficiency is 40 - 50% in normal AC system. DC system is considered as being more efficient, but one should be careful in selecting adapters. The adaptors have to change DC 12V to charging voltage of DC3.0-3.8V. Some adaptor only drops voltage by inserting resistors. It will decrease overall conversion efficiency to very low level, sometimes lower than that of AC systems.

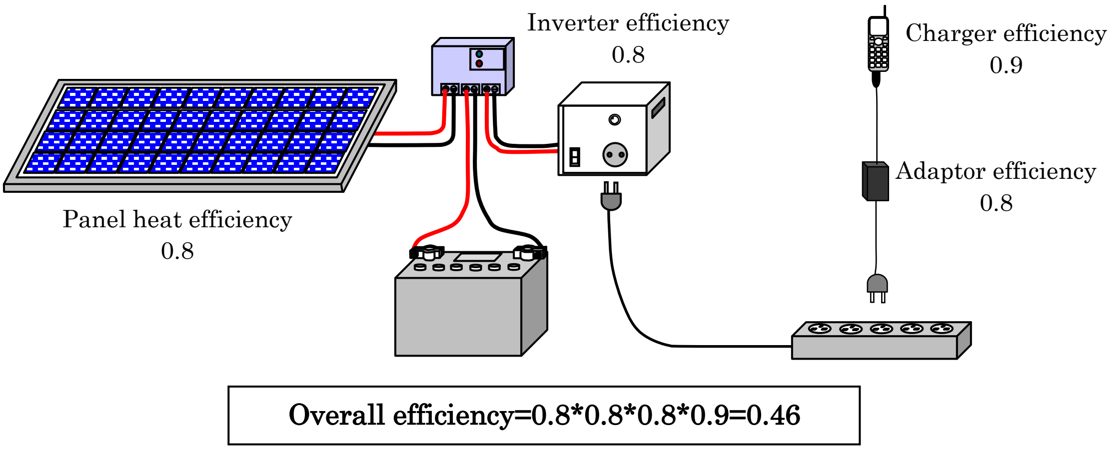


Fig. 23 Overall charging efficiency

<Operation hours>

In the charging system, most of the energy from PV panels is used for charging in daytime. Therefore, the battery is not charged so much in daytime. If charging service is continued at night, electricity in the battery decreases and it is hard to recover. The battery will be left un-charged for a long time, which will shorten its life span. Therefore, CSS should not be operated during night time. In order to avoid any operation at night, the charging stations of the pilot projects are not installed with any light.

<Recharge of lanterns>

Most batteries in solar lanterns are not solar (deep cycle) type. If lanterns are left un-charged for a several months, their batteries will be deteriorated and cannot be recovered. Therefore, they have to be frequently recharged even if the lanterns are not used because their self-discharge cannot be ignored. They have to be recharged at least once a month. This should be known to users so that users should not store lanterns without charging.

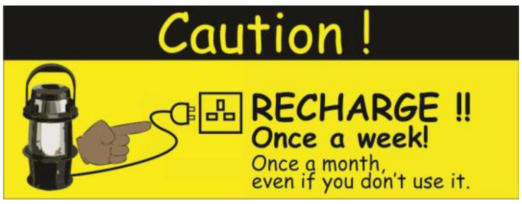


Fig. 24 Caution sticker

<LED lamps>

When the Project started, LED light was not common around the world. After 4 years, LED dissemination was so rapid that many LED rechargeable lamps are sold in most towns in Ghana. Currently, their price is around 20 – 40 cedi. Operation duration is 10 – 50 hours depending on the number of LEDs and the size of the battery. Compared with old fluorescent type rechargeable lamps, LED rechargeable lamp can operate longer time with same or higher brightness and with less charging energy. It is true that current LED rechargeable lamps are still expensive, but the price will come down in the near future. And, at that time, there will be more possibility of operating rechargeable lantern charging business. Concessionaires have to monitor LED rechargeable lamp market and be ready to find suitable lamps to expand their CSS business.

3.5.2 CSS business issues

<Charging fee>

Since Community Solar is introduced as a public service, it is installed under the government project or donor's project. In such a case, project implementers are likely to suppress the charging fee politically to serve more people. They are likely to consider that the system is provided for free. However, low fee will lead to difficulty in investment recovery and, in worst case, battery replacement will become impossible. Charging fee has to be determined from economical and business viewpoint.

The factors to be considered when determining charging fee are concession fee, battery replacement reserve, CA wage and other maintenance cost. The sample cash flow is shown in Chapter 3.4.5. The cash flow and concept of fee level must be carefully explained to DA, Concessionaire, CA and users in advance and get their consensus. The concept of CSS, whose income is to be used for the maintenance of public PV systems, also has to be explained at this time.

From the point of energy consumption, charging fee of lantern should be much higher than mobile phone charging. Charging fee of battery has to be much higher than lantern charging. But it is too difficult to directly reflect energy consumption ratio to charging fee. Basically, battery charging is not feasible. It should be operated as social welfare activity. Lantern charging might generate profit if it is operated efficiently. Concessionaire has to decide charging fee level considering users' affordability and his business feasibility.

<Maintenance cost>

Battery replacement will occur every 5 years. Cost for battery replacement can be easily calculated. However, cost estimate for other maintenance is difficult. In such a case, certain percentage of the systems cost is used as estimated maintenance cost. Usually, the percentage is 5 – 10%. However, considering that the systems is installed in a harsh environment and there are not so many reliable components in Ghana, 10 – 20% of systems cost (around 300 GHc) is recommended to use as maintenance cost.

