Chapter 6 Action Plan

6.1 Rebuilding of RESPRO

6.1.1 Problems facing RESPRO

The RESPRO is promoting electrification with off-grid PV systems under the fee-for-service model with the assistance of the GEF. Thus far, it has installed and owns a total of about 2,000 SHS. Even today, after the end of GEF assistance, it has carried the project on as an NGO and continues to operate and maintain facilities while collecting service fees from users.

However, maintenance of this fee-for-service model faces big problems. The SHS service fees, i.e., the fees collected from the users, amount to only about 2 dollars per month because they are based on the lifeline tariff applied by an electric power company (utility). Furthermore, the RESPRO must perform operation and maintenance (O&M) for facilities scattered over a wide area in the north, and cannot cover its O&M costs with service revenue.

A portion of the installed SHS are entering the period for replacement of their batteries, but the RESPRO no longer has the money to make the replacement. Although it is asking customers to buy new batteries, this would not make a major improvement in the RESPRO's financial position. In addition, its RE mission is to expand SHS installation and increase the electrification rate in the northern regions, but it does not have the margin to use project earnings for additional investment. It will not be able to make additional investments unless it receives a fresh injection of capital, for which it would, moreover, have to depend on aid from donors.

As the RESPRO is faced with these financial problems, its staff are apprehensive about its future and their morale is declining.

6.1.2 Downsizing of the business and disposal of existing SHS assets

As described above, there is no cause for optimism about the future of RESPRO projects applying the fee-for-service model. The situation is coming to a point that requires a comprehensive review of the RESPRO operations and rebuilding of the business to open up future prospects. From now on, it is advisable for the RESPRO to abandon continued application of the fee-for-service model, downsize the business, and concentrate on fields where it is competitive.

The conclusion of the fee-for-service business would demand disposal of the SHS assets installed with GEF funding and provisions for the existing customers. Naturally, the party to take over these assets from the RESPRO would be responsible for dealing with the users and operating the assets. For this reason, the transferee would have to possess the financial base and organizational setup sufficient for operation of the approximately 2,000 SHS at the very least.

The potential candidates that immediately come to mind are the community assemblies and the NED (as a power distribution company).

The assemblies would appear to be the better candidates in the aspect of local operation of the facilities, but would face many problems in constructing organizational setups and raising the funds to cover the requisite O&M costs. As was learned from the DANIDA project, even if transferred to assemblies with a low organizational capability, asssets are liable to be left unmaintained.

As a power distributor, the NED has a strong capability for organization including technicians and also has regional locations. There are several other benefits in transfer of the existing SHS to the NED, as follows.

First, although SHS are positioned as a supplement to grid electrification, the SHEP program to this end is saddled with problems in respect of continuity, and fallout from them is impairing the execution of projects for SHS electrification. If the NED takes over ownership of the existing SHS from the RESPRO, it could promote PV electrification by relocating SHS facilities that were installed for the interim until grid connection to the next unelectrified communities as grid electrification progresses.

Of the approximately 2,000 SHS already installed by the RESPRO, about half will have to be moved due to the arrival of distribution lines. In addressing this task as well, the NED could make sensible decisions in selecting communities for facility relocation as the SHEP program proceeds.

In the second place, if the NED becomes the SHS owner, the application of lifeline tariffs to SHS, the biggest issue in the fee-for-service model, would have proper grounds. If SHS utilization could be positioned as a provisional measure until connection to the grid as a service in power supply to customers by the NED, it would be possible to apply the same tariff scheme as for the supply by distribution lines. Although this would entail a sort of cross-subsidization within the NED tariff scheme, the issue would be the setting of the lifeline tariff itself, and ought to be resolved in the context of the overall tariff scheme.

In the third place, extension of distribution lines through the SHEP program imposes a big financial burden on the NED, and is the cause of the mounting deficit. The addition of PV off-grid electrification as one of the electrification options would allow the NED to postpone plans for unreasonable extension of distribution lines, reduce its investment on RE, and put its finances on sounder footing.

Considering the costs entailed by O&M over the coming years, there would be no incentive for the party to take over the assets unless the transfer price was extremely low. The existing RESPRO facilities were installed with GEF funding, and there consequently would be no actual debt left for the RESPRO. The transfer price would probably have to be minimal (e.g., 1 cedi) in order to offset the future O&M cost.

6.1.3 New business model for the RESPRO

The foregoing raises the question of the fields on which the RESPRO should concentrate if it develops business in place of the fee-for-service operation.

The fee-for-service business model is definitely a heavy burden for the RESPRO, which has a staff of less than ten and shaky financial foundation. At the same time, however, each member of the staff is highly competent and possessed of specialized skill in PV facility installation and O&M accumulated to date. As such, the RESPRO has a high competitiveness even as compared to private firms in the field. It should concentrate its energies in the following areas to make the most of this potential.

(1) O&M service contractor

The RESPRO is doing O&M work for the approximately 2,000 SHS already installed through the GEF project, and has strength in this field. As a first step, it could undertake the provision of O&M services on a contract basis for the party to which the existing facilities are transferred (e.g., the NED). To set prices for this service, it would have to conclude a separate contract on the level required for maintenance of the RESPRO business.

For the SHS installed so far with non-GEF funding, it would be necessary to increase the number of O&M service contracts with their owners.

(2) PV system installer for a dealer or in public works projects

PV system installation is another new business prospect. It should be noted that the RESPRO would not purchase SHS directly with government funding as to date; instead, it would merely perform installation under the umbrella of another private-sector PV dealer or in the context of PV projects promoted by the government.

The big difference from the situation of the RESPRO so far is that it would be placed on equal footing with private-sector PV dealers and other installers, and enter into competition in the market.

(3) Training of PV technicians and testing of PV equipment through partnership with local polytechnical schools

In the northern regions, cultivation of the PV industry is an urgent task, and it is vital to train technicians for on-site work and establish the test facilities needed for quality control. The local polytechnic schools already in these regions are keenly interested in these fields as means of contributing to the growth of the PV industry.

The construction of centers for training of technicians and testing of PV equipment in each district would also be necessary for establishment of the PV industry supply chain. As such, it would be advisable for the RESPRO to build such regional centers in partnership with the polytechnic schools.

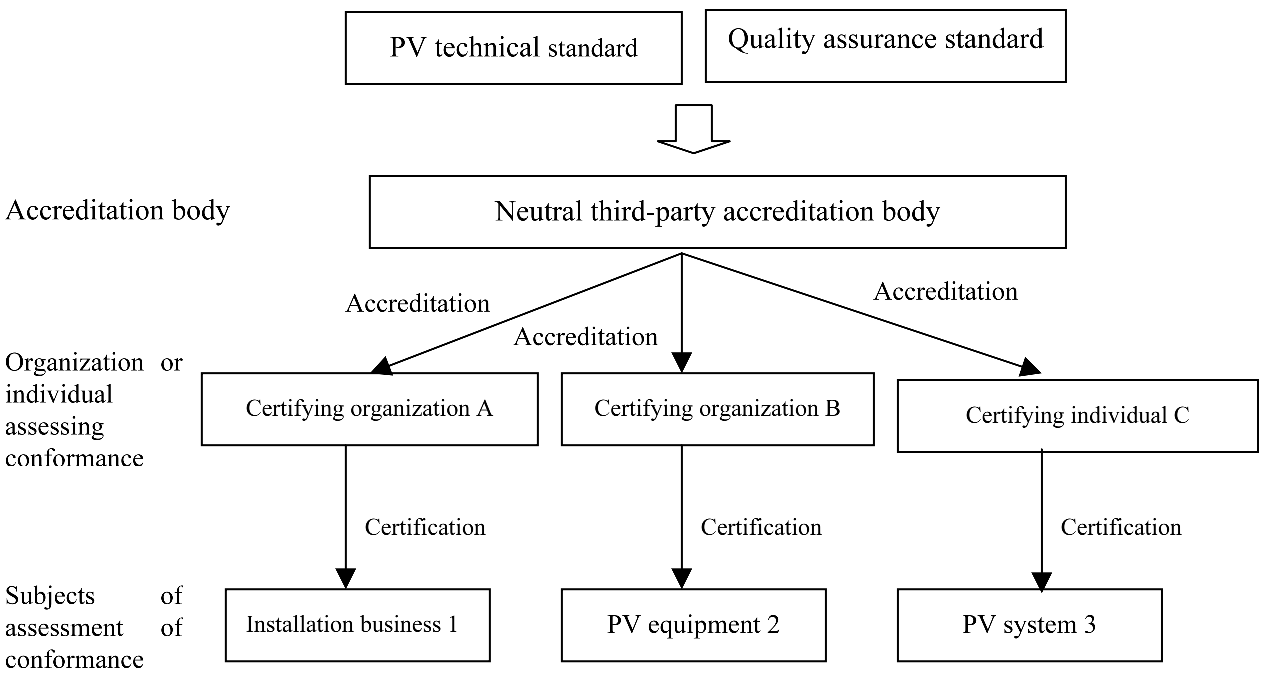
6.2 Establishment of the quality guarantee scheme

The PV industry in Ghana is still in its infancy, and efforts must be made to build the market. Under these circumstances, the circulation of low-quality PV equipment that would destroy the confidence of consumers must be avoided on all accounts. This is also important for protecting the interest of consumers.

6.2.1 Type of quality assurance scheme for credibility in the market

Perspectives on quality assurance are encompassed in standardization. Quality control and assurance ought to be implemented in accordance with the codes and standards of the country in question. Viewed from the standpoint of standardization, PV standards must be established not by the government but by an impartial third-party organization. Although it goes without saying that the membership of this third-party organization would include representatives of the competent government agencies, it would also have the participation of representatives of universities and other academic entities, private-sector firms, and consumers.

The entity accrediting organizations or individual parties that are to certify quality assurance under the scheme also must be a third party as opposed to the government. Figure 6.2.1 shows the general organization of the quality assurance scheme.



(Source) JICA Study Team

Figure 6.2.1 Organization of the quality assurance scheme

In Ghana, standardization is under the jurisdiction of the Ghana Standards Board. In coordination with the Board, the MOE and the EC should set PV technical standards together with representatives of other concerned parties such as PV industries and universities or other academic institutions, and build a quality assurance scheme as soon as possible.

The institutions (organizations) or individuals issuing certificates of quality assurance are allowed to engage in certification upon being accredited by the accrediting institution. These certifying organizations may be established by private parties; universities and other research institutions may also become involved. In addition, they could also be founded jointly by private firms and universities.

6.2.2 Training and establishment of test facilities

For Ghana's PV industry, there is an urgent need to establish a scheme for training engineers (technicians) and facilities for testing of PV equipment. Naturally, this training and testing requires a final accreditation, and this demands the construction of an organization following the flow of the accreditation scheme for quality assurance.

The body with this accrediting authority obviously need not be the national government; it may be a private firm or individual. The important thing is to have the organizations or individuals endowed with this authority to fully exercise their strengths and compete with each other in order to raise the overall level of quality. For example, the private sector has depth in on-site operations, and universities, in basic research, research facilities, and education. By drawing on their respective strengths and compensating for each other's weaknesses, they could build a distinctive training scheme and testing organization.

As mentioned in connection with its rebuilding, the RESPRO could provide a training program with an accrediting authority of its own in partnership with polytechnic schools in the northern regions. Meanwhile, large PV dealers headquartered in the national capital area could build suuch educational facilities and testing centers as industry counterparts, and also partner with national universities.

6.2.3 Official regulations

The EC has already instated a provisional license scheme for the PV industry, and a number of large PV dealers have applied for licenses. The scheme was instated by the EC precisely to avoid the loss of consumer confidence in PV systems by assuring the quality of those in the market, as mentioned at the outset of this chapter.

At the same time, overly harsh regulations are liable to stunt the growth of the market. For parties that intend to launch small PV businesses on a local level, acquisition of a license is by no means an easy proposition, for reasons of expense and other factors. Among the concerned parties, there are apprehensions about excessive regulation by the government.

Viewed in a different light, the instatement of a licensing scheme is merely a means of regulation. In discussion of the propriety of a licensing scheme, the important question is instead how to assure the quality of firms and technicians involved in the PV industry. The answer is instatement of the quality assurance scheme in accordance with the flow of standardization, as described above. Any framework which the government superimposes on the PV industry for regulation in some form must incorporate such a scheme. Needless to say, the firms and individuals that are certified for quality assurance would be equipped with the qualifications for licensing or registration.

The worth of the scheme of PV dealer registration lies in the fact that only firms with an assured quality of work may participate in tenders for the implementation of PV projects promoted by the government. It should be noted, however, that the examination standards must be in conformance with those of the quality assurance scheme.

As one of the most fundamental requirements, responses must also be made to doubts about the propriety of supervising businesses engaged in PV system installation and O&M by means of the licensing scheme. Unlike electric utilities, PV dealers do not have exclusive authority in the market and do not apply a tariff scheme in sales of PV systems. Prices are determined solely through the mechanism of competition in the market. In this respect, PV dealers do not differ at all in character from dealers of electrical appliances or automobiles.

The Study Team is also conferring with the EC about the pros and cons of a licensing scheme from these perspectives. In this dialogue, the EC side stated that it had no intention of restricting all PV dealer acts by means of the licensing and that the scheme would probably be applied only for businesses importing PV equipment.

6.3 Improvement of technical capabilities for PV systems (techhnical standards, test centers, training)

6.3.1 Technical standards, code of practice, and end user manuals

(1) Need for technical standards, code of practice, and end user manuals

Technical problems such as system design mistakes, improper installation, and insufficient O&M skills have often been cited in cases of past PV project failure. This sort of technical trouble not only impedes project continuity but also has an adverse influence on the expansion of the PV market because of the resulting loss of user confidence. As such, it is absolutely essential to establish technical standards and a code of practice in the form of a technical instruction document to support the quality assurance scheme proposed in the preceding chapter.

In Ghana, too, technical standards and a code of practice have been formulated under the leadership of the EC for the purpose of promoting the spread of appropriate PV technology. The draft standards and code are to be submitted to the GBS and officially approved as national standards upon deliberation by stakeholders including the concerned governmental agencies, research institutes, and enterprises.

Besides deepening discussion on technical points, the stakeholder conference must fully discuss application. More specifically, provisions must be made to collect views from a wide range of stakeholders in the conviction that the quality assurance scheme is a mechanism for expansion of the market, not its regulation. For example, it might be necessary to take a flexible approach that confines application of these standards etc. to governmental projects and permits a certain degree of substandard technology for systems installed on the individual basis.

(2) Framework for technical standards, code of practice, and end user manuals

The draft technical standards and code of practice prepared by the Study Team are for off-grid, i.e., stand-alone PV systems. (The on-grid PV systems to be installed in the future must conform with the technical standards imposed on electric utilities, and are not subjects of this study.) In addition, they do not regulate specifications in aspects such as system or equipment size; the subjects were restricted to items of performance as far as possible. The following perspectives lay behind the formulation.

- The technical standards stipulate a minimum requisite performance for each component, i.e., PV module (panel), charge controller, battery, DC-AC adapter, switches, and cable.
- The code of practice sets forth the proper procedure for design, installation, inspection, and O&M, all with consideration of meteorological phenomena such as harmattans as well as geographical factors. It also notes the basic handling procedure required when systems are handed over by installers, in the form of an end user manual.
- The code of practice contains attached documents presenting specific examples of design and installation with drawings and formulas that are easy to understand, as well as a checklist for use on the site.

Technical Standard and Code of Practice for Off-grid Photovoltaic Systems, prepared by JICA Study Team, are attached in Appendix.

6.3.2 Test centers and training centers

(1) Test centers

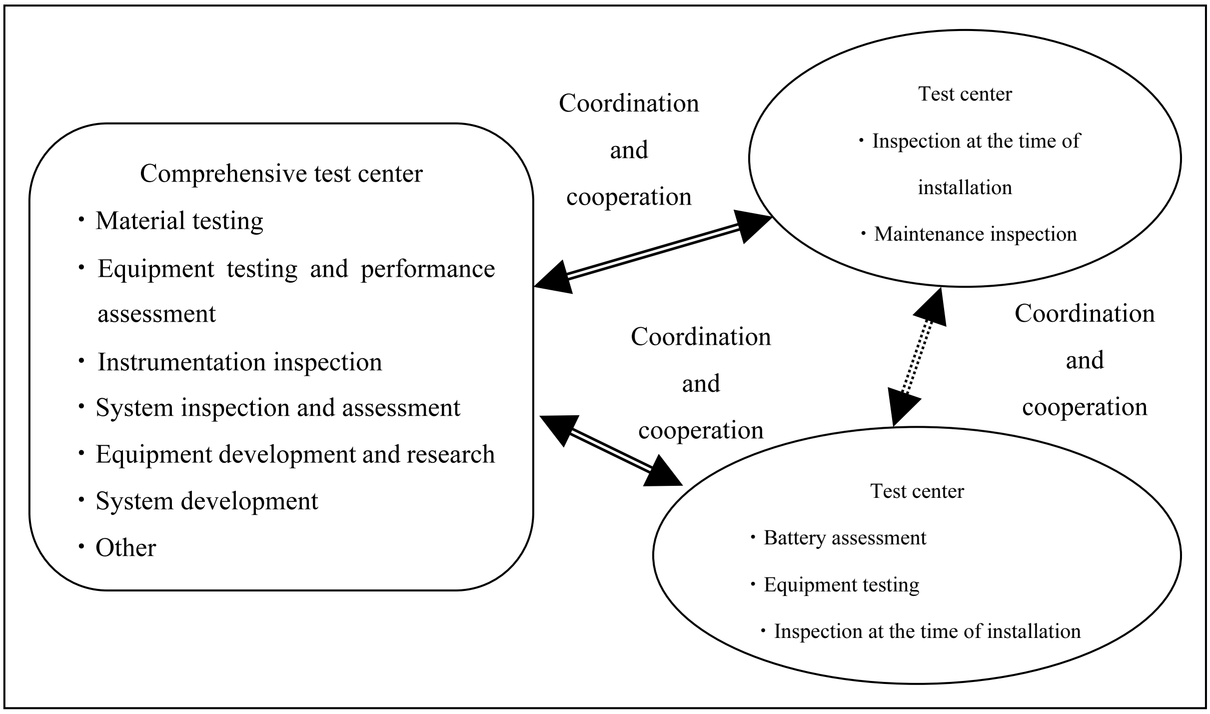
At present, almost all PV equipment in Ghana has been imported. The importers and PV dealers merely make visual inspections of this equipment and simple checks of its functions. The equipment quality generally depends on the data presented by the manufacturer and the O&M performed by the manufacturer itself. The KNUST and DENG have their own test centers to check equipment, but arrangements to this end are not yet fully organized.

This situation poses the risk that subquality products will flood the market in the process of PV system diffusion, and have the effect of destroying the credibility of all such systems. As a consequence, it is important to establish test centers for PV equipment in order to encourage local equipment development while also complementing the quality assurance scheme.

There would be two types of test center: 1) comprehensive test centers capable of conducting all operations from testing of PV cells and other materials to assessment of newly developed systems, and 2) test centers conducting routine inspections, such as system installation inspections and maintenance inspections. The former would be established at one or two locations (such as inside the KNUST), and the latter, at PV companies and local polytechnic schools. Both would be operated in mutual coordination within the framework of the aforementioned quality assurance scheme. This approach would make it possible to curtail the cost and efficiently operate test center facilities.

The test facilities could basically also be used as the training facilities of the training centers to be described below. As such, the test centers and training centers sould be located in the same institution to provide for effective use of facilities.

Figure 6.3.1 diagrams the operation of the test centers.



(Source) JICA Study Team

Figure 6.3.1 Diagram of test center operation

(2) Training centers

In Ghana, there is a shortage of PV technicians (engineers). In rural areas in particular, even if PV systems are installed, they often suffer a decline in performance or stop functioning because there are no technicians capable of handling maintenance, operation, or repair in the vicinity. The users may also have little knowledge of the PV equipment and do not perform proper O&M. The diffusion of PV systems therefore requires the training of technicians and establishment of training centers for that purpose.

The training centers could be established in the organizations participating in the quality assurance scheme advocated above, e.g., universities, polytechnic schools, and other educational institutions as well as PV companies and NGOs. The task is to construct a system whereby the various training centers can produce technicians in coordination with each otherand with a shared awareness while preserving their autonomy.

In the course of the work to this point, the Study Team prepared a draft training curriculum and pursued discussions based on it with universities, polytechnic schools, and PV businesses.

The draft is premised on courses that are aimed at educating PV system users, producing installation technicians and design technicians, and producing technicians with higher levels of expertise.

While sharing the same basic level of technology, the training centers could emphasize different areas in their respective training curricula. For example, those in universities could stress academic areas, and those in polytechnic schools and PV firms, more practical areas. It would also presumably be possible to offer either all courses or even just one. Flexible arrangements as regards the training curriculum could alleviate the burden of training center establishment, and increase prospects for the establishment of more training centers.

In the discussions between the Study Team and various entities, some participants proposed the inclusion of classes on construction, civil engineering, welding, painting, and other such skills in the training curriculum. However, such skills have little connection with the installation and O&M of small PV systems, and particularly off-grid ones. The Study Team consequently recommends the proposed curriculum at the present stage, in the judgment that training in such skills could be implemented separately by the various training centers or considered once PV systems are in widespread diffusion and needs arise for training in large-scale facilities.

Table 6.3.1 presents the draft training curriculum, and Table 6.3.2, a list of the training (and test) center facilities.