<Charging target>

The necessary energy for charging is roughly estimated as follows.

Lantern: 10 times more than mobile phone

Battery: 100 times more than mobile phone

On the other hand, charging fee for lantern and battery is not much different from mobile phone. This means that mobile phone charge is very profitable and battery charging is no more profitable.

At first in Tomefa, CSS was composed of car battery charging system (150W) and mobile-phone/lantern charging system (150W). After experiencing that demand for battery charging was not high and it was not profitable, the Project gave up battery charging and focused only on mobile-phone/lantern charging. Now, the chief of Tomefa, who is the Concessionaire of the CSS, is also considering of modifying battery charging system to mobile-phone/lantern charge system so that they can operate two profitable systems. If the Concessionaire expands the system in the future, installation of only mobile phone charging is much recommended.

<Training cost>

Training kit is composed of a PV panel, a board with a controller, inverter, a lamp and a battery, which can be considered as miniature size PV system. CAs practice wiring between them. The kit is a very good tool to understand the basic configuration of PV systems. In CA training, basic concept of PV systems was first explained to CAs using manuals and handouts. The CAs looked understand it. However, when their understanding was reviewed through practice of training kit, it was found that their understanding was not enough. After the practice, they were more confident in PV configuration and wiring.

A problem of the training kit is that it is very costly. The configuration is almost the same with a normal Solar Home System (SHS), and hence its cost is almost the same with SHS. To save the cost, components for installation should be shared as much as possible. In the Project, training kits were provided to the PV Agents who were involved in the pilot project.

Fig. 25 Training Kit

<Rental mode, sales mode>

Sales mode and rental mode can be considered for lantern charging. In general, rental fee is more expensive than charging fee. Therefore, frequent users should opt to purchase a lantern. (Sales mode) Rechargeable lanterns are sold at around 30GHc in towns, CSS had better to prepare it for its business. Occasional users may prefer renting lanterns. (Rental mode)

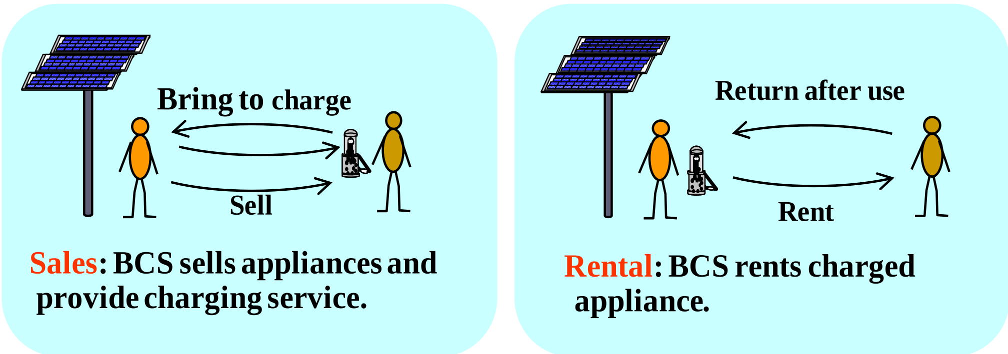


Fig. 26 Lantern charge business mode

In the pilot project, 5 lanterns were distributed to each site as kick start of lantern charge service. However, most of them were given to some senior people in the communities. Only Loagri uses them as rental business. This business mode should be explained not only to the Concessionaire but also CAs and community people before installation.

<Private initiative>

CSS is a system that is to be disseminated as public purpose. This is the reason why CSS is composed of a charging system and a public system, and the income from the charging service is used for the maintenance of the public PV system. Main objective of CSS is improving sustainability of public PV systems. This scheme should be used for the government projects because the government is responsible of electrifying public facilities, and sustainability of public PV was a challenge in many cases.

If CSS is managed completely for private purpose with private investment, no expense will be needed for public system maintenance and no payment will be needed for a concession fee. Instead of using income for the maintenance of public PV systems, the Concessionaire will be able to use it for recovery of his investment. The investment will be recovered within 3-4 years. After that, the Concessionaire will be able to use the money for new PV system installation. This is another possibility of disseminating PV systems in rural areas.

3.5.3 Management issues

<Selection of Concessionaire>

When introducing Community Solar System into a community as a public project, usually the Project visits the chief of the community to explain the project purpose. In most cases, the chief wants to take the Concessionaire's role. Chief has a strong power over the community and no one can make any objection on his management. If the chief has a good business mind, management will go quite well, but if not, management will collapse. The Project had to know chief's ability before visiting the community. Usually, District Assembly has good information on community's situation. It is better to visit District Assembly first and consult how to select Concessionaire.

<Charging station in Public facility>

At the beginning of the pilot project, MOE pointed it out inappropriate to install a charging station at school and clinic. PV system provides electricity to electrify public facilities but the charging station provides service other than school activities. MOE commented that the charging activity in public facility might lower the security level and disturb its activities due to the frequent entry of unknown persons. On the other hand, demand of electrifying public facility was very high. The Project recommended discussing it with public facility staff and deciding to install the charging station at the facility only when they accepted it. Among the pilot projects, only Mampong Nkwanta installed a charging station at school.

<Difficulty of concession fee collection>

In the Project, ownership of the CSS belongs to the DA of the area, and the DA commissions the operation of the CSS to a Concessionaire in the community for a fee. Actually, Some of DAs did not show positive attitude towards collecting the concession fee. There is no incentive for the DA's staff to go to the remote community to collect the fee. Likely, the Concessionaire does not want to go to the DA to pay the fee. Under MOU between the DA and the Concessionaire, the DA holds the right to confiscate the PV system in case of outstanding of fees. However, confiscation of the system sometimes costs more than the concession fee.

There was an idea to transfer the ownership to the Concessionaire by selling it to him and let him to bear full responsibility of CSS. This was an ideal solution because the Concessionaire could become more positive in the operation of the system. However, it was not acceptable because the Project's output could not be transferred to a private person. As a result, the ownership of the CSS remained in DA in the Project. The idea of transferring the ownership to the Concessionaire will be used in other opportunities. For example, including CSS in the application of loan system in GEDAP project so that the Concessionaire can use it to start his CSS business.

<Understanding of MOU>

Roles, rights and responsibilities are defined in MOU which is agreed between MOEn, DA and Concessionaires. In the MOU, Concessionaires have to pay a part of the income from the CSS to DA as a concession fee. The DA will use the concession fee for their management cost and further expansion of CSS to other communities. The Concessionaire uses the remaining part for the payment to CA and maintenance of PV systems. However, there was misunderstanding. Some Concessionaires and CAs considered that DA would bear the maintenance cost because they paid some fee to DA. In Ghana, many people are likely to take only favorable part of a story and forget about the other part. In reality, MOU is only a memorandum and not effective to force them to do their responsibility even if it is signed by concerning people. If people try to forget about MOU, the memorandum is meaningless. To avoid such confusion, it is better to convene the DA, the Concessionaire and CAs at once and buildup consensus about MOU among them. To facilitate building up consensus, the Project developed an illustration of explaining the management structure of CSS operation. It is shown in the next page.

<Formation of human network>

One of the difficulties in keeping sustainability of rural PV systems was for users to buy spare parts. It was also difficult to get appropriate information on how to do with their systems when troubles happened. The solution that the Project suggests is to implement human network with CA, PVA, Concessionaire and DA. A practical way of implementing this network is to let them meet together and be acquainted with each other. The best timing of having this meeting is installation. Fortunately, CA training has to be held by PVA at the time of installation. Concessionaire and DA should attend the training and form their network for maintenance.

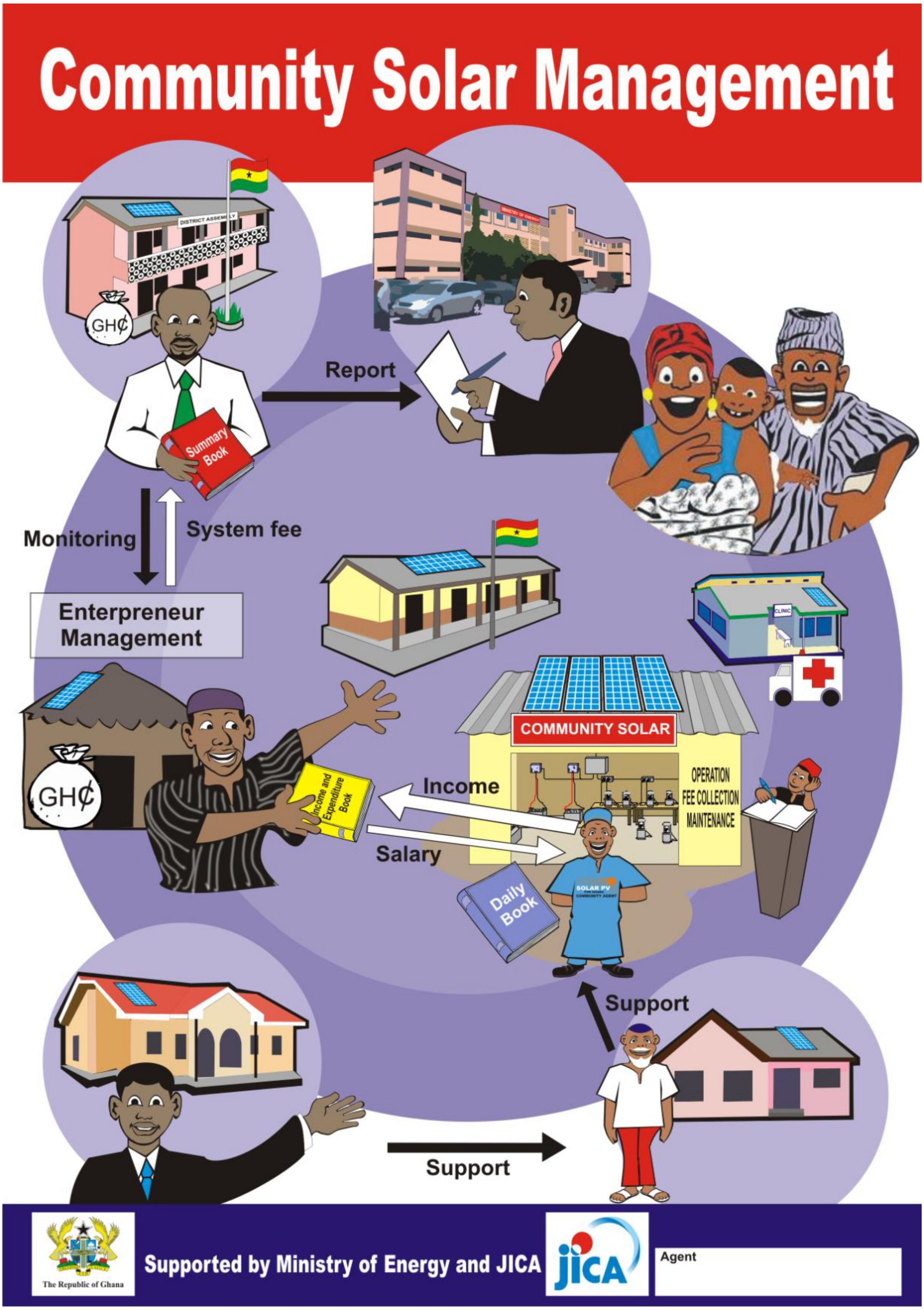


Fig. 27 Community Solar management structure

3.6 Scenario of PV dissemination

Based on the experience of PV projects in the past, business development plan for PV dissemination in remote areas should be redefined as a step-by-step approach.