Table 6.3.1 PV training center curriculum (Tentative plan)

Contents		user	Install engineer	Design engineer	Senior engineer
Ⅰ.Basics of Electric					
Ⅰ-1	Static electricity and an electric field		○	○	○
Ⅰ-2	An electromagnet and a magnetic field		○	○	○
Ⅰ-3	DC circuit	○	○	○	○
Ⅰ-4	AC circuit	○	○	○	○
Ⅱ.Basics of PV					
Ⅱ-1	Summary of PV	○	○	○	○
Ⅱ-2	Generation principle	○	○	○	○
Ⅱ-3	Solar radiation	○	○	○	○
Ⅲ.PV system appliances					
Ⅲ-1	Cell, Module, Array		○	○	○
Ⅲ-2	Charge controller		○	○	○
Ⅲ-3	Inverter		○	○	○
Ⅲ-4	Battery		○	○	○
Ⅲ-5	Electric appliances (DClight, bulb, etc.)		○	○	○
Ⅲ-6	Wiring appliances (switch, fuse, etc.)		○	○	○
Ⅳ.System design					
Ⅳ-1	Demand assumption			○	○
Ⅳ-2	Voltage drop and wiring size			○	○
Ⅳ-3	PV capacity			○	○
Ⅳ-4	Battery capacity			○	○
Ⅳ-5	Choice of Charge controller, Inverter			○	○
Ⅳ-6	Choice of wiring appliances			○	○
Ⅳ-7	Wiring diagram		○	○	○
Ⅴ.Measurement and testing facilities					
Ⅴ-1	Tester, Ammeter, Voltmeter, Whmeter		○	○	○
Ⅴ-2	Pyranometer , anemometer			○	○
Ⅴ-3	I-V curve tracer, Solar simulator				○
Ⅵ.Regulations					
Ⅵ-1	Technical standard for Off-grid PV		○	○	○
Ⅶ.Installation method					
Ⅶ-1	Materials and Tools		○		○
Ⅶ-2	Wiring		○		○
Ⅶ-3	Grounding		○		○
Ⅶ-4	Assembly and mounting		○		○
Ⅶ-5	Inspection		○	○	○
Ⅷ.Practice on the field					
Ⅷ-1	Assembly and mounting work		○		○
Ⅷ-2	Wiring work		○		○
Ⅷ-3	Inspection		○	○	○
Ⅷ-4	Measurement and Analysis			○	○
Ⅷ-5	Maintenance (ordinary)	○	○	○	○
Ⅷ-6	Maintenance (special)		○		○

(Source) JICA Study Team

Table 6.3.2 List of PV training center facilities and/or Test center facilities (Tentative plan)

1. Test devices, Measurement devices		
№.	Items	Use
1-01	Tester	Resistance, DC/AC Voltage, Frequency
1-02	Clamp meter	DC/AC Current
1-03	Ammeter	DC/AC Current
1-04	Voltmeter	DC/AC Voltage
1-05	Ohm-meter,	Resistance,
1-06	occilloscope	Voltage/current wave
1-07	Earth tester	Grounding resistance
1-08	Withstand voltage tester	Withstand voltage, Insulation resistance
1-09	Pyranometer	Iradiance (Iradiation)
1-10	Anemometer	Wind speed, Wind direction
1-11	Temperature meter,	Ambient temperature
1-12	Hygrometer	Humidity
1-13	Thermocouple	Module temperature
1-14	I-V curve Tracer	I-V Curve, PV Curve, Pmax, Isc, Voc, Ipmax, Vpmax
1-15	I-V checker	(portable type) I-V Curve, PV Curve, Pmax, Isc, Voc,
1-16	Solar simulator	Artificial light source
1-17	Spectroradiometer	Measures spectral distribution
1-18	Data logger	Save of measurement data
1-19	Personal computer	Save of measurement data, and analysis
1-20	Battery hydrometer	Specific gravity of a battery electrolyte
2. Appliances, Tools, Materials		
№.	Item	Contents
2-01	PV Systems	PV array, Charge controllers, Inverters, Batteries(Deep cycle and Automotive)
2-02	Electric appliances	DC light, Fluorescent lamp, Pump, Fan, TV set, Radio communication, Variable resistance, Variable load
2-03	Wiring tools	Driver, Pliers, Nipper,
2-04	Installation tools	Bob line, Direction magnet, Level, Angle meter, Spanner
2-05	Wiring appliances	Switch, Outlet, NFB, Fuse,
2-06	Materials	Wire, Terminal, Conduit, Bolt-Nut, Mounting structure

(Source) JICA Study Team

6.4 Measures for promotion of the PV industry through institutional conditioning

Besides the establishment of third-party institutions resting on public-private partnership under the scheme for quality assurance described in the preceding sections, the conditioning of the PV system market demands that government, private companies, and local markets each play their respective roles to support the scheme.

6.4.1 Market conditioning to be executed by the government

(1) Cultivation of the market through governmental projects

In Ghana, governmental funding is not clearly set aside for PV projects, and support is extremely limited, being confined to activities such as the implementation of pilot projects. The major reason for this is the lack of a clearly defined policy in favor of electrification by means of PV systems. In response, the MOE must explicitly target public facilities as the subjects of electrification in PV projects (eligible for public funding) and prepare a long-term program for PV electrification.

To provide incentive for certification, only firms that have been certified under the quality assurance scheme should be allowed to participate in tenders for the PV projects carried out under this program. This will make it possible to furnish them with the market for equipment procurement, installation, and O&M.

In the electrification of governmental facilities by the MOE, electrification funding should be provided only for the initial cost, and the PV facilities should be transferred to the competent ministry/agency upon installation. In past pilot projects, ambiguity about the ownership after delivery (installation) led to a lack of proper O&M and made sustained system use impossible. The MOE therefore must confirm the presence of the following arrangements for O&M in the ministry/agency as a precondition for project execution.

- Assurance of O&M budget
- Conclusion of an O&M contract with installers or other certified dealers
- Appointment of a party responsible for O&M in the facility (graduate of a user training program)
- Construction of a scheme for liaison with regional institutions and the national government

(2) Assurance of funds and establishment of a scheme for their effective use

There is also a shortage of electrification funding. The tax revenue collected by the RE Fund (1.7 cedi per kWh) and the Energy Fund (5 cedi per liter of petroleum product) are not enough. The amounts to be collected were fixed about ten years ago, and the value has dropped to about 5% of its original level due to galloping inflation and the cedi's depreciation. At present, the two funds each collect 3 - 5 billion cedi per year, or only about 0.6 - 1 million dollars combined.

According to the MOE, the PV electrification cost for major public facilities such as schools, medical facilities, and police stations comes to about 20 million dollars. The initial cost only for unelectrified facilities of these types in the three northern regions is estimated at about 5 million dollars (see Table 6.4.1).

Table 6.4.1 Initial cost of PV electrification of major public facilities in the three northern regions

(US$)

Facility	Unit Cost	Number	Total
CHIPS Compound	2397.4	50	119,870.0
Clinic	11693.3	50	584,665.0
Health Center	11693.3	66	771,757.8
Junior Seconrdary School	6060	481	2,914,860.0
Police and other public	2168.8	200	433,760.0
		Total	4,824,913

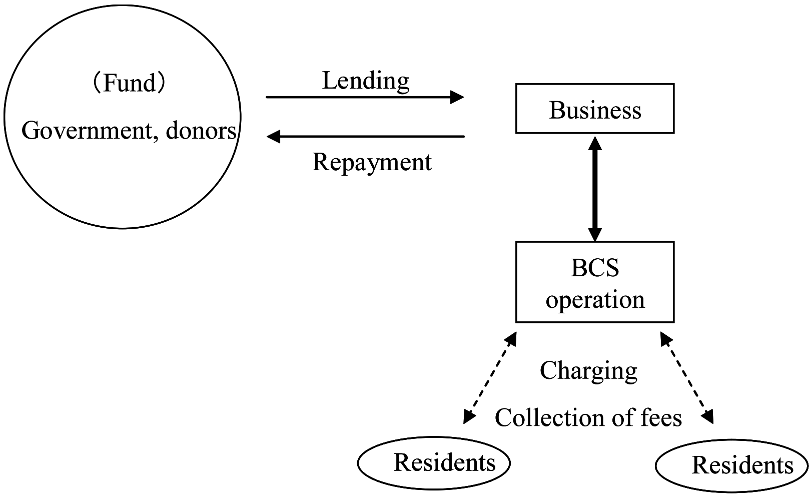
＊For Northern, Upper East, Upper West Region

(Source) JICA Study Team

One conceivable means of assuring these electrification funds would be to raise the amounts collected for the RE Fund and Energy Fund. These amounts have not be changed at all in spite of the ten-fold increase in power tariffs and oil prices since 1998. If they had been increased proportionately with the increase in power tariffs etc., the fund revenue would also have undergone a ten-fold increase, which would translate into income of 6 - 10 million dollars per year. Because these funds were also established for other purposes, not all of this revenue could be used for PV electrification. However, this step would be effective for funding improvement into the long term.

In contrast, the instatement of subsidies and provision of loans for housing, stores, and other such private-sector facilities would not be a realistic option, in light of factors including the lack of funding sources and the past occurrence of trouble due to the lack of a sense of ownership among customers that were "given" systems in this way.

In contrast, the option of providing financing in small amounts and at low interest rates for dealers, NGOs, and other such parties deserves consideration, partly because such parties presumably have a keener sense of responsibilities than individuals. One prospect, for example, is establishment of a revolving fund to make low-interest loans of operating funds to businesses installing BCS in rural communities, pay the funding recovered over the next few years back into the fund, and use it for loans to additional businesses. In this case, loans for a single 500-W system would be in range of 3,000 - 4,000 dollars. Punitive provisions would obviously have to be made for confiscation of the system in the event of failure to repay loans. Figure 6.4.1 diagrams the revolving fund concept.



(Source) JICA Study team

Figure 6.4.1 Conceptual diagram of revolving funds in PV projects

(3) Coordination with social development projects for improvement of public services

Off-grid PV electrification is not a final end in itself; it is a means of providing basic elements of the social infrastructure, such as improved education and medical services, and safer supply of water. In the case of medical facilities, for example, electrification is incorporated into programs along with a fuller assortment of medical equipment and the digging of wells. These programs are executed on budgets that are funded not only by the MOE but also by the MOH (with its own funds) and contributions from donors (such as UNICEF).

It is also possible that PV systems could be introduced in fields such as mini-irrigation. As such, the MOE (as the ministry in charge of promoting RE) must provide information on its own RE programs (both SHEP- and PV-based) at regular intervals, ascertain the status of RE programs in other sectors for more efficient formulation of RE plans. (The MOH is efficiently electrifying medical facilities by regularly obtaining SHEP information from the MOE and executing its own programs for facilities not covered by SHEP.)

(4) Preparation of a setup for information dissemination

Relative to on-grid electrification, there is a serious lack of knowledge about the objectives of PV-based electrification in remote communities. In addition, residents targeted for PV-based electrification often feel as if they have been abandoned as far as on-grid service is concerned. (In the northern regions, there are quite a few communities that have not been electrified for several years even though utility poles and transformers have been constructed in them. The residents expect the grid service to arrive, and feel neglected by it when PV systems are brought in instead. This is another factor impeding the spread of PV systems.) This points to a need to actively inform residents about the objectives of PV-based electrification (i.e., that it is an effective means of electrification in districts that cannot be reached by extension of the grid for at least a few years) and its benefits (i.e., that a supply of power sufficient for lighting will help to raise the level of education and medical services).

The measures that could be taken by the MOE itself on this front include the staging of demonstrations in communities for PV systems; and educational campaigns through spots on TV and radio. Nevertheless, these would not be sufficient in themselves for widespread diffusion in remote communities in the north. Diffusion on the resident level requires community-based activities, and interaction with other principals in the social development sector would be effective to this end.

For example, correct knowledge about PV systems could be provided by having schools and medical facilities stage meetings for presentation to residents/students and displaying posters showing the benefits of PV-based electrification.

6.4.2 Market conditioning to be performed by the private sector

In Ghana, the PV market is still in its infancy. Several prominent dealers and installers have appeared, but statements reflecting the interests of only certain firms sometimes emerge at stakeholder meetings. This is evidence that the industry has not yet been organized to the point that it can present unified positions.

As a first step for organization, the concerned parties should promptly establish an industrial window (association) for system-related rule-making, e.g., technical standards and a code of practice to assure system quality. Dealers are coming out with all sorts of system grounded in their wealth of experience, and certification of these systems as technology acknowledged by society as a whole would help to expand the market.

It should be added that the establishment of such an association is indispensable for actual operation of the arrangements for certification based on the quality assurance scheme, meaning tasks such as the issuance of certificates related to design, installation, and O&M, or for equipment (cooperation with test centers).

The industrial association would also have a vital role to play in the educational campaigns promoted by the government as noted above. In its publicity through mass media and posters, the government could display contact numbers for the association, so that customers could turn to it in addition to the MOE for effective information on installers and systems. (In Malawi, the industry instituted such an association, i.e., the Renewable Energy Industry Association in Malawi. REIAMA is partially subsidized by the government, and enages in educational activities while also participating in stakeholder meetings.)

From the standpoint of assuring PV system quality, it would be advisable to limit the circle of association members to those dealers that have been certified (or intend to obtain certification).

6.4.3 Conditioning of local markets

As is clear from the findings of the village socioeconomic study, commercial facilities and households in communities in the northern regions are physically dispersed and do not have enough money for purchase of costly PV systems (e.g., SHS) in large numbers. Furthermore, PV systems themselves have quantitative and qualitative limits, and cannot effect a dramatic improvement in the economic situation of these communities. To induce the spread of PV systems among stores and households, firms must curtail the costs of tariff collection and O&M to the very minimum; otherwise, the business cannot subsist.

To lower the costs of collection, for example, firms could consign the operation of BCS and SHS fee collection to local businesses such as filling stations. (For a 500W BCS installed in Pusiga, in the Upper West Region, RESPRO consigns the operation to a private business and receives a fixed monthly amount from it. The BCS is operating smoothly.) Even the largest BCS installed in remote communities would probably be fairly small (with a capacity of a few hundreds of Ws), and could be sited on filling station lots.

Even if a RESPRO-type fee-for-service model is applied, the business could have users bring fees to the filling station, from which it would later retrieve them. It would directly deal with the customer only for certain work, such as special maintenance or confiscation of systems from non-paying users. This arrangement would curtail operating costs.

Another option would be to have the community perform fee collection, but this cannot be strongly recommended, partly because ties of kinship make it difficult to collect fees from relatives in rural communities. Expectations for community participation would instead focus on means of conveying information on firms through the filling stations or other local operators (on items such as the schedule for maintenance and fee collection) to districts without telephones or other such telecommunications services.

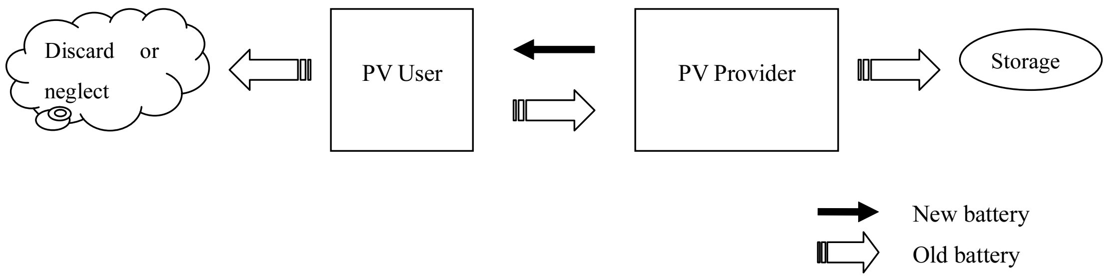
6.5 Improvement of the system of spent battery processing and recycling

6.5.1 Current status of processing and recycling of spent batteries

(1) PV battery processing and recycling

Deep-cycle batteries for PV systems are provided by the PV business to the user at the time of system installation and battery replacement. Almost none of these businesses recover, process, or recycle spent batteries. Although they sometimes collect them at the request of customers, they merely store the spent batteries on their premises and do not have any policies for their processing.

In nearly all cases, users neglect spent batteries or discard them in the vicinity. Figure 6.5.1 shows the flow of PV battery processing, and Figure 6.5.2, a photo of the storage of spent batteries at a certain PV business.



(Source) JICA Study team

Figure 6.5.1 Flow of PV battery disposal

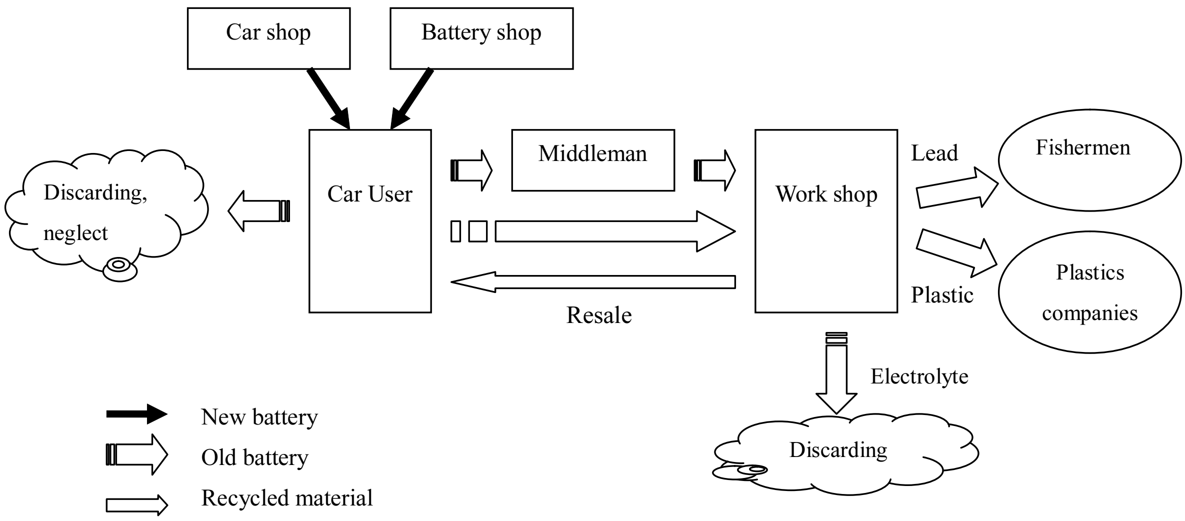
(Photo) JICA Study Team

Figure 6.5.2 Spent batteries in storage at a PV business

(2) Current status of disposal and recycling of automobile batteries

Arrangements have not yet been made for automobile battery recovery and recycling by the national government or industry, but lead and plastic from batteries is being recovered and reused by small businesses such as auto scrap dealers. Although it is not complete, there is consequently a certain level of recycling. The used batteries from scrap automobiles are handed over to the scrap dealers along with the automobiles. Firms that own a lot of automobiles transfer spent batteries to private companies free of charge, and these middleman companies resell them to even smaller businesses.

The scrap dealers remove the lead from batteries left in scrapped automobiles or purchased from the aforementioned middleman companies, recast it, and sell it to fishermen as weights for their nets. The battery cases are sold to plastics firms in Ghana. The electrolyte is reused if it is free of grime and has a good specific gravity; otherwise, it is discarded. Batteries in fairly good condition are sometimes resold as used batteries or reused through installation in used cars. Figure 6.5.3 shows the flow of the processing of automobile batteries.



(Source) JICA Study team

Figure 6.5.3 Flow of the processing of automobile batteries

(3) Current status of laws and regulation

In Ghana, dry cells and automobile batteries are classified as hazardous waste under the Ghana Landfill Guidelines of the EPA. The Guidelines merely stipulate their proper disposal, and there are no laws or regulations regarding the detailed methods of processing or recycling.

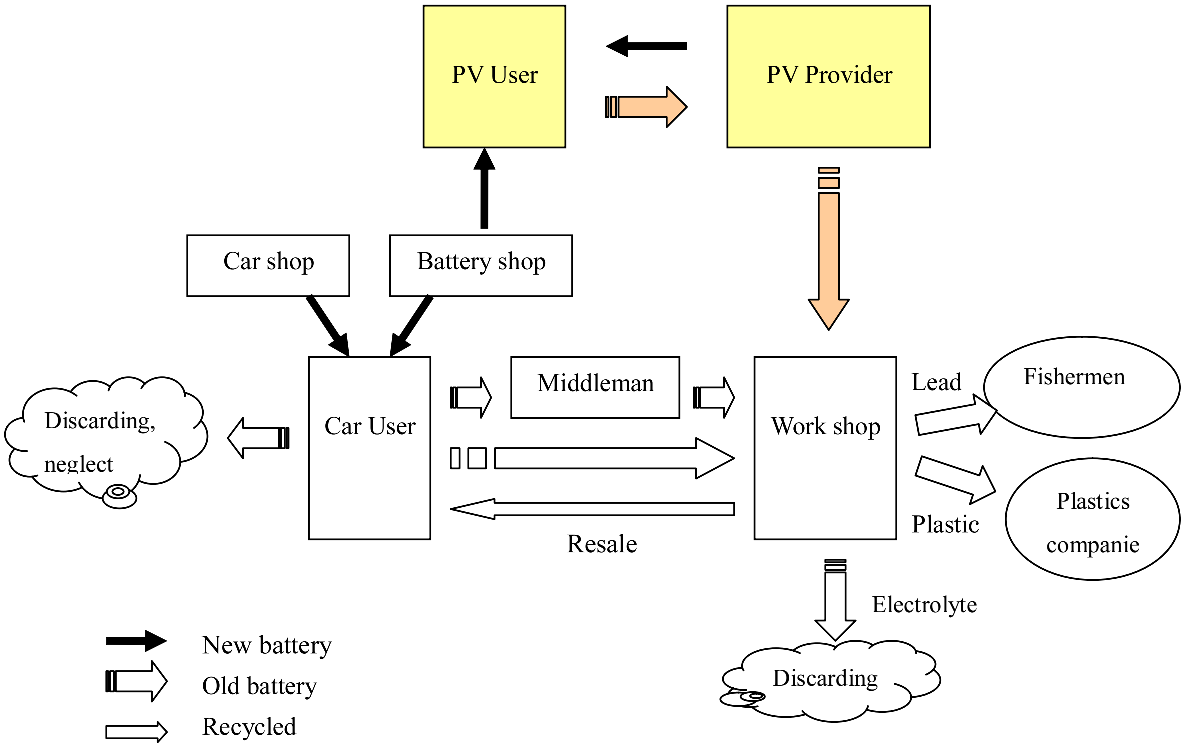
6.5.2 Proposal for improvement of the battery processing and recycling system

(1) Short-term improvement

PV batteries do not differ greatly from automobile batteries in respect of principle, structure, and material. With attention to certain points as regards the method of operation, automobile batteries can actually be used for PV systems. This raises the possibility that the same kind of procedure could be applied for the processing of spent PV batteries. It may also be noted that automobile batteries are in much wider circulation than PV batteries. Therefore, placement of spent PV batteries into the flow of automobile battery processing and recycling would presumably be a workable and effective measure for improvement over the short term.