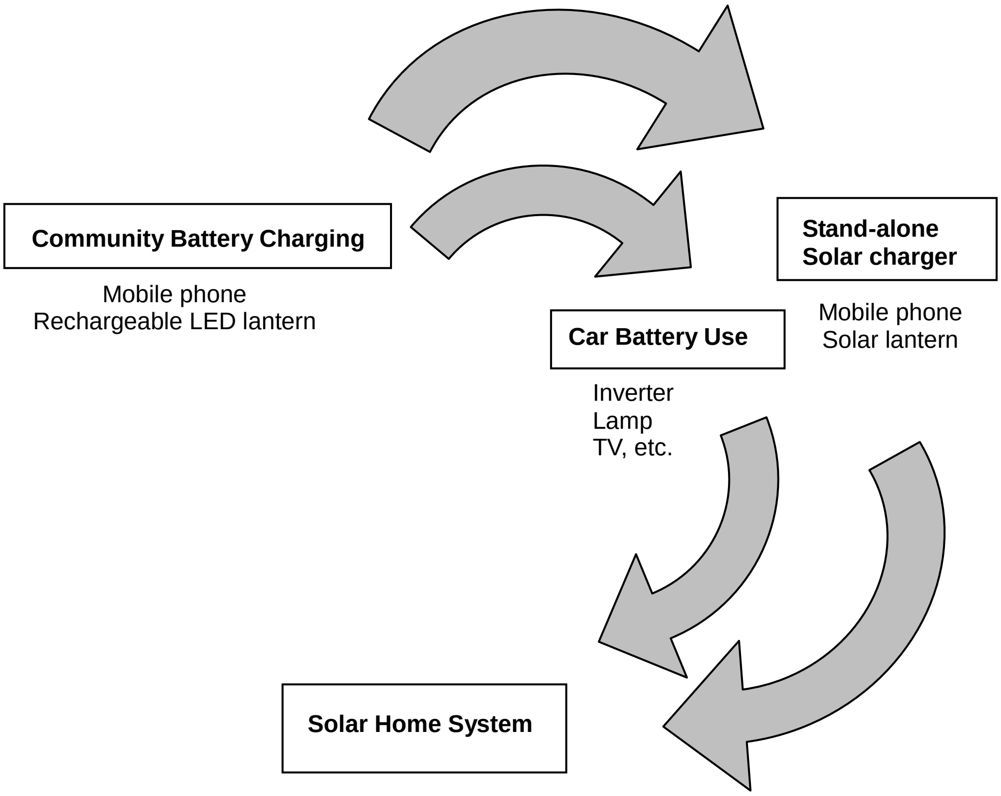
It is clear that there is a strong need for mobile phone charging even in remote communities. Installing a small PV system for mobile phone charging, as a first step, would be highly successful. The owner of PV charging system, CA or Concessionaire in the Project, would be eager to learn PV technology to run his system in a sustainable and profitable way. As a result, he would become a knowledgeable person in the community.

The small PV battery charging system would only be able to deal with mobile phone charging. Its capacity is not enough if the community people use appliances with large-size batteries such as rechargeable lamps (lanterns). In order to promote the use of rechargeable lamps in remote areas, the small-size PV charging system should be expanded. Sales of rechargeable lamps in rural areas would grow quickly if battery charging station has enough capacity to do those charging service and is accessible. Frequent use of PV system for battery charging improves PV skills of the owner and spreads knowledge on PV around the area. Then, rural people will gradually gain confidence in PV.

At this stage, many rural people will start to develop ideas on how to use PV to improve their life and consider purchasing PV products. There are some more promising PV products. People can use self-rechargeable PV lanterns without going to the charging station. There are also small PV products to charge mobile phones personally. In order to make these PV products to disseminate, providing necessary technical and financial support is indispensable. Technical support can be obtained from the CA or the Concessionaire. PV dealers have to consider introduction of credit sales for those PV products because they are still expensive.

Once necessary knowledge base for sustainable PV use is created based on the experience in recharging, the village people would get confident in PV products and purchase more complex PV products such as solar home systems.

Fig. 28 Stages of PV dissemination in rural communities



4. Activity on raising awareness

Development of materials to raise public awareness of PV is one of important activities in the Project. The objective of the materials is to raise awareness of effective use of PV systems. Three kinds of posters and a brochure were developed. In addition, four videos which show the Project activities were developed. Web pages where the Project activities are also explained are also developed. All developed materials and manuals can be downloaded from the web page. The following is briefs of the materials. (Posters and the brochure is in Attachment-27, 28, 29, 30)

Table 36 **Raising awareness materials**

Item	Contents
Posters (A2 size)	● Getting along well with SOLAR SYSTEM ● Two ways of charging mobile phone using SOLAR ENERGY ● Let's enjoy SOLAR LANTERS
Brochure (A5 size)	Solar Energy ….. is good for you ! (8 pages)
Video	● Tengzuk CA training (6 minutes) ● Tomefa CSS installtion (6 minutes) ● Krachi East survey (3 minutes) ● Practical guide for installation and management of off-grid solar system
Web	http:// ● Introduction page ● Publication page ● Data base page ● Photo page

Basically, these posters and the brochure are developed to spread the knowledge on the usefulness and proper use of PV systems. Posters are being distributed to the government organizations like DAs and AGSI members and put up at public places such as DA's offices and local PV dealers' offices. CAs put up the posters at the charging station. This was good not only for community people to know PV but also the CAs to review PV systems.

The brochures were distributed to AGSI members, DAs, PVAs and CAs. The brochure was very useful to show DAs how PV systems are when explaining PV project. CAs also appreciate its usefulness to review what he learnt on PV.

The videos are intended to show relevant people how PV works, how PV project proceeds and how CSS is. It is better to show them at workshops or seminars held by MOEn or AGSI. It is also good for MOEn to use when it explains PV project to DAs. MOEn can use the videos at local offices with its mobile projector. AGSI can also utilize the videos at the time of its annual meeting.

Table 37 Use of awareness raise materials

Posters Brochures	500 sets are printed. Distributed to MOEn (300 sets) and AGSI (100 sets).The rest is distributed to DAs, PVAs and CAs of the project sites. ● Used for people to know what PV system is. ● Used to explain users how to use PV systems properly.
Videos	10 copies of CD were made. Distributed to MOEn (5 copies) and AGSI (5 copies). ● Viewed at workshops and seminars by MOEn and AGSI. ● Viewed at local meetings using mobile projector

Fig. 29 Photo of posters in the sites

“Community Agent Manual” and “Community Solar Manual” can also be used as awareness raising materials. It is because they are composed of pictorial illustrations as much as possible so that rural people to understand easily. “Community Agent Manual” can be used for rural people to know how to use PV systems. “Community Solar Manual” can be used to explain CSS to DAs and Concessionaires. 1,000 copies were printed each.

5. Conclusion and suggestions

The Project targeted human resource development for the dissemination of PV systems based on the market mechanism. While human resource development is generally very important, the current small market size and possible limited resources should be taken into consideration. The scheme for human resource development should also be effectively programmed so that a fruitful output can be achieved.

The Project experienced some challenges at first due to difficulty in finding an effective human resource development mechanism. Based on this experience, the Project suggested a more desirable human resource development plan associated with PV rural electrification. The Project also requests MOEn to continue activities needed for the Project outcome to keep effects.

5.1 Background

<PV market in Ghana>

The PV market in Ghana is still in its infant stage. PV systems are too expensive for ordinary people to use in their daily life. Up to now, most PV systems were installed under government projects or donor projects. A problem with such projects was that PV systems were purchased directly by the donor and the government without going through the market. Therefore, it did not stimulate or contribute to the formation of a PV market. PV dealers in Ghana always looked to the government to carry out government project and did not pay much attention to the need of people. Currently, it is very hard to estimate the needs of the PV market.

The most serious problem in the formation of the PV market is its high price. Only very wealthy people can personally purchase a PV system. Currently, the 50W Solar Home System costs nearly 1,000USD and Solar Lantern costs around 100USD. There are other less expensive Solar Lanterns, but their use is limited (insufficiently bright, short operation time). PV is just starting to form a market. Much effort must be given to find potential PV business in order to prepare a market base.

Human resource development is an important factor in the formation of a sound market.

However, it is difficult for persons who have received PV training to find jobs in the current small PV market. Those willing to receive PV training were wealthy, and their numbers were limited. If an institutional PV training system can be set up, it will be financially difficult to sustain the system. Considering that most PV jobs are under government projects, it is better to incorporate human resource development into these projects. Human resources should be developed with actual jobs from such projects.

Quality control is in the same situation. If an institutional system for PV product certification is set up, the system will not be sustainable. Most PV products are imported by government projects without going through the market. Directly controlling product quality by these projects is sufficient.

Considering the current constraints of the PV market, promotion of potential PV business must be first addressed, and then expanding the PV market. Developing CSS business introduced in the Project is a possible answer for it. Human resource development should be incorporated in the CSS business development.

<Practical human resource development>

The PV industry of Ghana is also in its infant stage. At this point, human resource development in the industry should be more practical than theoretical. After an industry base is established, theoretical training becomes useful. Currently, it is better for Ghana to focus on practical training.

Practical training should not be only from the technical aspects such as installation, operation and maintenance, but also from the administrative aspects such as pricing and bookkeeping. Implementing pilot projects is a good way to provide practical training in all these aspects at the same time. Trainees can experience each required skill through actual work.

CA training is an important subject in PV Agent training. By being involved in actual CA training, PV Agents can be aware of what local technicians can and cannot do. PV Agents must know how to train CAs. Such knowledge will also be very useful for further PV promotion in rural areas. CA training should be implemented in pilot projects as a chance for PVA to practice.

<Persons targeted for human resource development>

Currently, AGSI is operating a PV training course in Ghana. Participants are invited through public announcement. Actually, most participants are students or people with steady income looking for new job opportunities. They are not eager to start a PV business. In addition, most live in large towns such as Accra. Few residents of rural areas where PV dissemination is mostly needed show interests. Seeking for trainees through public announcement does not work efficiently. Human resources for PV rural electrification should be specifically targeted.

The Project proposed two levels of human resources – a Community Agent (CA) who cares for PV systems installed in the community, and a PV Agent who promotes PV business in rural areas. The Project also introduced a CSS business model with a Concessionaire as business manager. The CA and Concessionaire should be residents of the community and are able to obtain daily work through CSS business. Identification of candidates for CA and Concessionaire is not difficult if the project implementer visits the community. Those with technical capability in the community can be suggested as candidates for the CA and those with business skills in the community can be for the Concessionaire.