More specifically, when PV businesses deliver new batteries to system users, they could recover the spent batteries and store them. Once they have recovered and stored a certain number of spent batteries, they could sell them to businesses that process automobile batteries (scrap dealers etc.) or have the latter pick them up free of charge.

To prevent the discarding of batteries by users, it would also be important for PV businesses to educate users about the adverse environmental impact of battery dumping when they install the PV systems and deliver batteries. Figure 6.5.4 shows the placement in the flow of autobmobile battery processing.



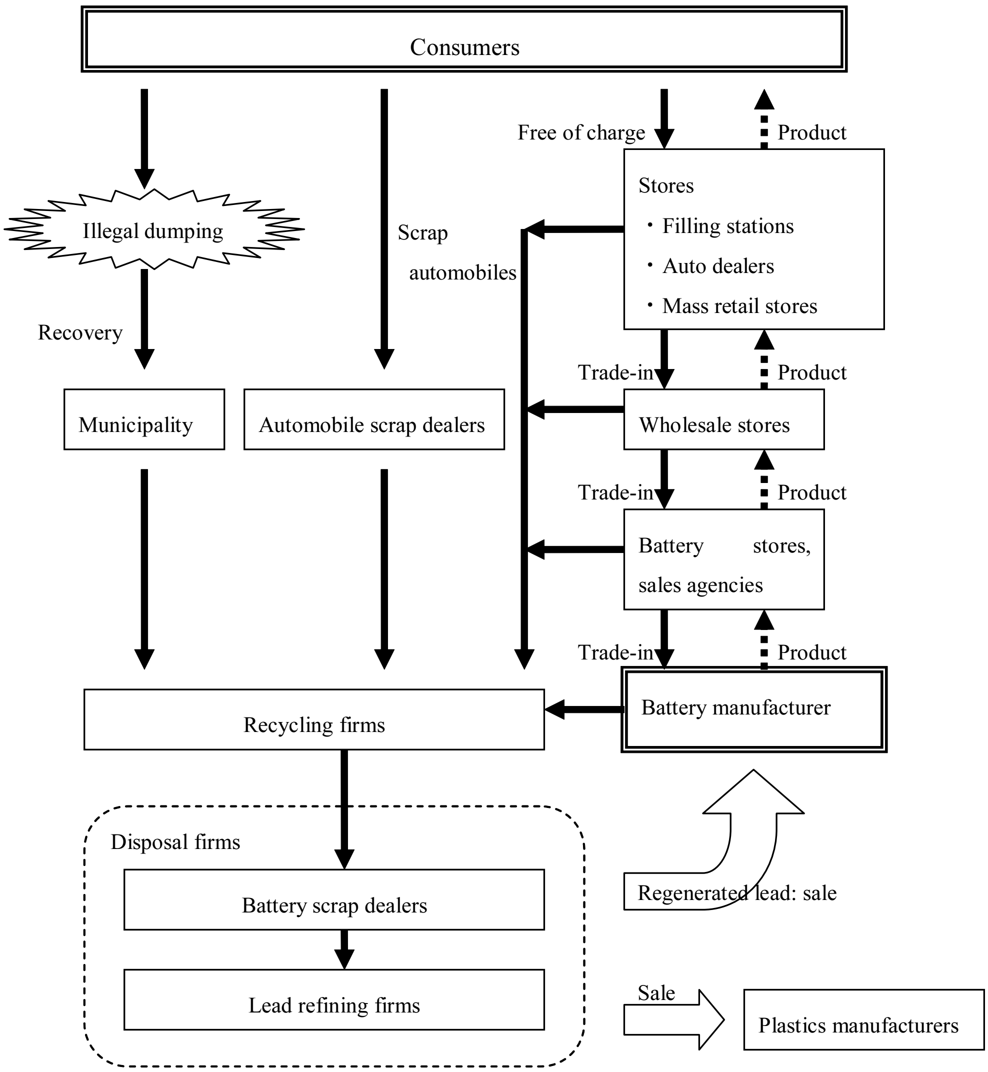
(Source) JICA Study team

Figure 6.5.4 Placement in the flow of automobile battery processing

(3) Proposals for future improvement

In Ghana, there is a certain amount of spent battery recycling, but not all businesses recover spent batteries, many of which are discarded or neglected by users. The lead recovered from spent batteries is put to use as weights for fishing nets, but this demand is on a low level, and there are apprehensions about the lack of prospects for its expansion as a recycling system (leading to an increase in the number of recovered batteries).

As such, improvement of the system for battery processing and recycling further in the future will probably require a major improvement of the current system. This section describes the case of Japan as a reference for future improvement of the system in Ghana. Figure 6.5.5 shows the flow of the battery recycling system in Japan.



(Source) JICA Study team

Figure 6.5.5 Flow of the battery recycling system in Japan

In Japan, consumers (battery users) have automobile scrap dealers pick up spent batteries along with the scrap automobiles or bring them into battery retail stores for recovery free of charge. The retail stores have these batteries collected by scavenger firms either directly or through wholesale stores or sales agencies and the like. Although some batteries are illegally discarded (dumped) by consumers, these are recovered by the municipality, which hands them over to scavenger firms. From the scavenger firms, the spent batteries go to battery scrap dealers and refineries, which refine the lead and resell it to the battery manufacturers. The spent battery cases are pulverized and sold as material for production of plastics.

Manufacturers of storage batteries are required by the Ministry of Health, Labour and Welfare and the Ministry of Economy, Trade and Industry "to take the necessary measures" for proper recycling of batteries in accordance with the Waste Treatment and Cleaning Act. They are consequently encouraged to become actively involved in battery disposal and recycling.

To promote the sure disposal and recycling of batteries in Ghana, it is important not only to enact relevant legislation and regulations but also to construct setups for cooperation by battery stores, promote the growth of scavenger and processing businesses, and educate consumers about environmental preservation.

Chapter 7 Construction of a GIS/data base

7.1 Need for a GIS/data base

The preparation of RE plans requires the handling of a lot of data and map information. The planning is liable to be inefficient and inappropriate if these data are not centrally managed and the data and map information are not tied to each other.

In the second field study, personnel visited concerned institutions to determine the whereabouts of and obtain data. Data concerning RE plans and map information were held separately by different institutions and assigned personnel, and were not centrally managed. Few institutions had a geographic information system (GIS), and there was generally no correlation of data and map information. This is also apparent from the lack of consistency between the RE plans and grid extension plans. These circumstances suggest the need for construction of a GIS data base for efficient preparation of RE plans.

GIS link character, numerical, and graphic data with maps. Through reproductions on computer screens, they consolidate and analyze all sorts of information from positions and locations, and display clear map expressions. They are in use in a wide range of business sites.

The Study Team is planning to make use of mainly the GIS software Arc View 9.0 (ESRI) and the data base software Microsoft Access to prepare a GIS data base that will be of value to the formulation of RE plans.

7.2 GIS development in Ghana

In advance of the study, it was learned that some institutions had data bases of GIS information for maps, infrastructural elements such as rivers and roads, and afforestation. The Study Team therefore interviewed the institutions in question. Table 7.2.1 outlines the findings of these interviews.

Table 7.2.1 Results of interviews concerning GIS

Institution	GIS possession	Findings
MOE	×	Wants to build one in this study
EC	○	Built with UNEP assistance in 2002
PURC	×	Interested, but does not have one
ECG	×	Currently preparing one targeted for completion in 2006
NED	×	Feels the need, but does not have one
MOEdu	×	Interested, but does not have one
MLGRD	×	Feels the need, but does not have one
Survey Department	○	Digitization of existing maps in 1997

(Source) JICA Study Team

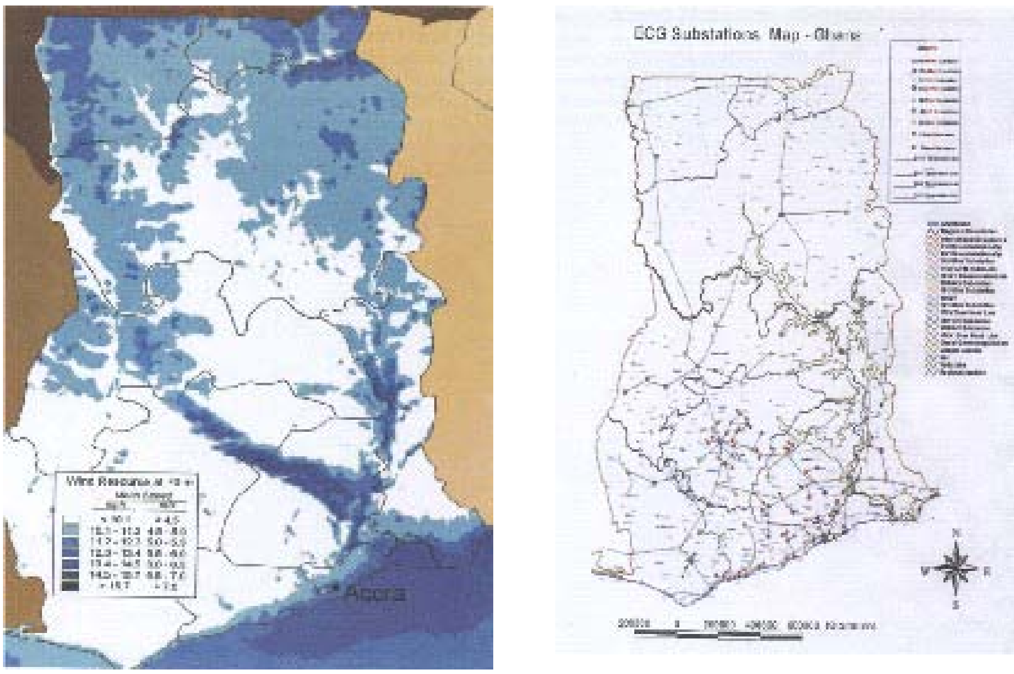
Each institution expressed an interest in GIS and perceived a need for one, but few had already built and owned one. More specifically, GIS had been built and were owned by the EC and the Survey Department.

The EC built a GIS data base on renewable energy with the assistance of the UNEP in 2002. The data base contains the information shown in Table 7.2.2, and has a high degree of completion. Table 7.2.2 shows the information in the GIS owned by the EC, and Figure 7.2.1, sample screens from this GIS.

Table 7.2.2 Information included in the GIS owned by the EC

Information title	
The Existing Solar Radiation Map	Population
Wind Resource Map	Road network
The Country's mini hydro sites	Topography
Electricity Company of Ghana Distribution Network	Land Cover

(Source) JICA Study team



(Source) EC Annual Report

Figure 7.2.1 GIS owned by the EC

The Survey Department digitized its existing 1:50,000 maps in 1997. The total of 102 maps cover all of Ghana, and 40 of them cover the three northern regions that are the subject of this study. The software used by the Survey Department is Arc Info (ESRI), of the same type as the Arc View 9.0 GIS software used by the Study Team. In light of the high data compatibility, the Study Team decided to purchase GIS data from the Survey Department in preparing a GIS data base. Table 7.2.3 shows the information contained in the GIS data of the Survey Department.

Table 7.2.3 Layers of the GIS data in the Survey Department

Layer title	
Cultural Polygon Layer	Cultural line/point Layer
Forest Layer	Transport Layer
Hypsographic Layer	Utility Layer
Hydrographic Layer	Text Layer
Landform Layer	

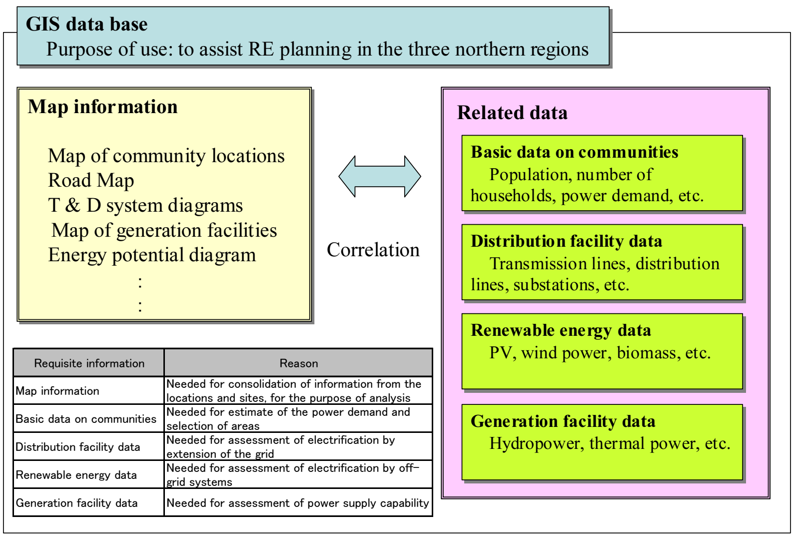
(Source) Prepared by JICA Study Team

7.3 Construction of the GIS/data base

7.3.1 Information needed for the GIS/data base

In the formulation of RE plans, it is necessary to handle electricity-related basic information and locational information, in addition to a huge amount of data on communities. This requires construction of a data base using GIS software to manage this information both efficiently and in a visual form (as graphic data).

As a first step, it is necessary to clearly define the kinds of data needed for GIS, which constitute the premise for consideration of the data base structure. The kinds of data currently available in Ghana include map information, basic community data (on population, number of houses, etc.), generation facility data, distribution facility (transmission and distribution lines) data, and renewable energy potential data. These are joined by in-depth socioeconomic data and demand-related data from the village socioeconomic study as the kinds of information required for this study. Figure 7.3.1 shows the information needed for the data base.



(Source) JICA Study Team

Figure 7.3.1 Information required for the GIS data base

7.3.2 Composition of the GIS/data base

If the GIS data base prepared in this study were to be used only by the MOE and the RESPRO, it would be both easier and more efficient to construct a data base around Arc View 9.0. This software, however, is designed exclusively for GIS and is costly. As a result, few related institutions and parties use it. Given the need for sharing information on the substance of this study, the data base should naturally be available for use by many concerned entities. In constructing the GIS data base, the Study Team therefore decided to use Microsoft Access for the management and viewing of map and other information, and Arc View 9.0 for the preparation and revision of map information by the counterpart, as was proposed in the Inception Report.

Microsoft Access is a general-purpose software, but has fewer users than Microsoft Word and Microsoft Excel. The second field study confirmed that the situation was the same among the related institutions in Ghana. Microsoft Access is an excellent data base software, but parties other than the data base preparer generally have trouble using it to perform detailed work. In constructing the data base, the Study Team therefore decided to use Microsoft Access only as an interface, and files prepared with Microsoft Excel or other software capable of use by all for data transfer. Figure 7.3.2 shows the data base vision which the Study Team has in mind.

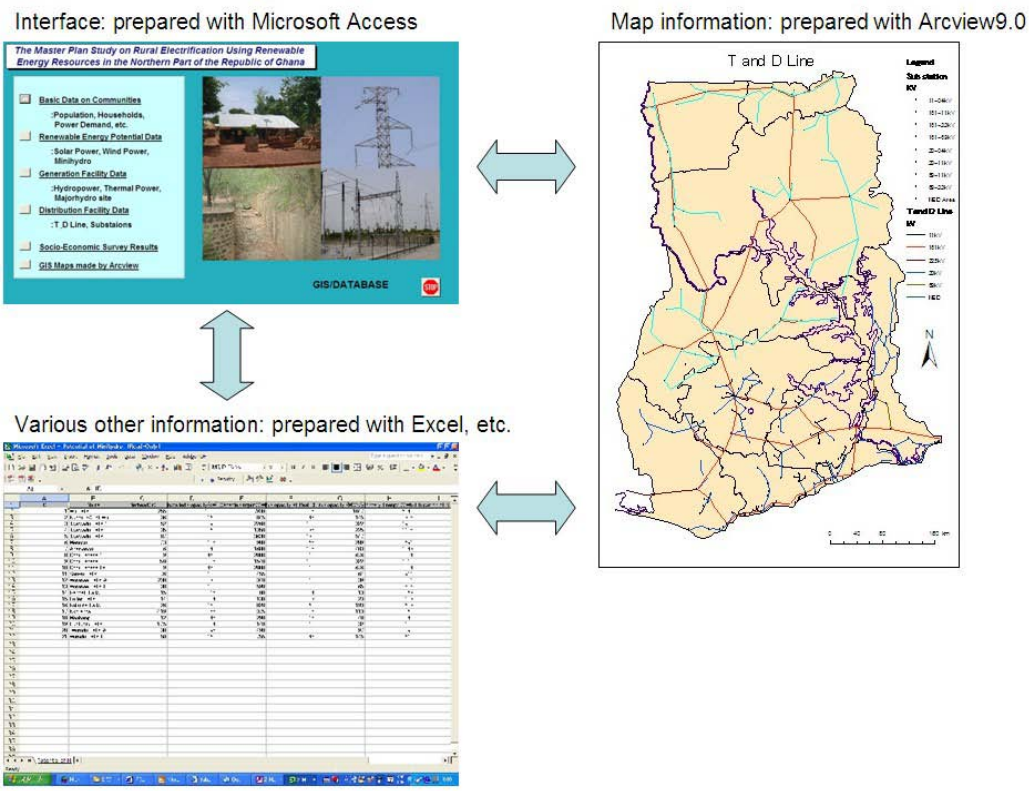
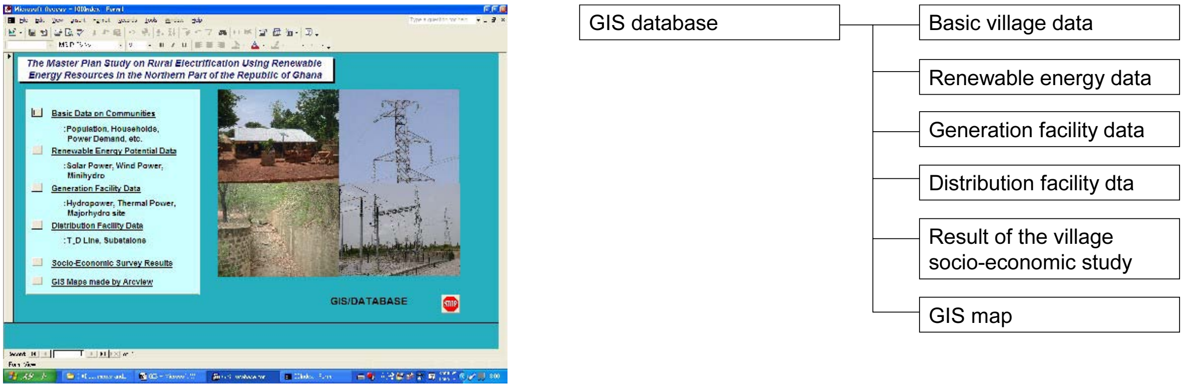


Figure 7.3.2 GIS data base vision

7.4 Structure of the completed GIS/data base

7.4.1 Main Structure

The GIS data base consists of six components: the basic community data, renewable energy data, generation facility data, distribution facility data, the data from the village socioeconomic study implemented in this study, and the GIS maps. The system enables users to view GIS maps prepared with these data on the computer screen. With the exception of the data from the in-depth village socioeconomic study, the maps and data cover not only the three northern regions but also all other parts of the country.

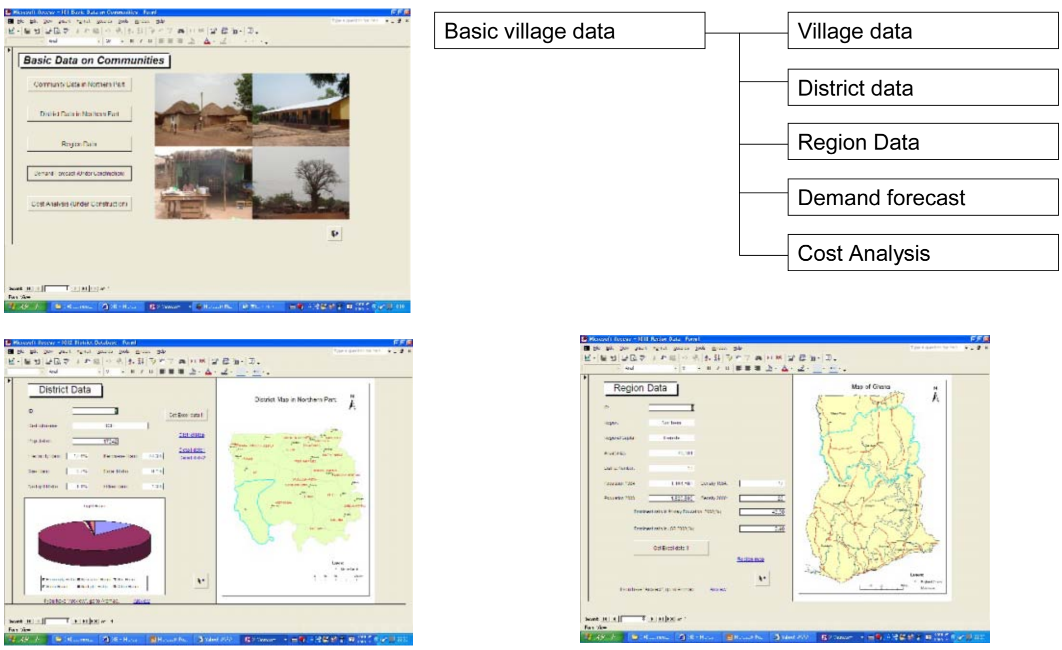


(Source) JICA Study Team

Figure 7.4.1 GIS data base, main screen

(1) Basic community data

The basic community data consist of regional data, district data, and community data, plus the results of the demand forecast and comparison of on- vs. off-grid electrification cost. This component also enables calculation of the on-grid and off-grid electrification costs based on the demand forecast proposed by the Study Team.

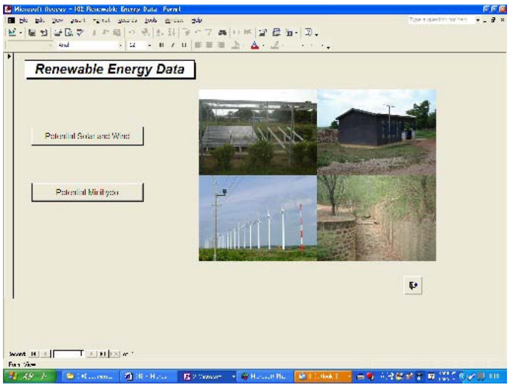


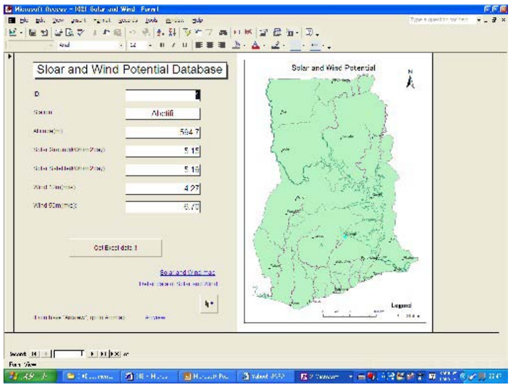
(Source) JICA Study Team

Figure 7.4.2 Basic community data

(2) Renewable energy data

The renewable energy data consist of solar and wind potential data, and hydropower potential data. This component makes it possible to check the potential amounts and sites of such energy by means of photographs and maps.



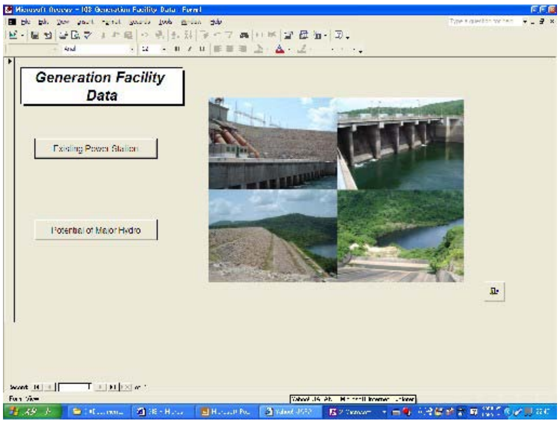


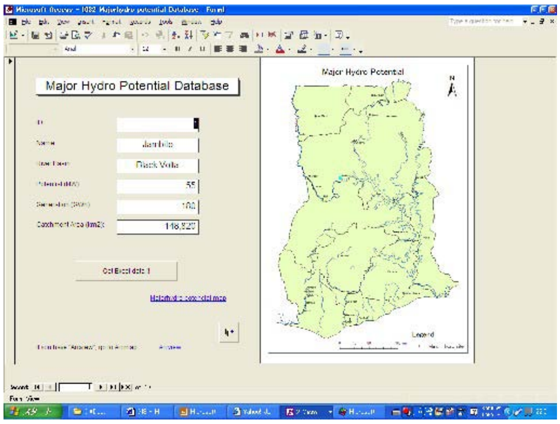
(Source) JICA Study Team

Figure 7.4.3 Renewable energy data

(3) Generation facility data

This component displays basic specifications and location information for existing facilities along with map information.



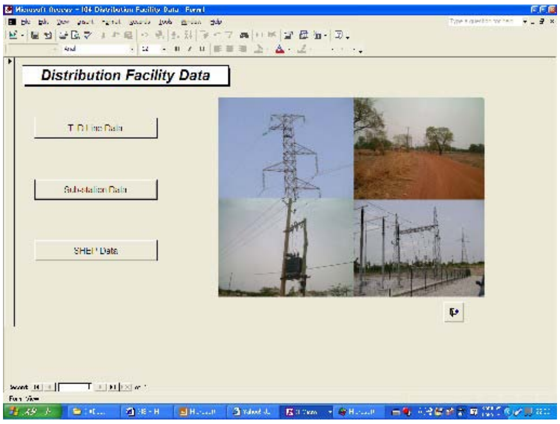


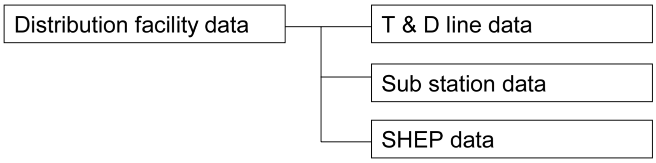
(Source) JICA Study Team

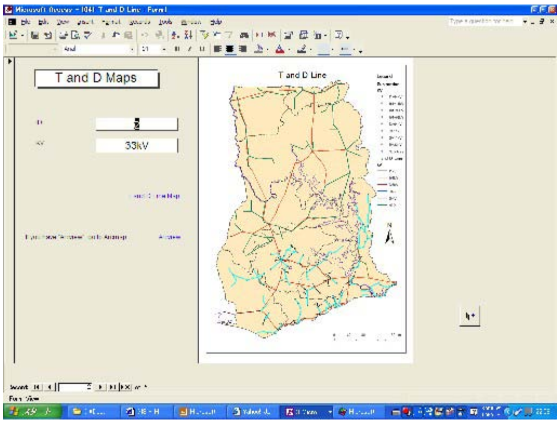
Figure 7.4.4 Generation facility data

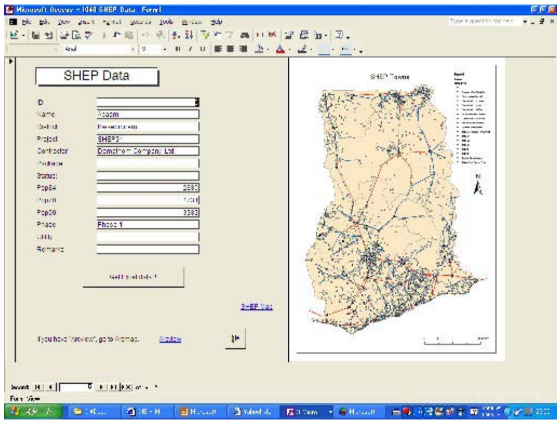
(4) Distribution facility data

The distribution facility data consist of data on transmission and distribution lines as well as substations obtained from the ECG and VRA-NED. They also include SHEP planning data obtained from the MOE.







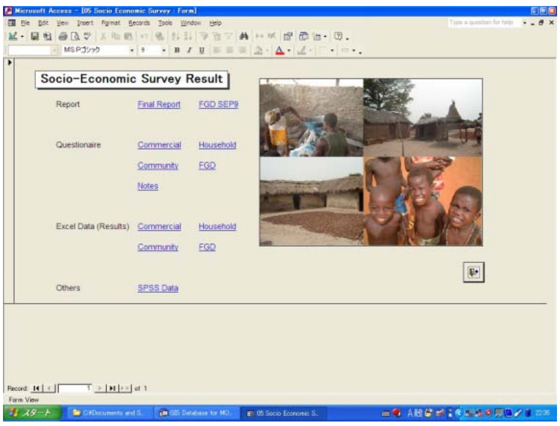


(Source) JICA Study Team

Figure 7.4.5 Distribution facility data

(5) Results of the village socioeconomic study

Users will be able to view the results of the village socioeconomic study implemented from June to August 2005.



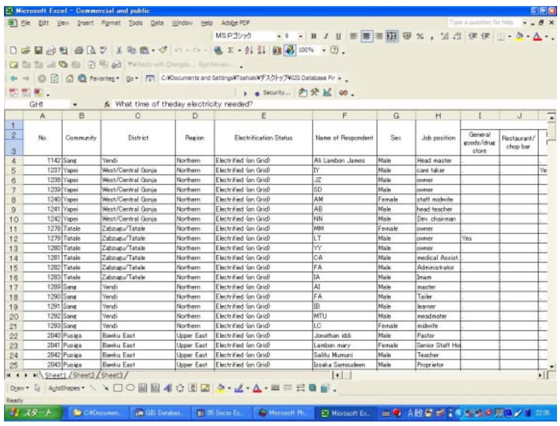
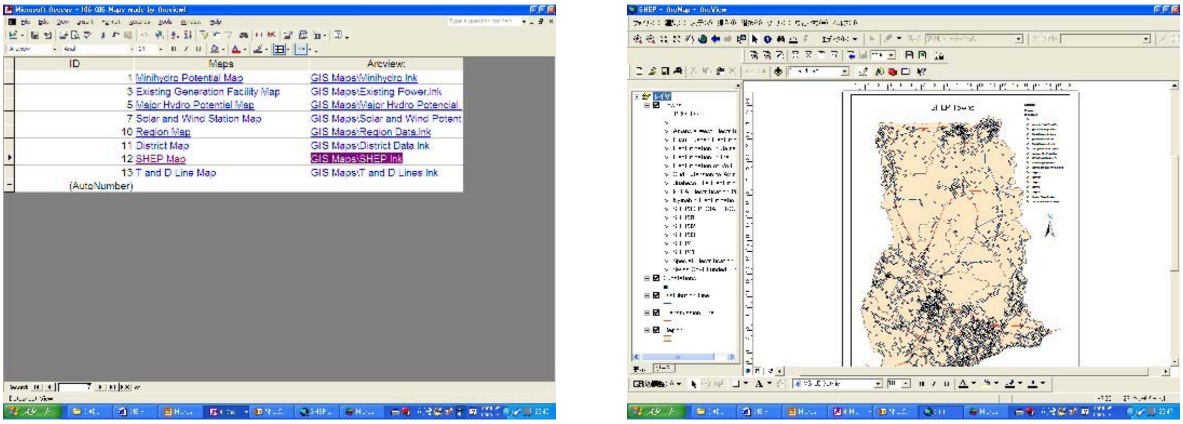


Figure 7.4.6 Socioeconomic data

(6) GIS map

This component enables users to view the GIS maps prepared for this study.



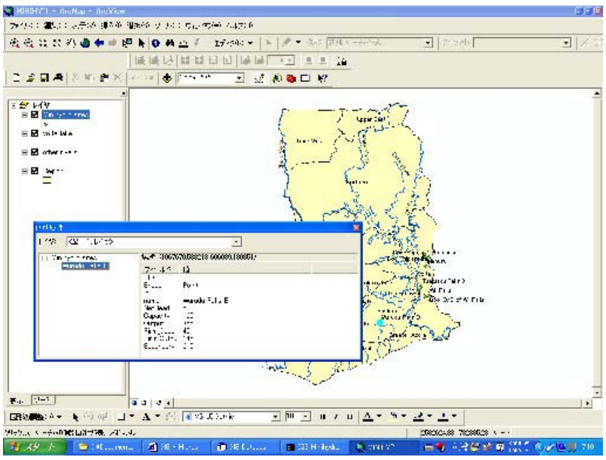
(Source) JICA Study Team

Figure 7.4.7 GIS map

7.4.2 Relationship between Access and Arcview

As noted above, the GIS data base uses Microsoft Access solely for the management and viewing of map information and other types of information. The overall system is constructed so that the counterpart members can use Arcview 9.0 for the preparation and updating of map information.

Users are also able to connect the Microsoft Access data (tabular) to map information by means of Arcview 9.0. Therefore, the management of data within Microsoft Access makes it possible to view the same data with Arcview 9.0.



(Source) JICA Study Team

Figure 7.4.8 Viewing of data with Arcview

7.5 Transfer of technology related to GIS data base

In many developing countries, data bases applying somewhat special software like that in this study end up unused because the counterpart is unable to review data and perform new editing. At the stage of constructing the GIS data base, members of the Study Team repeatedly engaged in discussion with those of the counterpart about the composition and took steps to facilitate their use of it.

To this end, the counterpart members must master the skills for data base preparation themselves. In this connection, the Study Team conducted a three-week program of technical instruction for the GIS data base in the fourth field study (from 29 October to 25 November 2005). On the counterpart side, EC technicians voluntarily participated in the program along with the MOE and RESPRO staff originally scheduled to take part in it.

During this period, while they were being instructed in the requisite technology, the counterpart members prepared the basic GIS/data base themselves. The main areas of technical instruction are shown below. Figure 7.4.1 shows scenes of the instruction.

- Basic operational procedure for software (Arcview 9, Microsoft Access, Microsoft Excel, etc.)
- Procedure for display of map information and input of locational information
- Technique for basic calculations (distance, etc.)

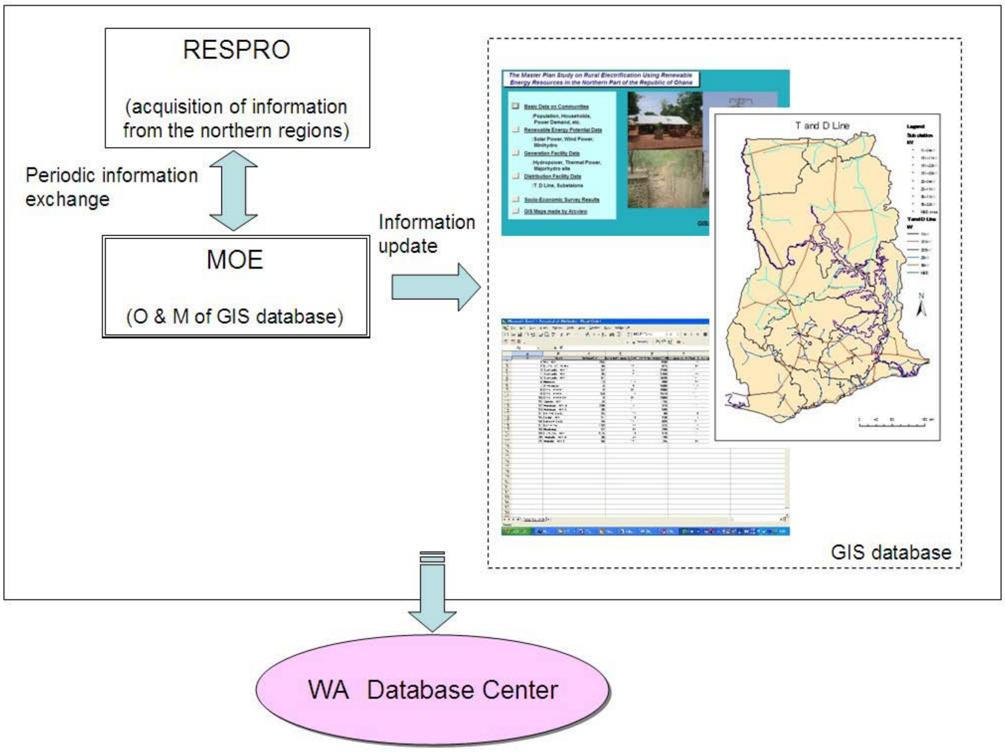
(Photo) JICA Study Team

Figure 7.5.1 Scene of GIS data base instruction

7.6 Setup for GIS data base maintenance and management

The GIS data base prepared in this study must be constantly updated. As such, the counterpart side must perform updating in correspondence with circumstances even after the conclusion of this study, and constantly maintain and manage it so that it always has the latest data reflecting the current situation. For this work, mainly the MOE and RESPRO shall always obtain the latest information from the concerned parties.

Considering extensive use of the system into the future, the construction of a setup for the maintenance and management of GIS data is a crucial task. As the ministry in charge of electrification, the MOE must perform management, updating, and other such work for the data base itself. As for detailed data on the socioeconomic situation in rural communities, the RESPRO could periodically relay information on the northern regions to the MOE. Figure 7.6.1 shows the management setup proposed by the Study Team. The Team also sees a need to consider operation that also takes account of coordination with the data base center scheduled for construction at WA .



(Source) JICA Study Team

Figure 7.6.1 Setup for GIS data base maintenance and management (proposed)

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Appendices

APPENDIX 1- a)

MASTER PLAN STUDY ON RURAL ELECTRIFICATION BY RENEWABLE ENERGY SOURCES IN THE THREE NORTHERN REGIONS OF GHANA

COMMUNITY PROFILES

Date______________________ Enumerator_______________________________

1.1 Community ______________________________________

1.2 District ______________________________________

1.3 Region __________________________________

1.4 Electrification status:
[1] = Un-electrified (proposed for Solar PV)
[2] = Un-electrified (can be electrified on-grid under SHEP)
[3] = Electrified (off-grid-before Dec 2001)
[4] = Electrified (off-grid-before Jan 2002)
[5] = Electrified (On-grid)

1.5 Population ______Male ______Female______

1.6 Approximate number of compounds __________

1.7 Distance from the nearest transmission/distribution line ___________________km

Commercial, Public and Social Facilities

1.8	**Type of Enterprise;**	Approx. No.	This facility Functioning (F)/ Not functioning (NF)	Electrified grid	Electrified PV	Electrified Gen. Set	Not energized
1.8.1	General goods/drug store						
1.8.2	Restaurant/chop bar						
1.8.3	Drinking bar/pito brewing						
1.8.4	Bakery						
1.8.5	Furniture making/ carpentry shop						
1.8.6	Handicraft making						
1.8.7	Tailor/seamstress						
1.8.8	Hair salon or barber shop						
1.8.9	Repair ship						
1.8.10	Grain milling						
1.8.11	Vegetable oil extraction						
1.8.12	Guest house						
1.8.13	Battery charging station						
1.8.14	Others , ______________						
1.9	**Type of Public or Social facility;**	Approx. No.	This facility Functioning (F)/ Not functioning (NF)	Electrified grid	Electrified PV	Electrified Gen. Set	Not energized
1.9.1	Pre/Primary School						
1.9.2	Junior Secondary School						
1.9.3	Senior Secondary School						
1.9.4	Vocational School						
1.9.5	Adult Literacy center						

APPENDIX 1- a)

1.9.6	CHPS compound						
1.9.7	Clinic						
1.9.8	Health center/ health post						
1.9.9	Mechanized water supply system						
1.9.10	Community center						
1.9.11	Governmental office						
1.9.12	Mosque/church						
1.9.13	Telephone services						
1.9.14	Public market						
1.9.15	Vehicle/bus station						
1.9.16	Street lighting						
1.9.17	Others, _______________						

2.0 A chief in the community ?

2.1 Village Organizations, community-based associations and self-help groups in the community

2.2 Recently completed projects or ongoing project in the community

2.3 Level of interest of community members in development activities

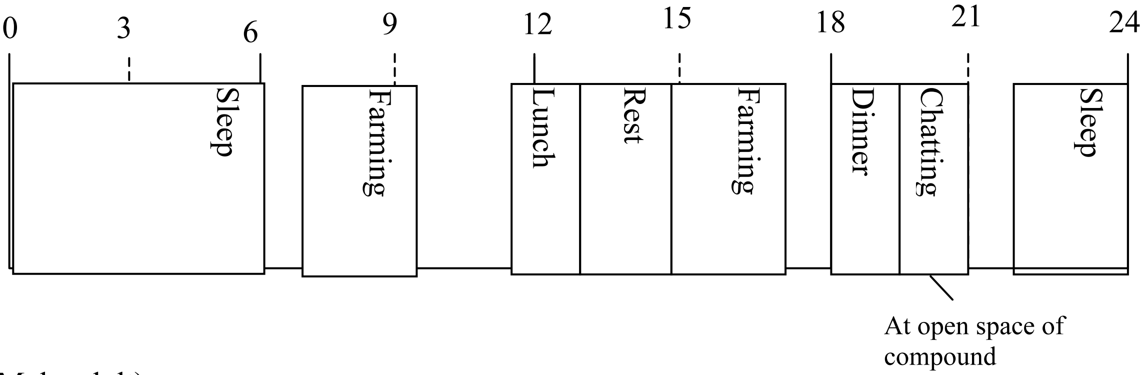
Make general assessment of the ability/interest of the community to connect to electricity and to be able to use electricity

APPENDIX 1- a)