On the other hand, identification of PV Agents in rural areas is difficult due to current PV market being too small for potential PVA candidates to start a business. In addition, rural communities are isolated. Technical backup and supply of information through some kind of network are necessary. The success of Grameen Shakti is that they already have a strong rural network through Grameen Bank. Grameen shakti placed technical centers in the network to support rural PV systems. Such a network is very important. The government must implement such a human resource network when carrying out PV project in rural areas. If it is difficult to determine the PV Agent, the government should use its own rural network. District Assemblies and schools are good candidates to form such network. They always have electrical technicians to maintain their facilities. Those technicians are good candidates to become PV Agents.

Therefore, the following persons can be targeted as human resources for PV rural electrification.

Table 38 Persons target for human resource development

Human resource	Candidates	Demand
PVA	Local PV dealer, Electrical technician at DA, Electrical technician at school	Several tens
Concessionaire	Person with business skills in the community (Shop owner)	Several hundred
CA	Person with technical skills in the community	Several hundred

<Human resource development method>

In consideration of the current PV market size, setting up an institutional system for PV training is not realistic. A practical solution is to train human resources within a project. Practice in training can be gained through the actual work in the project and trained human resources can find jobs in the project.

The technical contents of CA training are not difficult. Half a day is spent on lectures on PV basics, PV components and PV systems, and half a day for practice assembling with the training kit, plus lectures on management. This is followed by two or three times practicing of installation. From the point of sustainability, cost for training should be minimized. Manuals developed in the Project should be used. Materials for practice should be used for installation as well. Basically, PV Agents with sufficient installation experiences should conduct the training. Electrical technicians, such as those in DAs or schools, can also conduct training. Once such technicians attend and experience CA training, they will be able to carry it out themselves. Therefore, it is better to involve these technicians in the CA training so that a stronger human resource network can be created. This in turn will make it easier to promote PV in the area.

5.2 An effective PV project

The Project greatly impacts sustainability improvement by CSS introduction. The key to this impact is using the income from the charging service to improve financial sustainability for the maintenance of the public PV systems. Merits should be further utilized. Therefore, the Project proposes two types of PV projects to utilize CSS - one is an improved and more efficient sustainable PV rural electrification based on this Project, and the other is small business development using the merits of CSS. Proposal documents are shown in Attachment-31. Background and a brief are as follows.

- Sustainable PV rural electrification

The Project trained trainers at KNUST and Tamale Polytechnic for PV training. These Institutions form PV training bases. However, they are located in regional capitals, far from the communities that truly need PV electrification. Training bases should be located in more rural areas.

From experiences gained in the Project, contents of the training needed for PV rural electrification are not technically difficult but should be more adapted for the local people, such as using local language and materials. The Project also found that electrical technicians at DAs or local schools (such as Technical Schools) are good candidates for PV Agents or CA trainers. These people can operate a PV training base and support Community Agents. If MOEn can create a scheme to develop local training bases, it will facilitate further PV rural electrification. Establishing an effective way to develop a local PV training base and a standard training is the first proposal.

Sustainability of maintaining the training bases must also be considered. Therefore, a charging service station should be installed in the area. Installation is conducted as pilot project for related personnel (DA, PVA, Concessionaire, CA) to learn necessary knowledge and skills. After installation, part of the income from the charging service can be used for the sustainability of the base and training. DAs control the income and technical schools technically support the people.

- Small business development

The Project conducted a study tour at Grameen Shakti in Bangladesh. Grameen Shakti has a good network around the country to support maintenance of PV systems which have been installed in rural areas. A feature of the network is that the “Technical Center” and people assembling PV components at the Centers. Assembling activity itself contribute to local economy and assembled components can be used as spare parts when the local PV systems break down. In addition, those who manage the assembly work have sufficient knowledge and skill to repair the PV systems. Therefore, the Technical Center also works as a support center in the area.

Ghana already has basic knowledge on PV and can assemble PV components. Development of technical center similar to Grameen Shakti should be considered. Polytechnics can be the technical support for such a center.

LED lanterns are an emerging technology which can be effectively used in un-electrified areas. The charging station introduced in the Project targets LED lanterns as an important application. From technical viewpoint, the electronic circuit of the LED lantern is simple and suitable for Ghana to start an assembly industry. Assembled lanterns will be used at a charging station and the income from the charging service can be used to maintain the assembly work. Therefore, the development of a technical center with Polytechnic, which utilize the locally assembled LED lanterns and the introduction of a charging center as field test of the lanterns are the second proposal.

Once the lantern assembly is successful, it is not difficult to expand assembly products to other items such as controllers. This will stimulate the local economy and improve PV dissemination in the area.

5.3 Expected task of MOEn

The Project has made some achievements during the 4 years. To maintain those achievements, the Project wishes Ghana government to continue its efforts. Tasks requested to MOEn, in order to expand the utilization of the achievements of the Project, are as follows.

<Monitoring of pilot projects>

The Project introduced CSS at 24 communities and developed a monitoring system for them. Experiences in these sites are very important for Ghana to develop other sites for CSS. MOEn is requested to continue the monitoring after the Project. Basically, monitoring can be carried out through telephone calls to DAs and the Institutions to collect information. In order to maintain good monitoring, MOEn should request DAs and the Institutions to collect information from their sites. The Project recommends MOEn to study the following through the monitoring.