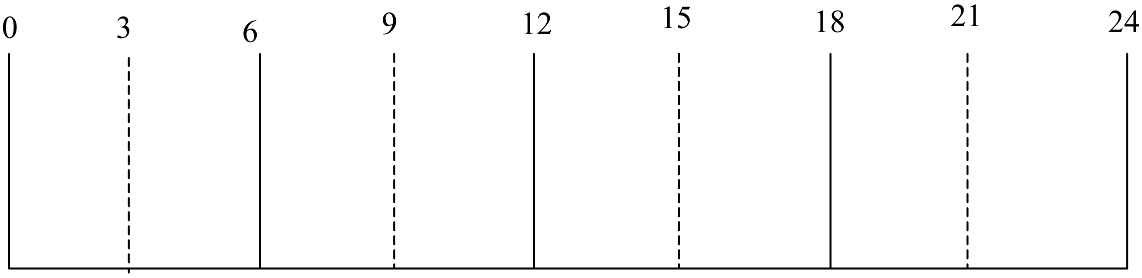
Settlement pattern (*draw rough sketch map below indicating where Houses (Compounds) concentrate or Commercial and Public/Social facilities are located as point of reference):

APPENDIX 1- a)

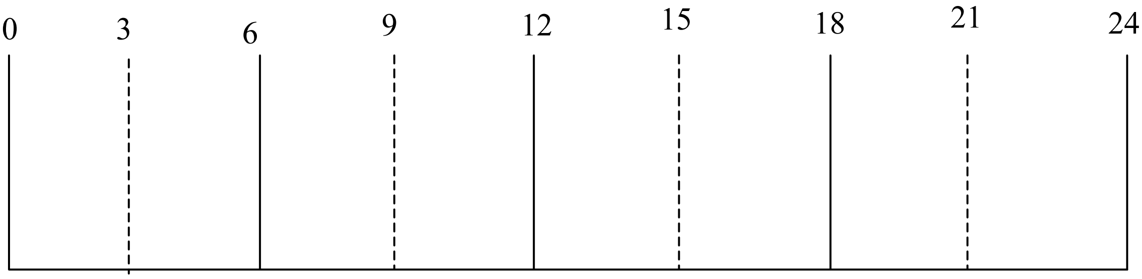
3.2 Daily Activity Map for 1) male adult, 2) female adult, 3) young male, 4) child (Example)



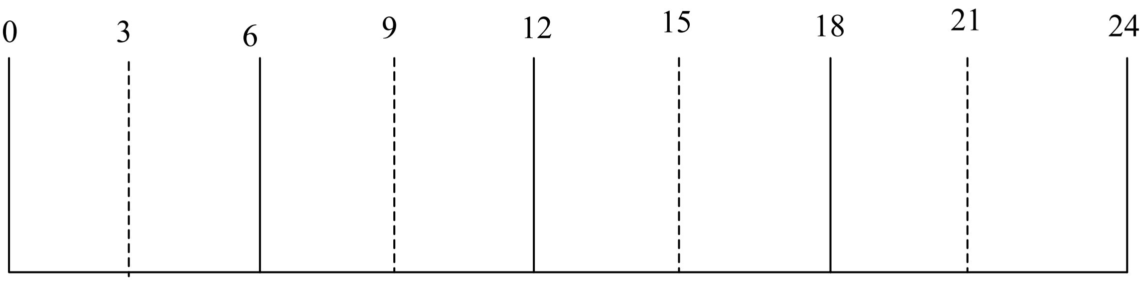
(Male adult)



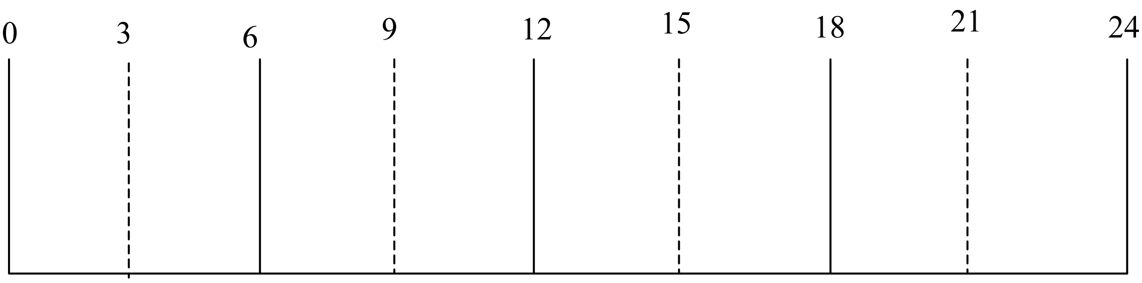
(Female adult)



(Young male)



(Child)



MASTER PLAN STUDY ON RURAL ELECTRIFICATION BY RENEWABLE ENERGY RESOURCES IN THE THREE NORTHERN REGIONS OF GHANA:
Socio-Economic Survey of Sample Communities
Households Questionnaire

Date:	Enumerator:

SECTION 1. HOUSEHOLD IDENTIFICATION

1.1 Community____________________________________ DISTR [ ]

1.2 District____________________________________ REG [ ]

TYPE [ ]

1.3 Region____________________________________

1.4 Electrification status:
[1] = Un-electrified (proposed for Solar PV)
[2] = Un-electrified (can be electrified on-grid under SHEP)
[3] = Electrified (off-grid-before Dec 2001)
[4] = Electrified (off-grid-after Jan 2002)
[5] = Electrified (On-grid)

HNO [ ]

1.5 Household Identification Number

1.6 Respondent Information

Must be household head or Spouse

1.6.1 Respondent's Name:__________________________

1.6.1b Are you household head? [______] [1]-Yes, [2]-No

1.6.2 Gender: [_______] [1]-Male, [2]-Female

1.6.3 Ethnicity [_______]

[1] Dagomba	[5] Gonja	[9] Grushie	[13] Kusasi
[2] Nanumba	[6] Konkomba	[10] Basare	[14] Mossi
[3] Mamprussi	[7] Sissala	[11] Kasena	[15] Ashanti
[4] Wala	[8] Dagao	[12] Builsa	[16] Other

1.7 Number of household members: [______] Male___ Female___

1.8 Number of compound members: [______] Male___ Female___

1.9 Occupation of the household head [______]
Code: [1] = Government official/employee
[2] = Artisan self employed
[3] = Businessman/trader
[4] = Farmer/Fisherman
[5] = Labourer /unskilled worker
[6] =Others, specify _________

1.10 Housing Characteristics

1.10a Construction Material of the House [_____]

[1] =Mud house with thatch roof
[2] = Brick house with corrugated roofing sheets
[3] = Brick house with thatch roof
[4] = Wood
[5]= Mixture Mud & Brick house with thatch roof/roofing sheets [6] = Mud house with mud roof
[7] = Others, specify____

1.10b Single or multiple occupancy _________ [1]-Single, [2]-Multiple

1.10c Type of tenancy enjoyed [______]

[1] = Owner-occupant [4] = Family compound
[2] = Rented [5] = Others, specify ______________________________
[3] = Being occupied for free with consent of owner

1.11 Is any part of your house used for income generating activity or commercial purposes? [_____]
Code: [2] = NO, **go to SECTION 2** [1] = YES, **go to 1.11a**

1.11a If part of the house is used for income generating activity, please indicate type. [_______]
Code: [1] = General goods/drug store
[2] = Restaurant/chop bar
[3] = Drinking bar/pito brewing
[4] = Bakery
[5] = Furniture making/Carpentry shop
[6] = Handicraft making
[7] = Tailor/ seamstress
[8] = Hair salon or barber shop
[9] = Repair shop
[10]= Grain milling
[11] = Vegetable oil extraction
[12] = Guest house
[13] = Others, specify_____________________________

If the responding household is engaged in more than one type of business, enter the one that generates the most income for the household.

SECTION 2. ENERGY ISSUES

ENERGY USE PATTERN

For un-electrified household, (*Regarding Q2.1.1-2.1.5, don't explain the characteristics of the way of electrification to the respondent. After finishing whole questions, you can explain the characteristics)

2.1.1	Do you know the procedures to follow to get connected to the national electricity grid (ie VRA-NED supply) ? [1]-Yes, [2]-No	
2.1.2	Do you know about SHEP procedures for getting electricity? [1]-Yes, [2]-No	
2.1.3	Do you know about Solar Home System? [1]-Yes, [2]-No	
2.1.4	Do you know Battery charging system for getting electricity? [1]-Yes, [2]-No	
2.1.5	Now that you know about the main options for electrification, which of the systems would you prefer if your household were to be given electricity? [1]=On-grid [2]= Solar Home System [3]= Battery charging system, [4] I don't know	
	And why?	

For both electrified and un-electrified household

2.2 What is the main source of energy for lighting? (Rank as 1, 2, 3, in order of importance)

2.2.1 Electricity from the National grid __
2.2.2 Electricity from own generator __
2.2.3 Kerosene lantern __
2.2.4 Candles __
2.2.5 Dry cell batteries __
2.2.6 Solar Home System __
2.2.7 Battery Charging system __
2.2.8 Solar Lantern __
2.2.9 Others, specify___________________________

2.3 What is the monthly cost of energy for lightning and electricity for electric appliances (Specify cedis)

	A: Initial cost	B Running cost
2.3.1 Electricity from the National grid	________________	________________
2.3.2 Electricity from own generator	________________	________________
2.3.3 Kerosene lantern	________________	________________
2.3.4 Candles	________________	________________
2.3.5 Dry cell batteries	________________	________________
2.3.6 Solar Home System	________________	________________
2.3.7. Battery Charging system		________________
2.2.8 Solar Lantern	________________	
2.2.9 Others, specify_____________	________________	________________

2.4. Do you own and use any of these electrical appliances in your home:

No	Item	Qty	Estimate Price (specify cedi)	Total Value (specify cedis)	Hours of use /day	Way of electrification: On-grid/ Solar PV/ Other Sources (generator, battery, etc)
1	TV (colour) –small					
2	TV (colour)- big					
3	TV (black & white)					
4	VCR/VCD					
5	Radio					
6	Stereo (including Radio)					
7	Refrigerator-small					
8	Refrigerator-big					
9	Freezer-small					
10	Freezer-big					
11	Cell phone					
12	Lights (incandescent)					
13	Lights (fluorescent)					
14	Fan					
15	Flash light					
16	Sewing Machine					
17	Electric Iron					
18	Coil heater					
19	Table top single burner electric cooker					
20	4/ burner electric cooker					
21	Other, specify___________					
22	specify___________					

2.5. In addition to the electric appliances you mentioned above, which electric appliances do you want to own and use in the next. Pick up three electric appliances in high priority and describe why.

No	Item	Why
1	TV (colour)-small	
2	TV (colour)-big	
3	TV (black & white)	
4	VCR/VCD	
5	Radio	
6	Stereo (including Radio)	
7	Refrigerator-small	
8	Refrigerator-big	
9	Freezer-small	
10	Freezer-big	
11	Cell phone	
12	Lights (incandescent)	
13	Lights (fluorescent)	
14	Fan	
15	Flash light	
16	Sewing Machine	
17	Electric Iron	
18	Coil heater	
19	Table top single burner electric cooker	
20	4/ burner electric cooker	
21	Other, specify_________________________	
22	specify_________________________	

For electrified household

2.6.1	What year did you connect to on-grid system (e.g. Jan. 2000)	
2.6.2	What year did you acquire your PV system (e.g. Jan. 2000)	
	How did you acquire it? Code: [1] = Loan [2] = Cash payment [3] = Rented [4] = Through RESPRO project, fee for service [5] = Through New Energy project [6].= Other donor project [7] = Others, specify _______________________	

2.7 How would you rate the quality of service from the grid utility company (Very good=1/ Good=2/ Fair=3/ Poor=4)

Rating Reason

2.7.1 Reliability __
____

2.7.2 Cost __
____

2.7.3 Response time to faults __
____

2.7.4 Billing and collection __
____

2.7.5 Other customer services , explain
____

2.8 How would you rate the quality of service from the Solar PV fee-for-service provider? (Very good=1/ Good=2/ Fair=3/ Poor=4)

2.8.1 Reliability __
____

2.8.2 Cost __
____

2.8.3 Response time to faults __
____

2.8.4 Billing and collection __
____

2.8.5 Other customer services, explain
____

2.8b Has your electricity service ever been disconnected, Y___N___ If no, Reason____________________________

2.9 If you use a PV system, have you or a member of your household been taught about how to carry out routine checks on the system. [______] [1]-Yes, [2]-No

PREFERENCE AND WILLINGNESS TO PAY FOR ELECTRICITY (*no matter On-grid or Solar PV)

For un-electrified household.

2.10	What time of the day do you think electricity is most needed? Code: [1] = Whole day (24 hours) [4] = From 6 p.m. until 10 p.m [2] = Daytime only (from 6 a.m. to 6 p.m.). [5] = From 10 p.m. to 6 a.m. [3] = Nighttime only (from 6 p.m. to 6 a.m.) [6] = Others, specify ______________	
2.11	What type of payment would you prefer? Code: [1] = Quarterly [4] = Others, specify _____________________ [2] = Monthly [3] = Bi-monthly	
2.12	According to what you have told me, your household currently spends about ______ cedis per month for lighting (add up all expenditure for lighting fuel from Q2.3) to provide energy to your household. If electricity were available in your area, how much are you willing to pay? Code: [1] = Same as current spending for fuels [2] = More than current spending fuels, **go to 2.13** [3] = Lower than current spending for fuels, **go to 2.14**	
2.13	You said you are willing to pay more than the current energy expenditure for lightning, please tell me exactly how much you are willing to pay per month?	
2.14	You said you are willing to pay less than the current energy expenditure for lightning, please tell me exactly how much you are willing to pay per month?	
2.15	What mechanism of payment do you think is most convenient? Code: [1] = Through banks [4] = Through pre-paid meters [2] = With a collector [5] = Others, specify _________ [3] = Pay to utility providing service	

APPENDIX 1- b)

SECTION 3. HOUSEHOLD CONDITION

INCOME & EMPLOYMENT

3.1 Income from Agricultural Activities

3.1.1 What is the total area of your farm in acres? ______________________
3.1.2 What is the main type of irrigation in your farm? _____

[1] = Rainfed	[4] = Tubed/piped well
[2] = Open well	[5] = Gravity water/Irrigation
[3] = Stream, river, lake	[6] = Others, specify ____________________

3.1.3 Income by Type of Crops Planted for the Past Twelve Months

Type of crop/ livestock	Harvest in bags (maxi) other unit	Estimated value	Own consumption	Amount sold
Yam				
Cassava				
Grain				
Rice				
Onion				
Cotton				
Vegetable				
Groundnut other legumes				
Fruit trees				
Sheep and goats				
Guinea fowls and fowls				
Cows				
Others, specify________				

3.2. Income from Employment

3.2.1 Type of employment : Permanent___ Casual/seasonal
3.2.2 Monthly gross wages__________________
3.2.3 Earnings in-kind _____________________
3.2.4 Other Income (specify and estimate annual)________________

HOUSEHOLD'S DESIRE FOR SERVICES

3.3 Which of the following services would you like to have first, second, third, etc.?
(Rank the services listed from 1, 2, etc.)

1	House ownership	
2	Good educational services and facilities	
3	Public transportation	
4	System for getting clean water	
5	Irrigation	
6	Roads, bridges, and other infrastructure	
7	Good electricity	
8	Good health services and facilities	
9	Latrines	
10	Job Opportunities	
11	Others, specify _________________________	

Why? (especially, the reason for the top 3)

APPENDIX 1- c)

MASTER PLAN STUDY ON RURAL ELECTRIFICATION BY RENEWABLE ENERGY RESOURCES IN THE THREE NORTHERN REGIONS OF GHANA

Socio-Economic Survey of Sample Communities:
Commercial, Public and Social Facilities Questionnaire

Date______________________ Enumerator_______________________________

SECTION1: COMMUNITY INFORMATION

1.1 Community _______________________________________

1.2 District_______________________________________

1.3 Region ___________________________________

1.4 Electrification status:
[1] = Un-electrified (proposed for Solar PV)
[2] = Un-electrified (can be electrified on-grid under SHEP)
[3] = Electrified (off-grid-before Dec 2001)
[4] = Electrified (off-grid-after Jan 2002)
[5] = Electrified (On-grid)

SECTION2: GENERAL INFORMATION ABOUT RESPONDENT

2.1	Name of respondent	
2.1a	Sex	
2.1b	Job position	
2.2	**Type of Enterprise;**	
2.2.1	General goods/drug store	
2.2.2	Restaurant/chop bar	
2.2.3	Drinking bar/pito brewing	
2.2.4	Bakery	
2.2.5	Furniture making/ carpentry shop	
2.2.6	Handicraft making	
2.2.7	Tailor/seamstress	
2.2.8	Hair salon or barber shop	
2.2.9	Repair ship	
2.2.10	Grain milling	
2.2.11	Vegetable oil extraction	
2.2.12	Guest house	
2.2.13	Battery charging station	
2.2.14	Others	
2.3	**Type of Public or Social facility;**	
2.3.1	Pre/Primary School	
2.3.2	Junior Secondary School	
2.3.3	Senior Secondary School	
2.3.4	Vocational School	
2.3.5	Adult Literacy center	
2.3.6	CHPS compound	
2.3.7	Clinic	

APPENDIX 1- c)

2.3.8	Health center/ health post	
2.3.9	Mechanized water supply system	
2.3.10	Community center	
2.3.11	Governmental office	
2.3.12	Mosque/church	
2.3.13	Telephone services	
2.3.14	Public market	
2.3.15	Vehicle/bus station	
2.3.16	Street lighting	
2.3.17	Others	

2.5 Daily sales and profit (where applicable. Specify cedi or)
sales ___________________ profit ___________________

2.6 Daily attendance/visits of facility (where applicable)________________________

2.7 When was this facility established___________________________

SECTION3: ENERGY/ELECTRICITY SERVICES

<u>For both electrified and un-electrified facility</u>

3.1 What is the main source of energy for lighting? (Rank as 1, 2, 3, in order of importance)

3.1.1 Electricity from the National grid __
3.1.2 Electricity from own generator __
3.1.3 Kerosene lantern __
3.1.4 Candles __
3.1.5 Dry cell batteries __
3.1.6 Solar Home System __
3.1.7 Battery Charging system __
3.1.8 Solar Lantern __
3.1.9 Others, specify____________________________

3.2 What is the monthly cost of energy for lightning and electricity for electric appliances (<u>Specify cedis)</u>

	A: Initial cost	B Running cost
3.2.1 Electricity from the National grid	______________________	______________________
3.2.2 Electricity from own generator	______________________	______________________
3.2.3 Kerosene lantern	______________________	______________________
3.2.4 Candles	______________________	______________________
3.2.5 Dry cell batteries	______________________	______________________
3.2.6 Solar Home System	______________________	______________________
3.2.7. Battery Charging system	______________________	______________________
3.2.8 Solar Lantern	______________________	______________________
3.2.9 Others, specify	______________________	______________________

APPENDIX 1- c)

3.3 Which electrical appliances do you use in this facility

	Electric Appliance	Qty	Hours of use /day	**Way of electrification:** On-grid/ Solar PV/ Other Sources (generator, battery, etc)
3.3.1	TV (colour)-small			
3.3.2	TV (colour)-big			
3.3.3	TV (black & white)			
3.3.4	VCR/VCD			
3.3.5	Radio			
3.3.6	Stereo (including Radio)			
3.3.7	Refrigerator-small			
3.3.8	Refrigerator-big			
3.3.9	Freezer-small			
3.3.10	Freezer-big			
3.3.11	Lights (incandescent)			
3.3.12	Lights (fluorescent)			
3.3.13	Fan			
3.3.14	Sewing Machine			
3.3.15	Electric Iron			
3.3.16	Air Conditioner			
3.3.17	Electric motor			
3.3.18	Computer/Printer			
3.3.19	Telephone/Fax machine			
3.3.20	Power tools			
3.3.21	Irrigation			
3.3.22	Hair dryers			
3.3.23	Water pump			
3.3.24	Microphone/Speakers			
3.3.25	Others			

3.4 In what ways has electricity (*no matter on-grid or Solar PV) improved the operation of your enterprise/facility/services

	Impact Areas	Vast Improvement	A little improvement	No improvement
3.4.1	Lower cost of production			
3.4.2	Higher sales/Higher profitability			
3.4.3	Higher production output			
3.4.4	Less effort and drudgery			
3.4.5	Better quality products and services			
3.4.6	Academic performance			
3.4.7	Teaching and learning environment			
3.4.8	Higher attendance/use of facility			

APPENDIX 1- c)

4.1 Is this premises connected to the national grid. _____Y/N
If No, **go to Q 4.8**

4.2 When was this premises connected to the electricity system__________

4.3 How would you rate the quality of service from the grid utility company
(Very good=1/Good=2/ Fair=3/ Poor=4)

		Rating	Reason
4.3.1	Reliability		
4.3.2	Cost		
4.3.3	Response time to faults		
4.3.4	Billing and collection		
4.3.5	Other customer services		

4.4 Have you received information on how to use electricity productively and efficiently from the electricity company or anyone else. Yes______ No_______

4.5 Does the cost and reliability of grid electricity service have a serious effect on the profitability of your business, if yes explain

---

4.6.1 What is your monthly cost of grid electricity __________________

4.6.2 Who pays the grid electricity bill at the end of the month ________

4.6.3 Has your electricity supply ever been disconnected for late payment ______

4.7 If not connected to the electricity grid, what is the reason for not connecting?

4.7.1 High connection cost ____________
4.7.2 High monthly tariff ____________
4.7.3 High cost of wiring house ____________
4.7.4 No electricity network in the area ____________
4.7.5 Have a solar PV system ____________
4.7.6 Other reason, specify____

5.1 Are you receiving electricity from a solar PV system _____Y/N
If No, **go to Q 6.1**

5.2 What type of Solar PV System?

5.2.1 Battery Charging System _____________
5.2.2 Solar Home System (less than 50Watts) _____________
5.2.3 Solar Home System (50Watt-100 Watts) _____________
5.2.4 Solar Home System (>100 Watts) _____________
5.2.5 Water pumping system _____________
5.2.6 Vaccine refrigeration system _____________
5.2.7 Radio communication system _____________
5.2.8 Street Lighting system _____________

APPENDIX 1- c)

5.3 How did you acquire the Solar PV System?________

Code: [1] = Loan
[2] = Cash payment
[3] = Rented
[4] = Through RESPRO project, fee for service
[5] = Through New Energy project
[6] = Other donor project
[7] = Others, specify ______________________

5.4 What maintenance arrangement is in place for your PV system?

Code: [1] = None
[2] = Self maintenance
[3] = Local Technician
[4] = Solar Technician

5.5 How would you rate the quality of service from the Solar PV fee-for-service provider?
(Very good=1/ Good=2/ Fair=3/ Poor=4)

		Rating	Reason
5.5.1	Reliability		
5.5.2	Cost		
5.5.3	Response time to faults		
5.5.4	Billing and collection		
5.5.5	Other customer services		

5.6 Have you or a member of your household been taught about how to carry out routine checks on the system. . Yes______ No_______

5.7 Does the cost and reliability of Solar PV fee-for-service service have a serious effect on the profitability of your business, if yes explain

---

5.8.1 What is your monthly cost of electricity from Solar PV fee-for-service __________________

5.8.2 Who pays the Solar PV electricity bill at the end of the month ________

5.8.3 Has your Solar PV electricity system ever been disconnected for late payment ______

APPENDIX 1- c)

For un-electrified facility.(*commercial facility only. If public or social facilities, **go to 7.1**)

6.1	What time of the day do you think electricity is most needed? Code: [1] = Whole day (24 hours) [4] = From 6 p.m. until 10 p.m [2] = Daytime only (from 6 a.m. to 6 p.m.). [5] = From 10 p.m. to 6 a.m. [3] = Nighttime only (from 6 p.m. to 6 a.m.) [6] = Others, specify ____________	
6.2	What type of payment would you prefer? Code: [1] = Quarterly [4] = Others, specify ____________________ [2] = Monthly [3] = Bi-monthly	
6.3	According to what you have told me, your household currently spends about ______ cedis per month for lighting (add up all expenditure for lighting fuel from Q3.2) to provide energy to your household. If electricity were available in your area, how much are you willing to pay? Code: [1] = Same as current spending for fuels [2] = More than current spending fuels, **go to 6.4** [3] = Lower than current spending for fuels, **go to 6.5**	
6.4	You said you are willing to pay more than the current energy expenditure for lightning, please tell me exactly how much you are willing to pay per month?	
6.5	You said you are willing to pay less than the current energy expenditure for lightning, please tell me exactly how much you are willing to pay per month?	
6.6	What mechanism of payment do you think is most convenient? Code: [1] = Through banks [4] = Through pre-paid meters [2] = With a collector [5] = Others, specify _________ [3] = Pay to utility providing service	

For both electrified and un-electrified facility

7.1 Are there any expectations of electrification that are not being met presently, Explain

____
____

7.2 What improvements do you expect from the electricity service to enhance your business further

____
____

APPENDIX 1- c)

SECTION3: OTHER ISSUES/CONCERNS

8.1 What type of employment is being created by this enterprise/ public or social service ?

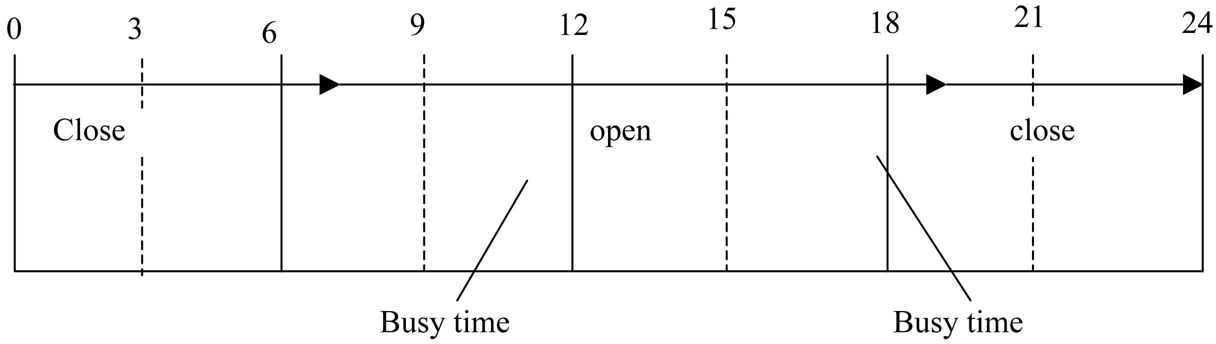
a) 1-2 fulltime,
b)>2 fulltime,
c) 1-2 par time,
d)>2 par time
e) other

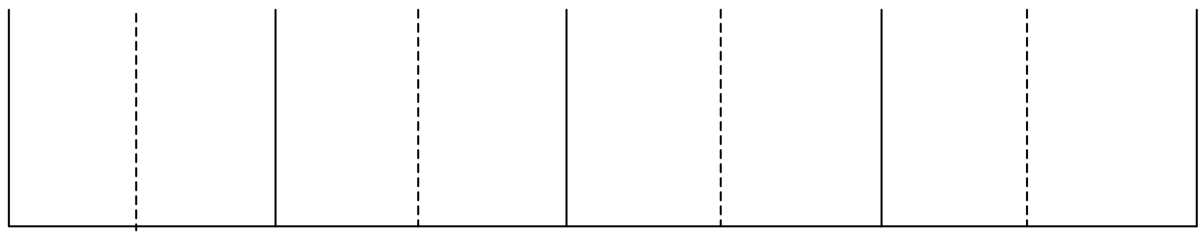
8.2 What are the constraints to further expansion of your business

	Constraints to business expansion	Rank (top 3 constraints only)
5.2.1	Lack of capital/credit	
5.2.2	Inadequate market size	
5.2.3	Inadequate electricity supply	
5.2.4	Other (please specify)	

Daily Operation Pattern

(Example)





APPENDIX 1-d)

MASTER PLAN STUDY ON RURAL ELECTRIFICATION BY RENEWABLE ENERGY SOURCES IN THE THREE NORTHERN REGIONS OF GHANA

Socio-Economic Survey of Sample Communities

FOCUS GROUP DISCUSSION GUIDE

1. Objectives:

1.1 Draw insights on the community's perceptions of quality of service from existing electricity services, expectations, needs, and demands pertaining to electrification future electrification programs.

1.2 Gauge the community's absorptive capacity to maximize use of electricity for their socio-economic development

2. Participants:

FGD will be administered to a group of 8 -10 people representing groupings that will indicate possible differences in terms of socioeconomic contexts. Representations will be any of the following:

1. Chief or village head
2. Teacher or health worker
3. Assemblyman or woman
4. Unit committee member
5. Women's representative
6. Individual employed in farming activity
7. Individual employed in non-farming activity
8. Member of water and sanitation committee
9. Facilitator or member of adult literacy group
10. Religious leader
11. Village volunteer, eg Red cross, guinea-worm, or fire volunteers

3. Contents of discussion:

3.1 Introduction of the background and purpose of the survey.

General Information

3.2 Approximate population

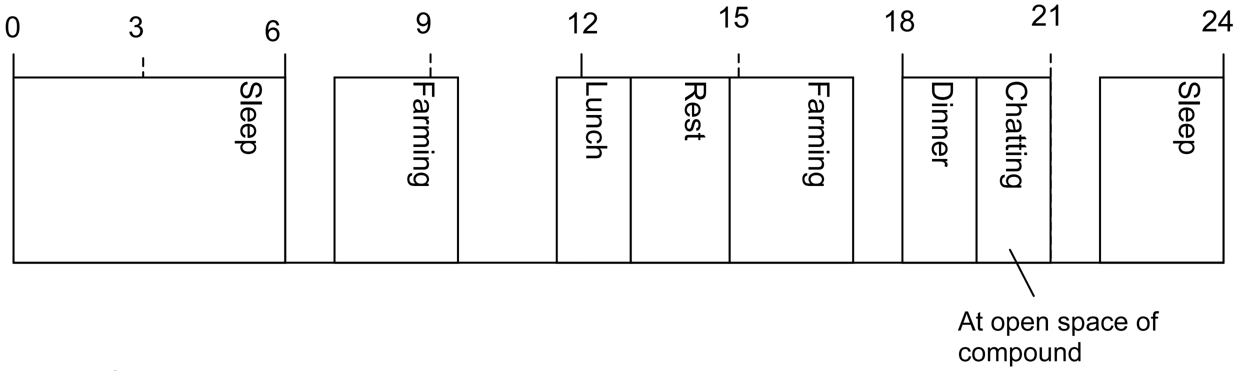
3.3 Approximate Number of compounds

3.4 Settlement Pattern

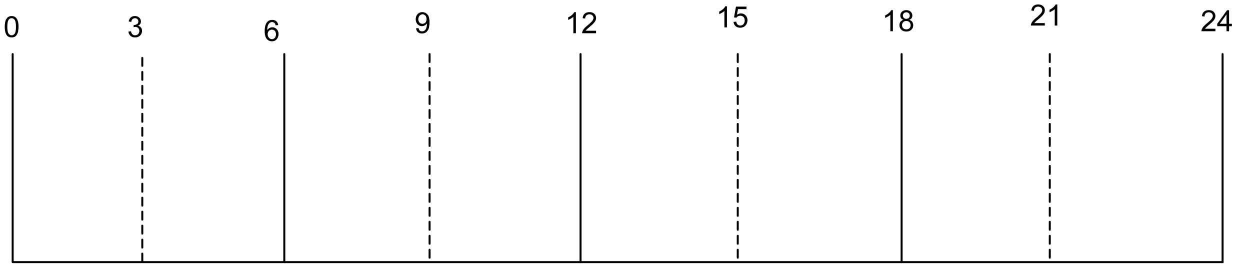
APPENDIX 1-d)

3.5 Daily Activity Map for 1) male adult, 2) female adult, 3) young male, 4) child

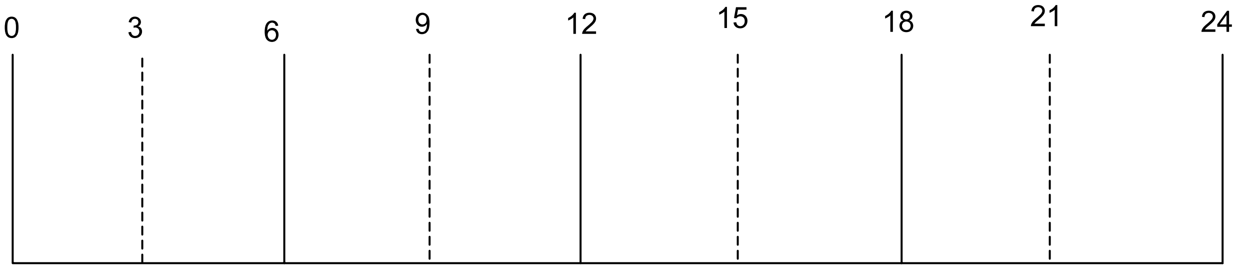
(Example)



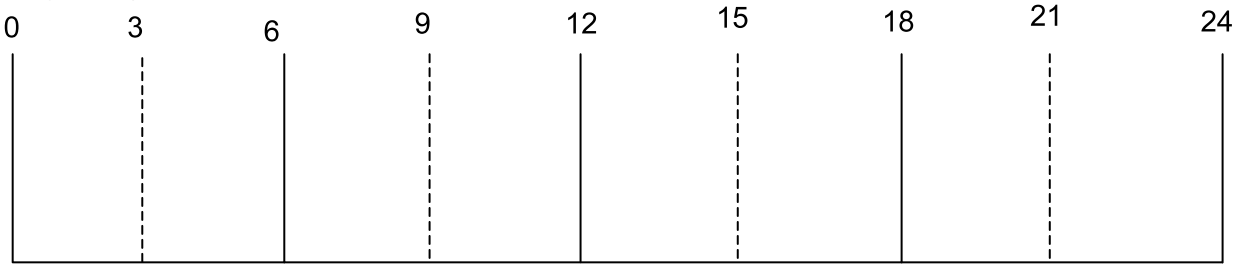
(Male Adult)



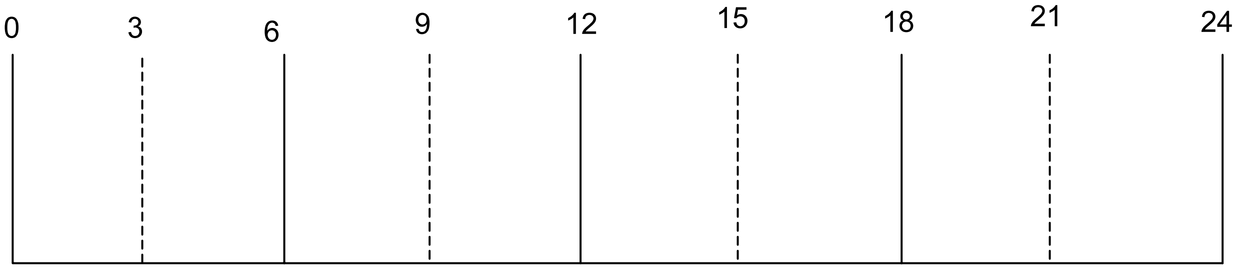
(Female Adult)



(Young male)



(Child)



APPENDIX 1-d)

3.6 Migration pattern – which is more pervasive, please check::

Trend	Gender		Age group	
	Male	Female	Youth	Adult
___Out – migration				
___In - migration				

3.7 Enquire about community Commercial, Public and Social facilities (facilitator should probe into the existence, and functionality of all these facilities. Where some services are functioning unsatisfactorily, enquire into the reasons).

3.8 Are there any village organizations, community-based associations or self help groups, name them and describe what they do.

3.9 Are there any recently completed projects or ongoing project in the community

3.10 Which of the following services would you like to have first, second, third, etc.?
(Rank the services listed from 1, 2, etc.)

		Male adult	Female adult	Young
1	House ownership			
2	Good educational services and facilities			
3	Public transportation			
4	System for getting clean water			
5	Irrigation			
6	Roads, bridges, and other infrastructure			
7	Good electricity			
8	Good health services and facilities			
9	Latrines			
10	Job Opportunity			
11	Others, specify ________________________			

Why? - describe the reasons for and situations of top three services? (for Male adult)

Why? - describe the reasons for and situations of top three services? (for Female adult)

Why? - describe the reasons for and situations of top three services? (for Young)

APPENDIX 1-d)

Electrification Issues

a) For electrified communities

3.11 For electrified communities the facilitator should enquire into when and how the service was delivered to the community. What efforts did the community have to make towards the connection, and what monetary or other contribution in kind was made.

3.12 Who provided the low voltage distribution poles used in the electrification project.

3.13 Were any inhabitants of the community employed to work for the electrification contractor?

3.14 What problems do you encounter concerning present distribution and use of electricity?

Should include problems on :

- distribution,
- utilization,
- ability to pay, mode of payment of bills,
- maintenance,
- Safety and security of equipment,
- How do you think they can be solved?

3.15 What proportion of households are connected to the electricity service, probe for reasons of low connection rate.

3.16 What are the impacts (both positive and negative) of electrification at the household and community levels? **(Facilitator should probe which sector benefited or suffered most and why)**

3.17 Do some people in the community possess television sets/radios, and what is the quality of reception. How important is your radio/TV in your daily life?

3.18 Where is it possible to buy electric appliances?

3.19 How do you think you can contribute to the better management of electrification system in your area? (**Probe responses and categorize later**)

b). For Non-electrified community,

3.20 Why are you still not electrified?

3.21 Have you heard about SHEP. (Y/N). If yes, do you know how your community can get electrified through SHEP?______

3.22 From where did you get your information about SHEP?

3.23 Has this community initiated any action to get access to electricity through any of the on-going electrification programmes, such as SHEP or Solar Programme from RESPRO or other NGO.

3.24 Electrification is currently being provided to communities by means of solar pv or grid connection. If you had a choice now, which option would you choose for your community?, Why. **(* Facilitator should not explain the characteristics of the way of electrification to the participant in this stage. At the end of discussion, you can explain the characteristics)**

3.25 When this community gets electrified what needs do you think will be met by electrification? Or what are your perceived benefits from electrification? **(Encourage participants to express their own their perceived benefits from electrification, even if this may result in only a partial list of the full benefits of electrification to the community due to lack of awareness of the full benefits of electricity)**

3.26 What are your perceived problems from electrification?

3.27 Electricity like any other fuel is not free, How much are you willing to pay for electricity per month? Use bidding game to establish range.

APPENDIX 2- a)

Technical Standard for Off-grid Photovoltaic System

Draft

Scope of this draft : Since technologies are developed day by day, these standards do not specify very details of technical specifications to avoid limiting development of technologies. Simple and practical minimum requirements are described.

Abbreviations

AC	Alternate Current
BCS	Battery Charging Station
CCFL	Cold Cathode Fluorescent Light
CFL	Compact Fluorescent Light
DC	Direct Current
FL	Fluorescent Light (conventional type)
HVD	High Voltage Disconnect
HVR	High Voltage Reconnect
IEC	International Electro technical Commission
Ipm	Peak power current (Maximum power current
Isc	Short circuit current
LED	Light-Emitting Diode
LVD	Low Voltage Disconnect
LVR	Low Voltage Reconnect
PTC(PPTC)	Polymeric Positive Temperature Coefficient
PWM	Pulse Width Modulation
STC	Standard Test Conditions (STC) as defined in IEC61215 and IEC60904-3.
SHS	Solar Home System
Vpm	Peak power voltage (Maximum power voltage)
Voc	Open circuit voltage
Wp	Peak power (Maximum power, Watt peak)

APPENDIX 2- a)

References

IEC60896-1 Stationary lead-acid batteries – General requirements and method of test – Vented types

IEC60896-2 Stationary lead-acid batteries – General requirements and method of test – Valve regulated types

IEC60904-1 Photovoltaic devices-Measurement of photovoltaic current-voltage characteristics

IEC60904-2 Photovoltaic devices-Requirement for reference solar cells

IEC60904-3 Photovoltaic devices – Measurement principals for terrestrial photovoltaic(PV) solar devices with reference spectral irradiance data

IEC60904-8 Photovoltaic devices-Guidance for the measurement of a photovoltaic (PV) devices

IEC60904-8 Photovoltaic devices-Solar simulator performance requirement

IEC61173 Overvoltage protection for photovoltaic (PV) power generating systems-Guide

IEC61194 Characteristic parameters of stand-alone photovoltaic (PV) systems

IEC61277 Terrestrial photovoltaic (PV) power generating systems – General and Guide

IEC61215 Crystalline silicon terrestrial photovoltaic(PV) modules – Design qualification and type approval

IEC61427 Secondary cells and batteries for photovoltaic energy systems (PVES)-General requirements and methods

IEC61836 Solar photovoltaic energy systems-Terms and symbols

The off-grid photovoltaic systems include SHS, clinic, school, BCS, and other systems. These systems use 12VDC PV modules and Batteries.

APPENDIX 2- a)

1. PV modules

1.1. PV modules shall comply with the IEC publication about PV modules. (i.e.IEC61215)

1.2. Vpm shall be more than 16V at STC in 12V-system.

1.3. Each PV module or each PV array shall have a bypass diode.

1.4. PV module shall be equipped with a waterproof junction box.

1.5. The PV modules shall be framed with material of corrosion resistance such as aluminum frame (super straight structure) in such a way as to allow secure connection to the PV array mounting structure.

1.6. PV array shall consist of identical PV modules that could be replaceable.

1.7. A blocking diode shall be used for each parallel connection of PV array.

1.8. Each PV module shall have a label with the following information:
  a) Manufacturer's or Installer's name and address
  b) Model No.
  c) Serial number
  d) Ratings: Wp, Ipm, Vpm, Isc, Voc at STC
  e) Date of manufacture (month and year) or installation date.

1.9. Warranty period: Must be disclosed in warranty period. Expected Period is 10 years.

2. Charge controllers

2.1. Following functions shall be available on each charge controller.
  a) Charging contrrol : PWM charging control with overcharge and over discharge protection.
  b) Indication: charging status, battery status (low voltage, low voltage disconnect, etc.)

2.2. Following circuit protections shall be available whith each charge controller:
  a) Short circuit protection
  b) Reverse polarity protection
  c) Reverse current leakage prevention from battery to modules
  d) Surge protection

2.3. Self-consumption shall be below 100mA or 1% of rated capacity whichever in smaller.

2.4. The voltage drop within charge controller (PV to battery and battery to load) shall not exceed 0.6V at rated current.