- Charging trend
- Financial sustainability
- Management ability of the Concessionaires and DAs
- Any problem
- Battery replacement

The most difficult thing in sustainability of PV systems is battery replacement, which will occur around 5 years after installation. MOEn should continue monitoring to confirm battery replacement.

<Raising awareness of CSS>

MOEn is well aware of the potential of CSS to improve sustainability of the PV systems. In Ghana, there are many PV projects that have been introduced by other organizations, such as NGOs and missions. In order to increase the potential of CSS, MOEn should use various opportunities to raise awareness of CSS among related parties. The following activities can be mentioned for this purpose.

- Hold workshops and report CSS
- Attend workshops of other organizations and report CSS
- Request each DA to put the posters at their office

- Request relevant organizations to link to the developed website
- Request AGSI to report CSS in its meetings

<PV testing>

The Project provided PV testing equipment and transferred PV testing technology to the trainers. Unfortunately, the equipment has not been fully utilized because there are not enough opportunities to test the PV products. The Institutions and MOEn need to raise awareness of the PV testing facilities among relevant organizations and increase opportunities for the Institutions to conduct PV testing.

If increasing testing opportunities is difficult, MOEn, MOEd and the Institutions should redistribute the equipment to organizations which can more fully utilize them. One way of thinking about redistribution is as follows.

- LABView of Tamale Polytechnic is transferred to KNUST.
  KNUST has many students who studied LABView abroad and would like to use it at KNUST. Currently, KNUST has only one license on LABView. Increasing the number of licenses and promoting the use of LABView by the students are desired.
- Battery testers at Tamale Polytechnic and KNUST are transferred to GSB
  Both KNUST and Tamale Polytechnic have few possibilities to conduct battery tests. GSB has a battery tester and conducts battery tests as part of its authorized business. Unfortunately, GSB's battery tester is very old and deteriorated. In addition, having multiple battery testers is advantageous because battery tests take a long time. It would be good if the battery testers of KNUST and Tamale Polytechnic be transferred to GSB.

<PV training/education>

Trainers have acquired knowledge and skills on PV through the Project. They also gained experience in PV training and education. Now, they can conduct CA training, PVA training and PV education. MOEn and the faculty of the Institutions should use of the ability of the trainers. PV education targets students and can be controlled by the faculty of each Institution, but CA training and PVA training should be held along with PV projects because training can be included in the installation. Unfortunately, the Institutions can't provide sufficient opportunities for PV installation. Currently, expansion of their practice sites will be once a year or less. Therefore, MOEn is requested to involve the Institutions in its PV projects to a greater degree and provide them with installation opportunities.

List of attachments

(Supplement)

Current status of the Community-Solar (CS) Pilot-Project

- As of the end of November 2011, 20 CS systems were in operation. Sales at the battery charge stations (BCS) vary from site to site. At some sites, sales remain on a low level, below 50 cedis a month. If this poor sales situation continues, sustainable operation and maintenance (O&M) might be difficult from the viewpoint of cost recovery. On average, sales at the major sites are between 100 and 200 cedis a month, and the situation is basically the same as we initially expected.
- Three sites located in the Western Region are typical examples for poor sales. Since they are mountainous villages, they are small (with populations estimated at less than 500) and also have low income levels. As a result, sales remain on a low level.
- In contrast, certain other sites such as Tomefa located in the suburb of Accra have sales of more than 200 cedis a month. As compared to communities in the Western Region, they have larger populations (estimated at more than 2,000) and higher income levels. Sales in Kabiti, Kacheibi, and Odumase in the Volta Region are also high due to a similar business environment.
- The above is the current operational situation. However, it is still too early to determine the conditions required for CS site selection. The pilot project has commenced operation, but the majority of the CS systems have short operation records (for only a few months). Nobody knows whether the prevailing conditions will continue.
- Viewed from the perspective of the business environment, sites where both population and income level are high have a comparative advantage. However, we cannot say that this business environment will be a prerequisite for site selection. Villages with high population and income levels also have a high possibility of electrification by grid extension. In other words, such sites are not to be preferred for installation of dispersed-type PV system. This is the case of Tomefa, which recorded the highest sales. In less than two years after the commencement of the CS operation, the grid has already been extended to the village. It is obvious that nobody will use the BCS when the grid is energized.
- Needless to say, we should not select a village which will probably be electrified in the near future. The real problem is, however, that nobody knows the exact electrification plan. Some rules exist for electrification, but electrification is decided politically in many cases. The reality is that neither the electric company nor government officials can predict the future course of electrification plans with sufficient accuracy.

Table 1: Status of the CS operation

Site	System	Asset owner	Operational status
Kpalbe	BCS 300W	Tamale Polytechnic	• Installation work was completed on 16 March 2011, but BCS sales data were not recorded until the end of June. Data recording on the book began in June, as we requested. • Charge fee for cell phones was 20 pesewas in the initial stage but increased to 30 pesewas in June. • Monthly sales in July and August were on the level of around 150 cedis. The condition of the CS operation is good. We did not find any problem.
Bengmal	BCS 100W		• Installation work was completed on 18 September 2011. • Grid has already been extended to neighboring villages, and BCS sales are not expected to be more than 100 cedis a month. We recommended Tamale Polytechnic to relocate the facility to another non-electrified village.
Akyerekyerekrom	BCS 300W School 50W	KNUST	• Installation work was completed in late May. Operation commenced on 2 June 2011. • Operation of the CS was commissioned to the Millennium Villages Project, while KNUST receives 35% of the sales as a concession fee. • Charge fees are 30 pesewas for both cell phones and lanterns.
Mampong Nkwanta	BCS 300W School 100W	Korofidua Polytechnic	• BCS operation commenced on 15 March 2011. • 25% of the sales are paid to the CA as a fee, and Korofidua Polytechnic takes the remaining 75%. • Charge fees are 40 pesewas for cell phones and one cedi for batteries. • Monthly BCS sales were around more than 150 cedis until now. The condition of the CS operation is good.
Piisi	BCS 150W Clinic 75W	Wa Polytechnic	• BCS operation commenced on 7 June 2011. • Charge fees are 5 • 0 pesewas for cell phones and one cedi a week or three cedis a month for batteries (no limitation on the number of charges). • 30% of the sales are paid to the CA as a fee. The remaining 70% is the gross revenue for Korofidua Polytechnic (at present, an additional 2% increase in the CA fee is under negotiation between the CA and the institution). • Since June, BCS sales have been in the range of 160 – 190 cedis a month.
Tampala	BCS 150W School 75W		• BCS operation commenced in early June. • Charge fees are the same as in Piisi. • The CA fee of 20 cedis a month is under negotiation. • Since June, BCS sales have been in the range of 100 – 140 cedis a month.
Liero (Kur Karni)	BCS 150W School 75W	Lambussi DA	• The DCE arbitrarily changed the site from the originally planned village, Liero, to Kurkani. • In the record book, BCS operation commenced on 11 June 2011, but sales were almost nil until now. • We requested the DA to relocate the facility to another village.
Kelegan		Sissala West DA	• Due to the split of the administration area of the district assembly, identification of the site (village) was in confusion. As a result, the facility has not yet been installed. • Relocation of the site to Wa Polytechnic is under negotiation.
Loagri	BCS 150W School 75W	West Mampurusi DA (the	• BCS operation commenced on 9 May 2011. • Since the concessionaire is a PVA, the CS has been operated and managed in good condition.

		concession fee is 30% of sales)	• In the initial stage, sales were only around 100 cedis a month. However, sales continued to increase and reached as high as 190 cedis a month in August and September.
Kabiti	BCS 150W School 75W	Nkwanta South DA (concession fee is 40% of sales)	• BCS operation commenced on 26 May 2011. • Charge fees are 50 pesewas for cell phones and one cedi for lanterns. • Monthly BCS sales are in the range of 200 – 250 cedis.
Kacheibi	BCS 150W		• BCS operation commenced on 5 August 2011. • At present, monthly BCS sales are more than 200 cedis, and the condition of the CS operation is also good.
Kue (Nyambong)	BCS 150W Clinic 75W		• O&M condition is not good. BCS sales are also as disappointedly low as around 30 cedis a month. • The DA official found false records in the book and ordered the operation to be stopped. • The concessionaire is currently the village chief. The official advised the chief to change the CA and assign a trustworthy person.
Odumase	BCS 150W		• Operation commenced on 25 May but stopped on 1 June due to controller trouble. We replaced the broken controller with a new one. • Since 5 August, BCS sales have been remained on the level of more than 200 cedis a month. The operation condition is good.
Njare	BCS 150W	Krachi East DA (the concession fee is 30% of sales)	• The BCS was installed in May 2011, but it overlapped with the same facility of the Spanish project. The two facilities butted each other in the market, and BCS sales are now on the level of around 100 cedis a month. • The concessionaire is often not available in the village, and the responsibility for CS operation is left to the CA. There is much room to improve management.
Tekporkope			• Due to the conflict with the Spain project, the facilities will be relocated to the KNUST and Koforidua Polytechnic sites. ✓ KNUST: Ayiem, Amansie West District ✓ Koforidua Polytechinic: Asare Kwao, Fanteakwa District
Kodorkope			
Danladi	BCS 150W School 75W	Nkwanta North DA (the concession fee is 30% of sales)	• The operation of the BCS commenced in August 2011, but an inverter was broken on the second day. It was replaced on 27 October. • Sales on the first day were 12 cedis. Data collection for a certain period has just started.
Ayawara	BCS 150W School 75W	Ellembelle DA	• BCS operation commenced on 15 April 2011. • Due to inverter trouble, the BCS operation stopped between May and mid-June. • BCS sales are less than 50 cedis a month.
Babianiha	BCS 150W School 75W		• The O&M condition is not good, and the installed equipment is dusty. Up to now, inverter trouble has occurred twice. • Operation rate is quite low, and sales are almost nil.
Mantukwa	BCS 150W School 75W		• There has not yet been any trouble. However, BCS sales are as low as 30 cedis a month. • The market outlook is bleak (village size is small, income level is also low, and the reception of phone signals is very weak).
Bomigo	BCS 100W	Keta DA	• The BCS has continued to work without any trouble since the commencement of operation on 1 April 2010. • BCS sales have fluctuated in the range of 100 – 200 cedis a month. Average sales are around 150 cedis a month.
Blemazado	BCS 100W		• BCS operation commenced on 15 March 2010. • BCS sales were as high as 250 cedis a month, but the operation stopped in spring of 2011 because the village

			was electrified.
Azanu	BCS 100W		• BCS operation commenced on 10 March 2010. • The BCS achieved sales as high as 300 cedis a month, but the operation stopped at the end of December 2010 because the village was electrified.
Tomefa	BCS 340W School 85W Clinic 85W	MOEn	• BCS operation commenced on 21 December 2009. Except for the inverter trouble in November 2010, the operation has remained in a good condition. • Since 2011, sales have been in the range of 300 – 400 cedis a month. This is the best record among all sites. • However, the grid was extended to the village and will be energized in the near future.

Source: Prepared by using the monitoring data