2.5. Coating to prevent corrosion shall be applied for printed circuit board.

2.6. The following technical information shall be provided:
  a) Charging control algorithm
  b) Set point voltages at LVD, LVR, HVD and HVR
  c) Kinds of protections : short circuit protection, surge protection, etc.
  d) Operations : equalizing, gassing for vented type battery, etc.
  e) Suitable battery type : vented type only, vented or sealed type selectable, sealed type only

2.7. Each charge controller shall have a label with the following information:

  a) Manufacturer's or Installer's name and address
  b) Model No.
  c) Serial number
  d) Capacity
  e) Date of manufacture (month and year) or installation date.

2.8. Warranty period: Minimum 1 years.

APPENDIX 2- a)

3. Batteries

3.1. Batteries shall be deep cycle vented or sealed (valve regulated) type.

3.2. Batteries shall comply with IEC60896-1 or IEC60896-2.

3.3. The following technical information shall be provided:
- a) Rated capacity with indications of several discharge rates (at least C/20 discharge rate based on IEC60896-1 or IEC60896-2)
- b) Cycle life at several depth of discharge (at least 30% depth of discharge based on IEC60896-1 or IEC60896-2)
- c) Self-discharge rate per month
- d) Maximum charging voltage (cycling and floating)
- e) Final voltage

3.4. Terminals shall be lug (bolt-nut) type.

3.5. Each battery shall have a label with the following information:
- a) Manufacturer's or Installer's name and address
- b) Model No.
- c) Serial number
- d) Rated voltage
- e) Rated capacity with an indication of discharge rate

3.6. Warranty period: Minimum 1 year

4. DC-AC Inverters

4.1. The output voltage shall be 220/240VAC ± 5% and a frequency of 50Hz.

4.2. The output wave form shall be sine wave.

4.3. The efficiency of the inverter shall be in excess of 85%.

4.4. Each inverter shall have the following protections:
- a) Low voltage shut down: 10.5V – 11.0V
- b) Over voltage shut down 15.0V－16.1V
- c) Surge power
- d) Reverse polarity protection
- e) Short circuit protection
- f) Over Load shut down
- g) Over temperature shut down

4.5. The following technical information shall be provided.
- a) Continuous output capacity
- b) Type of output wave form
- c) Low voltage shut down voltage and reconnect voltage
- d) Over voltage shut down voltage and reconnect voltage
- e) Maximum operating voltage
- f) Maximum surge power capacity in one minute or equivalent short period
- g) Kinds of protections

4.6. Each DC-AC inverter shall have a label with the following information:
- a) Model No.
- b) Serial number
- c) Ratings: continuous operating power, maximum operating power in one minute

4.7. Warranty period: Minimum 1 year.

APPENDIX 2- a)

5. Outlets (Sockets / Plugs / Switches)

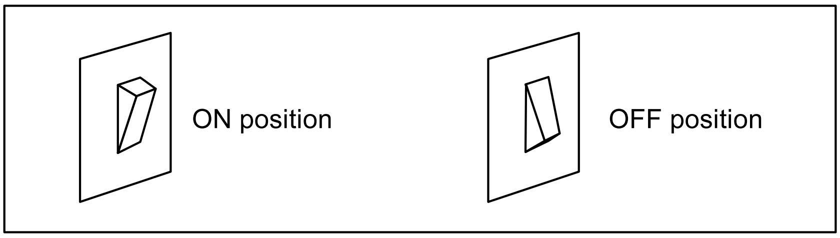
5.1. The DC outlets require asymmetrical shape to prevent reverse insertion. AC outlets are acceptable since DC outlets are not easily available.

5.2. Polarity shall be as follows.
- a) DC sockets/plugs : Positive : Big rounded pin Negative : Small rounded pin
- b) AC sockets/plugs : Positive : Live pin Negative : Neutral pin

5.3. Each socket and plug shall be permanently marked "12VDC" with green label.

5.4. The sockets shall be wall-mounted.

5.5. The ON/OFF position of wall-mounted switch shall be as follows.
- a) ON lower part of the switch is pressed.
- b) OFF upper part of the switch is pressed.



6. Wiring

6.1. PVC insulated stranded cables shall be used for wiring.

6.2. Following color codes shall be applied for DC wiring.
- a) Positive: Red or Brown
- b) Negative: Black or Blue

APPENDIX 2- b)

Code of Practice for Off-grid Photovoltaic Systems

(Draft)

Scope of this draft: The photovoltaic system should work three to five years without any problems since the systems has no mechanical parts. This should be the standard condition, however, poor components and poor installation always make it difficult. The aim of code of practice is to achieve continuous working of the systems for two to three years.

Minimum provisional standards have been set by the Ministry of Energy. These are intended to form a basic reference for use in all photovoltaic installations in Ghana. They will help promote the installation of safe, and high quality PV systems.

The installation must also include the completion and tidying up of any work that is a direct result of the installation. The contractor should repair any damage to surface walls or fittings caused by or as a result of the installation. An element should be included in the original quotation to allow for this.

In general, all visible parts of the installation must be completed in a professional manner.

Definitions

Deep cycle batteries

Mainly used for Photovoltaic systems. Maximum depth of discharge is up to 70%.

Shallow cycle batteries

Mainly used for automotive batteries. Maximum depth of discharge is less than 50%.

Essential systems

The systems that continuous operation to maintain functions of appliances such as refrigerators and radio communications is most important.

Standard systems

The systems are other than essential systems.

The system is used for appliances such as light and TV Radio.

Ipm

Current at maximum power point of a PV module.

Vpm

Voltage at maximum power point of a PV module.

APPENDIX 2- b)

1. System Design

1.1. Basic design factors

Following design factors shall be used. See Annex 1.

a) Total loss factor of PV modules

Total loss factor (temperature, dust, etc.) shall be 0.85 as a safety margin.

b) Charge-discharge efficiency of batteries

Charge-discharge efficiency varies on types and models of batteries.

The charge-discharge efficiency shall be 0.8 as a safety margin.

c) Peak sunlight hours per day

System shall use minimum month. See Annex 2.

d) Daily depth of discharge

Standard system : Deep cycle battery up to 23%, Automotive battery up to 16%

Essential system : Deep cycle battery up to 14%, Automotive battery up to 10%

e) Autonomy

Standard system : minimum 3 days

Essential system : minimum 5 days

As long as daily depth of discharge is maintained, the necessary autonomy is automatically achieved. In areas predicted that rainy days or cloudy days continue for a long time, Autonomy to have a long more is required. See Annex 3.

f) Inverter efficiency

Inverter efficiency varies on types and models of Inverters. You must confirm specifications of inverter to use.

The inverter efficiency recommends more than 85%.

g) Cable loss (voltage drop)

Wiring size must be decided so that voltage drop is less than 5%. See Annex 7.

h) Charge controller safety factor

The Charge controllers shell be more than Voc of a PV module.

The charge controller shall be capacity more than maximum current including starting current of load.

In addition, it is desirable to have enough 20% as for the charge controller capacity.

i) Inverter safety factor

Capacity of inverter shall be more than a total of load.

The Serge capacity of inverter shall be more than the maximum serge power of load.

In addition, it is desirable to have enough 20% as for the Inverter capacity

APPENDIX 2- b)

2. Installation

2.1. Right of installation

Installation work shall be done by certified technicians or under supervision of certified technicians. After the installation, stick a label on the place that it is easy to look at. The label shall indicate following information:

a) Supplier/installer's information (name, address, telephone)

b) Name of certified technician who installed/supervised the system and his certified number.

c) Date of installation

2.2. Circuit protections

For maximum safety, protections at following points are recommended in addition to the charge controller's built-in short circuit protection. See Annex 4.

a) Short circuit protection between charge controller and load.

b) Lightning protection (knife switch) between charge controller and PV module.

2.3. Mounting of PV modules

a) Azimuth angle: South ± 5 º

b) Tilt angle : 15° ± 5 º

c) No object (trees, buildings etc) should shade any part of the panel at least between 8 a.m. and 4 p.m. since around 90% of power generation is obtained during this period.

d) Ground mounting for SHS should be avoided whenever possible.

e) Roof mounting requires minimum 10cm airflow space from the roof.

f) Cables shall not touch to metal roof and/or metal mounting brackets to avoid short circuit caused by melted down insulation.

g) All holes in the roofing shall be thoroughly sealed and made waterproof with UV-resistant silicon sealant or suitable sealing compound.

2.4. Battery boxes

If a battery box is used, the following specifications are recommended.

a) The battery boxes shall be made of suitable durable material; however, if it is made of wood it shall be well preserved against insects (termites), rotting and acid.

b) The battery boxes shall have a smooth finish.

c) The battery boxes shall be lockable

d) The battery box having enough ventilator ability to avoid repletion of explosive gas while battery charging.

e) The battery boxes shall be located in cool place and fresh air flow is available.

APPENDIX 2- b)

2.5. Batteries

a) Deep cycle battery shall be used. For institutions, maintenance free battery shall be used.

b) Automotive batteries are acceptable only for private houses if the user requested it after explanation of advantages of deep cycle battery.

c) Terminals shall be lug (bolt-nut) type. In case the terminals are tapered type, terminal brackets shall be provided. Direct wiring on tapered terminals is not acceptable.

d) Deep cycle battery's life cycles at 70% discharge cycles shall exceed 400 cycles , and Automotive battery's life cycles at 50% discharge cycles shall exceed 200 cycles .

e) Batteries that manufactured date exceeds following maximum storage period shall not be used.

Vented battery at wet condition	:	six months
Vented battery at dry condition	:	one year
Sealed battery :		one year

f) When vented battery is used, apply grease to terminals as a corrosion protection after cable connection.

g) The owner shall return the dead battery to the installer and/or the supplier for recycling so that the dead battery is not thrown away.

2.6. Charge controllers

a) Set point voltages for LVD, LVR, HVD, HVR to meet battery specifications.

b) The charge controller shall be installed in the place that the indicator is easy to look at.

2.7. DC-AC Inverters

a) DC-AC Inverters shall be located where they can easily be switched on and off.

b) It is recommended that DC-AC Inverters are to be located close to the battery without directing above.

2.8. Outlets (Sockets / Plugs / Switches)

a) The DC outlets require asymmetrical shape to prevent reverse insertion. AC outlets are acceptable since DC outlets are not easily available.

b) When AC switches are used for DC system, 200% of current rating should be used to reduce corrosion caused by DC arcing (sparking).

c) Each socket and plug shall be marked "12VDC" with green label. See Annex 5.

d) The sockets shall be wall-mounted.

2.9. Wiring

a) Cables can be joined by use of junction boxes, block connectors or soldering (with insulating sleeves). All cable joints must be contained in a suitable junction box.

b) Use of conduits or cab tire cables (double insulated weather resistant cable) is recommended for overhead wiring outside. When single cable is used, counter measure against short circuit when insulation is broken down by degradation should be taken. The recommended counter measures are keeping distance of each other and/or use of spacers.

c) The lowest point of suspended cables shall be at least 2.7 meters above ground level.

d) Conduits and/or cab tire cables (double insulated weather resistant cable) shall be used for underground wiring.

e) Underground cables shall be buried a minimum of 0.3 meters below the surface and be indicated with markers.

f) Cables through roofing shall be contained in roof entry boxes, which shall also form a waterproof seal to avoid leakages. Holes through roofing should be avoided where possible.

g) All cable shall follow color-code standard. Positive connections shall be RED or BROWN, negative connections shall be BLACK or BLUE.

h) Cable lugs are required for connections to terminals of components. In case cable lugs are not available, proper workmanship is required for connections.

i) All installations shall have wall-mounted brackets (or tower clips).

j) Larger size of cables may be required to meet maximum voltage drop specifications.

k) If the size of cable is less than the specification, doubling wire may be acceptable but not tripling. Minimum 1cm of full contact shall be maintained. If the junction hole is smaller than the size of doubled wire, up to 50% of strands can be cut from each wire. See Annex 6.

l) The maximum voltage drop shall be as follows.

- between charge controller and PV module:	0.5V
- between charge controller and battery:	0.1V
- between charge controller and loads:	
- for loads within same building	0.6V
- for small lights installed in another building as an extension of main system	1.0V

Since the voltage drop varies with current drawn, use Imp of PV modules between charge controllers and batteries, and between charge controllers and PV modules. Use maximum load current (switch on all loads) between charge controllers and loads. See 0.

2.10. Connecting sequences

As a PV module generates high voltage (approximately 18V), lights or other load components will be damaged if this high voltage reached to them. The Battery activates the charge controller and works as voltage stabilizer to pull down voltage. Therefore, always batteries have to be connected first and be disconnected last. Connecting sequence at installation and/or at maintenance, follow the rule of "First battery, Last battery".

a) Sequence at connection Battery → PV → Load

b) Sequence at disconnection Load → PV → Battery

3. Inspections

After the completion of the installation, the certified engineer must inspect it using standard inspection check sheets. See Annex 8.

The installer must prepare a name, an address, a phone number to understand a user

4. User's manuals

Installers shall provide user's manuals and shall explain contents to users.

User's manuals shall include following contents.

a) Differences between 12VDC and 240VAC.

Make clear understanding of 12VDC that has polarity and appliances of 12VDC can not be used for 240VAC.

b) Tampering

It is very important what is tampering and how tampering damages the system. Once users understood that tampering does not benefit them, they may not do tampering.

c) Life of battery

When the capacity of the battery becomes 80% of initial capacity, it is considered as the time of replacement. The user still can use battery, however, the usage time became shorter and shorter. Users are often trying to restore the life by replacing new acid, cleaning electrodes, etc. but those do not work.

d) Replacement of battery

Users shall return the dead battery to the installer and/or the supplier for recycling when replacing the battery.

e) Available usage of each appliances

Explain how many hours they can use their appliances and how they can calculate trade off usage times among appliances. If TV usage is increased, how many hours they have to reduce lighting hours, etc.

Explain that users experience that they can use more than instructed usage times. However, it is overloading the battery slowly and it will cause power out in two to three weeks. If it happened, reduce usage time in half for at least one week or until the indication of the charge controller shows battery is full.

f) Half use in cloudy/rain days

Users should limit the usage time to half during cloudy/rain days and the next sunshine day to allow recovering of battery status.

g) Battery status check

The batteries are supposed to be charged fully every day. Users have to check battery status from charge controller every day if it becomes full during day time. If not, usage of loads are over loaded and users must to reduce usage time.

h) Cautions (acid, fire, lightening)

Acid damages cloths, metals, wood, floors. Avoid skin contact and eye contact. In case of skin contact and eye contact, wash with plenty of water. Eye contact may cause loss of eyesight.

For vented batteries, hydrogen gas is produced during charging. Avoid fire/smoking near battery.

Disconnect loads from sockets such as TV and radio during lightning. In case that a knife switch is installed between charge controller and PV module, switch it off.

i) Maintenance of battery (shake, top up)

Stratification of acid reduce capacity and life. The users are requested to shake batteries to mix electrolyte. This should be done especially for automotive battery as it builds up bubbles between electrodes often.

If maintenance free batteries are not used, explain how to top up battery water and where they can get (no well water, river water, mineral water, rain water).

j) Maintenance of PV module (cleaning, shade check)

PV module has to be cleaned when its surface has dust and/or droppings of birds.

To clean the surface, use wet towels without any detergents to clean up until all residues have disappeared.

Do not use dry towels as they may scratch the surface.

It is very important that droppings of birds has to be cleaned immediately since it causes hot spot and may degrade the cell.

Users think shading of small area of PV module may reduce power generation a little and may not be a problem.

However, any small shades over the PV module almost stop power generation.

It is very important to teach users about this misunderstanding.

Avoid any shades between 8a.m. and 4p.m..

5. Maintenance

Users shall be responsible for maintenance described in user's manual.

The periodical maintenance for institutional systems may be carried out by contracted installers using standard maintenance check sheets. See Annex 9.

Annexes

Annex 1. Example of system design

In this case, System is 12V-DC standard system, and using appliances are following table, and system is installed in TAMALE

※ 12V-DC system : Inverter efficiency = 1.0, standard system : Autonomy = 3days

Table :Electric power demand

Item	Rated power (W)	Qty	Used time (hour)	Power consumption (Wh)	Current (A)	
Light	8	2	4	64	1.3	
W&B TV	30	1	2	60	2.5	
Radio	15	1	1	15	1.3	
Total				139		

a) PV module

$$\text{Daily use current Iu} = \frac{\text{Power consumption (Wh)}}{\text{System voltage (V)}} = \frac{139\text{Wh}}{12\text{ V}} = 11.58\text{ Ah}$$

$$\text{Necessary current In} = \frac{\text{Iu}}{\text{Battery efficiency} \times \text{Inverter efficiency} \times \text{PV total loss}}$$

$$= \frac{11.58}{0.8 \times 1.0 \times 0.85} = 17.03\text{ Ah}$$

$$\text{Necessary PV power(Wp)} = \frac{\text{In} \times \text{system voltage (V)}}{\text{Peak sunshine hours}}$$ (see Annex 2)

$$= \frac{17.03\text{ (Ah)} \times 12\text{(V)}}{4.84} = 42.2\text{(W)}$$

⇩

You must choose PV module that maximum power is more than 42.2 Wp .
for example,
manufacturer=Isofoton, model=I-55
Wp=55±10%, Ipm=3.16A, Isc=3.38A, Vpm=17.4V, Voc=21.6V

APPENDIX 2- b)

b) Battery

$$\text{Battery capacity (Ah)} = \frac{\text{Iu} \times \text{Autonomy (days)}}{\text{Depth of discharge} \times \text{Inverter efficiency}}$$

$$= \frac{11.58\ (\text{Ah}) \times 3(\text{days})}{0.7 \times 1.0} = 49.63\ (\text{Ah})$$

⇩

You must choose Deep cycle battery that capacity is more than 49.63 Ah.

c) Charge controller

Capacity of a charge controller must be more than Isc.

And in the case of a DC system, Capacity of a charge controller must be more than load current.

Maximum (starting) current varies on a kind of appliance, and there are generally as follows.

Lights : rated current × 1 ~ 2

TV : rated current × 2.5 ~ 5

Motor : rated current × 5 ~ 10

In this case, load current are follows.

appliance	Rated current (A)	Maximum current (A)
Light	0.67	0.67×2= 1.34
W&B TV	2.5	2.5 ×5=12.5
Radio	1.25	1.25×2= 2.5

Maximum load current (A) = Lights rated current + TV maximum current + Radio rated current

= (0.67×2Qty) + 12.5 + 1.25

= 15.09 (A) ＞ 3.38 (A):Isc

⇩

You must choose Charge controller that capacity is more than 15.09A.
If possible, capacity had better increase 20% for safety factor,
In this case, Charge controller capacity is more than 18.11A is better.

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Annex 2. Peak Sunshine hours (Irradiation)

Monthlyirradiation (kWh/m2・day)

Synoptic station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Average**
Navrongo	5.39	5.40	5.78	5.96	5.93	5.72	5.34	5.10	5.32	5.68	5.62	4.82	5.05
Wa	5.46	5.81	5.80	5.86	5.87	5.61	5.14	4.94	5.13	5.64	5.65	5.38	5.52
Yendi	5.16	5.46	5.56	5.86	5.92	5.42	5.04	4.63	4.96	5.62	5.67	5.17	5.37
Tamale	5.12	5.48	5.61	5.89	5.87	5.51	4.95	4.84	5.00	5.47	5.70	5.21	5.34
Bole	5.42	5.82	5.76	5.80	5.71	5.09	4.65	4.49	4.83	5.54	5.52	5.25	5.32
Krachi	5.11	5.41	5.68	5.97	5.86	5.19	4.68	4.53	4.77	5.35	5.65	5.12	5.28
Wenchi	5.19	5.50	5.48	5.71	5.51	4.97	4.36	4.12	4.41	4.93	5.13	4.91	5.02
Ho	4.87	5.22	5.51	5.72	5.58	4.92	4.60	4.19	4.66	5.50	5.62	5.07	5.12
Abetifi	5.03	5.53	5.56	5.58	5.41	4.82	4.75	4.60	4.68	5.24	5.56	5.07	5.15
Kumasi	4.82	5.31	5.31	5.36	4.71	4.03	4.04	3.78	3.99	4.71	5.00	4.55	4.63
Akuse	4.63	5.06	5.25	4.95	5.28	4.59	4.30	4.11	4.73	5.30	4.77	4.81	4.81
Koforidua	4.71	5.14	5.26	5.43	5.29	4.64	4.07	3.84	4.44	5.17	5.24	4.86	4.84
Akim Oda	4.51	4.77	4.88	5.18	4.90	4.30	4.02	3.80	4.24	4.78	4.93	4.50	4.57
Bekwai	4.70	5.08	5.27	5.50	5.31	4.56	4.11	3.75	4.07	4.95	5.01	4.45	4.73
Ada	5.00	5.38	5.65	5.94	5.57	4.98	5.06	5.07	5.51	5.87	5.48	5.36	5.41
Accra	4.66	5.21	5.26	5.67	5.42	4.61	4.19	4.53	5.11	5.62	5.51	4.93	5.06
Saltpond	4.90	5.56	5.49	5.68	5.35	4.44	4.67	4.48	5.00	5.68	5.69	5.15	5.17
Takoradi	4.79	5.38	5.46	5.66	5.23	4.36	4.38	4.23	4.59	5.52	5.55	4.98	5.01
Axim	4.88	5.40	5.57	5.61	5.05	3.94	4.24	4.23	4.38	5.18	5.47	4.99	4.91
average	4.97	5.36	5.48	5.65	5.46	4.83	4.56	4.38	4.73	5.36	5.41	4.98	5.10

Reference：Energy Commission

Annual irradiation (kWh/m2・day)

Navrongo	Wa	Yendi	Tamale	Bole
5.51	5.52	5.37	5.39	5.32
Krachi	Wenchi	Ho	Abetifi	Kumasi
5.28	5.02	5.12	5.15	4.63
Akuse	Koforidua	Akim Oda	Bekwai	Ada
4.81	4.84	4.57	4.73	5.41
Accra	Saltpond	Takoradi	Axim	average
5.06	5.17	5.01	4.91	**5.10**

Reference：Energy Commission

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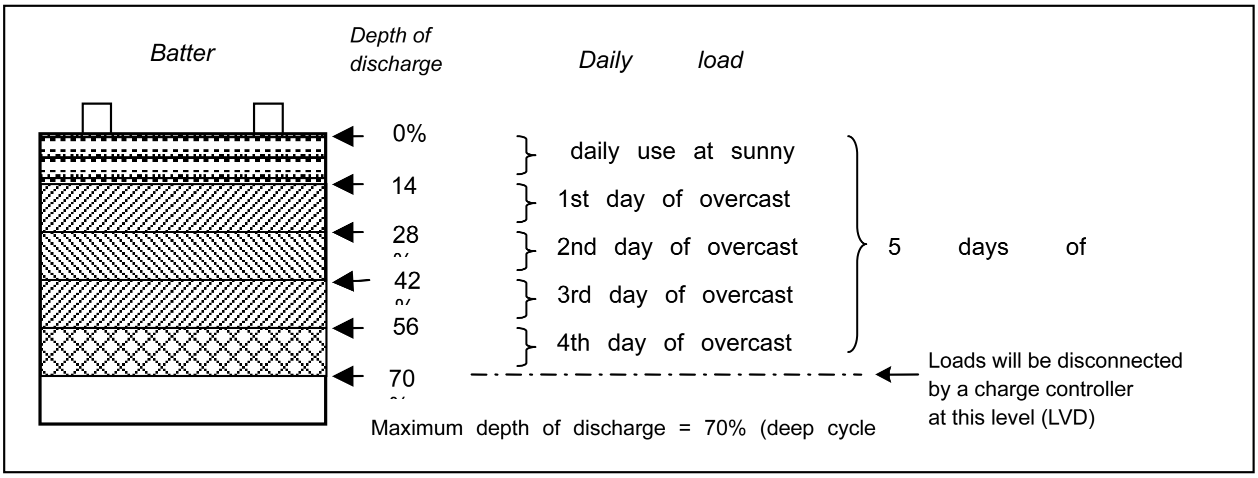
Annex 3. Example of a depth of discharge and autonomy

The following diagram shows an example that the system is designed at 14% daily depth of discharge with a deep cycle battery. The shallow cycle operation (depth of discharge=14%) ensure longer cycle life of the battery and covers 5 days of autonomy.

Daily depth of discharge = Maximum depth of discharge / (Days of autonomy)

= 70% / 5 = 14%



Annex 4. Recommended circuit protections

The use of DC circuit breaker and/or PTC resettable fuse is recommended. Avoid conventional fuse as much as possible because it is easily replaced by metal wire once it is blown.

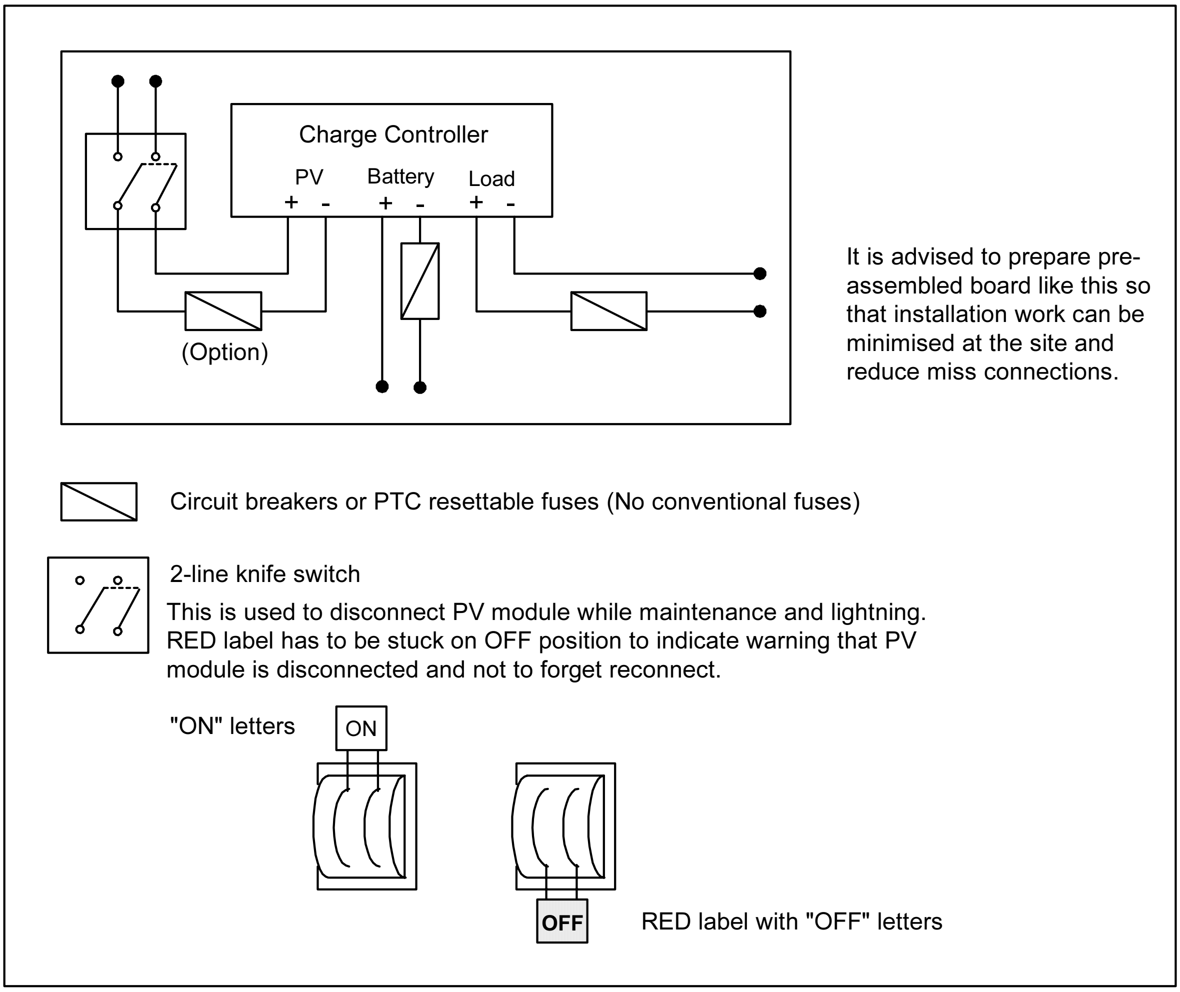
These protection should work before controller's built-in short circuit protection. To achieve this, consider current rating of each devices. The capacity of the charge controller may require more than double of rated protection devices.

a) DC circuit breaker: Trip current is 125% to 150% of rated capacity. Trip speed is between conventional fuse and PTC resettable fuse.

b) PTC resettable fuse: Trip current is 200% of rated capacity. Trip speed is slowest.

c) Conventional fuse: Trip current is 125% to 150% of rated capacity. Trip speed is fastest.

The next diagram shows the recommended circuit protections.



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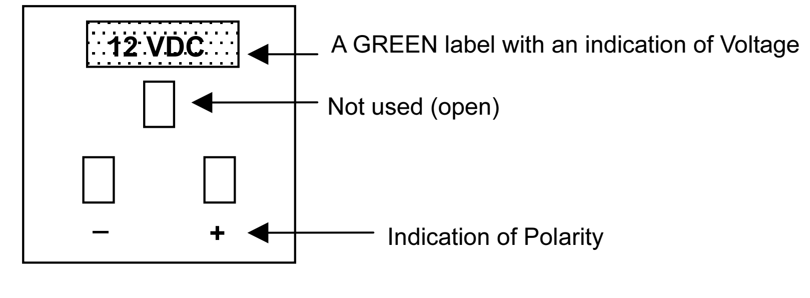
Annex 5. Polarity of Outlets

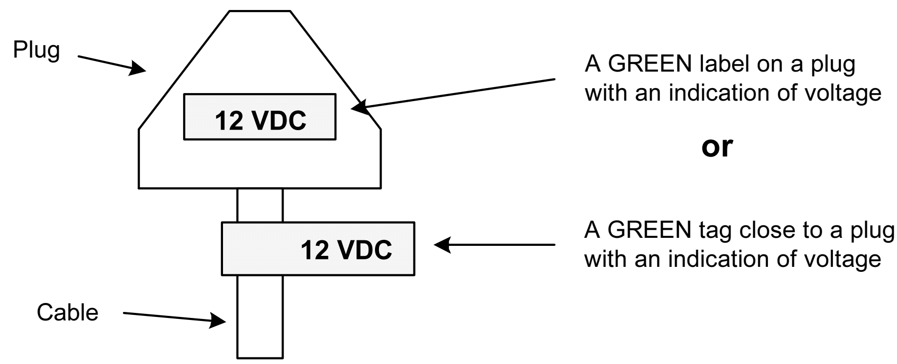
Indication of voltage and polarity of sockets/plugs shall be as follows.

Positive : Right, Negative : Left



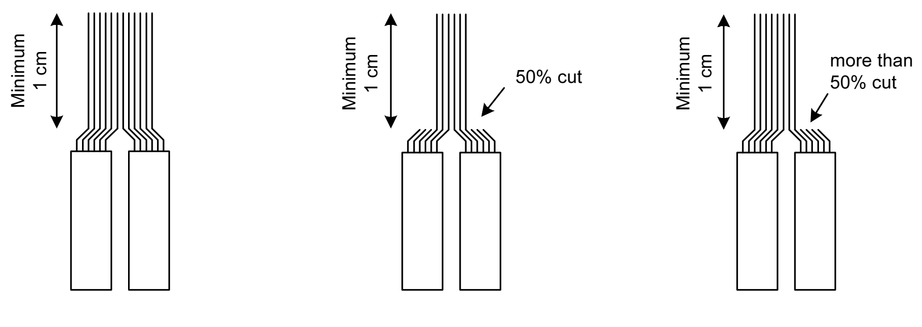
AC socket used as DC socket

Indication of voltage on plugs shall be as follows.



Annex 6. Doubling wire

To double the wires, maintain minimum 1cm contact and at least 50% of strands on each wires.



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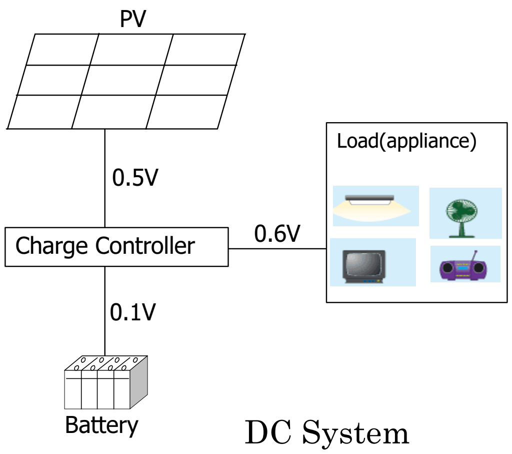
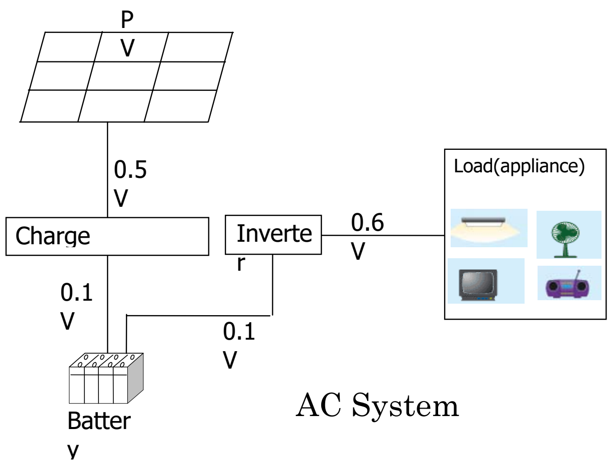
Annex 7. Voltage drop

The maximum voltage drop and measuring current for the voltage drop is shown table and figure below.

Connection	Maximum Voltage Drop	Amount of current to measure voltage drops
C/C to PV module	0.5V	Use Ipm at STC (55Wp=3A, 75Wp=4A, etc.)
C/C to Battery	0.1V	
C/C to Loads (Loads within same building)	0.6V	Use maximum load (all loads on)
C/C to Loads (Small lights as an extension from main system)	1.0V	



DC System



AC System

The maximum distance within specified voltage drop is calculated by the following equation.

Voltage drop e[V]

$$e = \frac{35.6 \times L[m] \times I[A])}{1000 \times a[mm^2]}$$

$\Rightarrow$

Maximum distance L[m]

$$L = \frac{e[V] \times 1000 \times a[mm^2])}{35.6 \times I[A]}$$

※ Using Copper wires
※ DC-2 wire, or AC-2 wire single phase

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Maximum distances at each wire size based on above equation are shown below.

Wire size (m^2)	Vdrop total	Load current											
		1 A	2 A	3 A	4 A	5 A	6 A	7 A	8 A	9 A	10 A	15 A	20 A
2.5	0.1 V	7.0 m	3.5 m	2.3 m	1.8 m	1.4 m	1.2 m	1.0 m	0.9 m	0.8 m	0.7 m	0.5 m	0.4 m
	0.5 V	35.1 m	17.6 m	11.7 m	8.8 m	7.0 m	5.9 m	5.0 m	4.4 m	3.9 m	3.5 m	2.3 m	1.8 m
	0.6 V	42.1 m	21.1 m	14.0 m	10.5 m	8.4 m	7.0 m	6.0 m	5.3 m	4.7 m	4.2 m	2.8 m	2.1 m
	1.0 V	70.2 m	35.1 m	23.4 m	17.6 m	14.0 m	11.7 m	10.0 m	8.8 m	7.8 m	7.0 m	4.7 m	3.5 m

Wire size (m^2)	Vdrop total	Load current											
		1 A	2 A	3 A	4 A	5 A	6 A	7 A	8 A	9 A	10 A	15 A	20 A
4.0	0.1 V	11.2 m	5.6 m	3.7 m	2.8 m	2.20 m	1.90 m	1.60 m	1.40 m	1.20 m	1.1 m	0.7 m	0.6 m
	0.5 V	56.2 m	28.1 m	18.7 m	14.0 m	11.2 m	9.4 m	8.0 m	7.0 m	6.2 m	5.6 m	3.7 m	2.8 m
	0.6 V	67.4 m	33.7 m	22.5 m	16.9 m	13.5 m	11.2 m	9.6 m	8.4 m	7.5 m	6.7 m	4.5 m	3.4 m
	1.0 V	112.4 m	56.2 m	37.5 m	28.1 m	22.5 m	18.7 m	16.1 m	14.0 m	12.5 m	11.2 m	7.5 m	5.6 m

Wire size (m^2)	Vdrop total	Load current											
		1 A	2 A	3 A	4 A	5 A	6 A	7 A	8 A	9 A	10 A	15 A	20 A
6.0	0.1 V	16.9 m	8.4 m	5.6 m	4.2 m	3.4 m	2.8 m	2.4 m	2.1 m	1.9 m	1.7 m	1.1 m	0.8 m
	0.5 V	84.3 m	42.1 m	28.1 m	21.1 m	16.9 m	14.0 m	12.0 m	10.5 m	9.4 m	8.4 m	5.6 m	4.2 m
	0.6 V	101.1 m	50.6 m	33.7 m	25.3 m	20.2 m	16.9 m	14.4 m	12.6 m	11.2 m	10.1 m	6.7 m	5.1 m
	1.0 V	168.5 m	84.3 m	56.2 m	42.1 m	33.7 m	28.1 m	24.1 m	21.1 m	18.7 m	16.9 m	11.2 m	8.4 m

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Annex 8. Inspection check sheets

Solar Photovoltaic Systems Inspection Check Sheet	
Installation site:	Name of client:
Inspection Date:	Commissioning Date:
Client's comments on system's performance:	Excellent Good Satisfactory Poor

Name of Company: ______________________________________

Name of Lead Technician: _________________________________

Name of Inspector(s): ____________________________________

Checklist to be filled before go to the site

1. PV module

Manufacture and model No.: ____

Ratings Wp:_________ Voc:_________ Isc:_________ Vmp:_________ Imp:_________

2. Battery

Manufacture and model No. : ____

Capacity per battery: ________________ Number of batteries: ______________

End-of-charge voltage (cycle use): ______________________

3. Charge controller

Manufacture and model No. : ____

Capacity: ___________________

Type of short circuit protection: __________________________

In case it is a fuse, number of spare fuses provided : _________________________

HVD:__________ HVR:__________ LVD:__________ LVR:__________

Does HVD match to end-of-charge voltage of the battery? ______________

Checklist to be filled at the site

Cable size

C/C to PV module:________ C/C to Battery:________ C/C to Loads:________

Switches

Capacity of current:_________ Rated voltage:________

1. Are the types of wires, cables, cords and conduits correct for each application? _______
2. Are all electrical boxes adequately sized, covered and accessible? _______
3. Are all electrical connections accessible? _______

4. Are all connections through roof and/or outside walls protected from water? _______
5. Are all sockets and plugs clearly marked “12VDC” with green label? _______
6. Was a system maintenance logbook provided? _______

Measurement of system

Weather

CS : Clear & Sunny, PC : Partly Cloudy — Today _________________

CB : Cloudy but Bright, O : Overcast, R : Rain — Yesterday _________________

PV Module

Shade condition _________________

1: No shade all day, 2: Some before 8am and after 4pm, 3: Some between 8am and 4pm

Azimuth angle: _____________ Tilt angle: __________

Status of Battery

Condition	Voltage (V)	Current (A)
Load All Off	------------	------------
Measure battery voltage and current		
Measure PV module voltage and current		
Disconnect positive cable of PV module	------------	------------
Measure battery voltage		------------
Two lights ON for 5 min. Measure voltage and current before switch off		
Switch off lights	------------	------------
Measure voltage		------------
Connect positive cable of PV module	------------	------------
Measure PV voltage and current		

Voltage drop

C/C to PV: (measured) __________ Load current: __________

(calculated Voltage drop at Imp) __________ Load current: __________(Imp)

C/C to Battery: __________ Load current: __________

(calculated Voltage drop at Imp) __________ Load current: __________(Imp)

C/C to Loads (lights): __________ Load current: __________

C/C to Loads (Refrigerator): __________ Load current: __________

C/C to Loads (Radio system at transmission): __________ Load current: __________

Charge controller setting (measured)

HVD:__________ HVR:__________

Does HVD match to end-of-charge voltage of the battery? _____________

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Status of all system

	Check items	Status	Action
Connection - loosed screw - rats bite - cracked plug - grease - etc.	PV to C/C		
	Battery to C/C		
	Loads to C/C		
	Battery Terminal		
	Wires of TV, Radio, Cassette, etc.		
	Plugs of TV, Radio, Cassette, etc.		
Lights	Insects		
	Blackened		
Battery Box	Insects, Dust, Rust		
PV module	Surface condition		
	Is mount shaking by wind?		

Additional comments:

__________________ _______________

Signed Date

APPENDIX 2- b)

Annex 9. Maintenance check sheets

Solar Photovoltaic Systems Maintenance Check Sheet	
Installation site:	Name of client:

Name of Company: ____

Name of Lead Technician: ________________________________

Date :_____________ Time of arrival :_____________ Time of leaving :_____________

Weather

CS : Clear & Sunny, PC : Partly Cloudy — Today ________________

CB : Cloudy but Bright, O : Overcast, R : Rain — Yesterday ________________

PV Module (Shade condition)

1: No shade all day, 2: Some before 8am and after 4pm, 3: Some between 8am and 4pm ______________

Status of Battery

Condition	Voltage (V)	Current (A)
Load All Off	------------	------------
Measure battery voltage and current		
Measure PV module voltage and current		
Disconnect positive cable of PV module	------------	------------
Measure battery voltage		------------
Two lights ON for 5 min. Measure voltage and current before switch off		
Switch off lights	------------	------------
Measure voltage		------------
Connect positive cable of PV module	------------	------------
Measure PV voltage and current		

Status of all system

	Check items	Status	Action
Connection - loosed screw - rats bite - cracked plug - grease - etc.	Panel to C/C		
	Battery to C/C		
	Load to C/C		
	Battery Terminal		
	Wires of TV, Radio, Cassette, etc.		
	Plugs of TV, Radio, Cassette, etc.		
Light	Insects		
	Blackened		
Battery Box	Insects, Dust, Rust		
Panel	Surface condition		
	Is mount shaking by wind?		

Any system failure since last visit

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<u>This page must be filled by the client with his/her own handwriting.</u>

Writing by the technician is prohibited.
Only authorized technician can maintain your system.

Authorized technician to maintain your system is : ______________________________

1. Did the technician check all system? ____________
2. Is there any cable which has wire parts exposed? ____________
   If Yes, did the technician fix it? ____________
3. Is the surface of PV panel clean? ____________
   If No, did the technician clean it? ____________
4. Did you experience any power out or low voltage indication since last visit? ____________
   If Yes, how many times did the power out or low voltage indication occur? ____________
5. Do you satisfy the system's performance?
   Excellent Good Satisfactory Poor
6. Any other comments

Name of client:________________ Signature :______________ Date :__________