No.

Japan International Cooperation Agency

Preparatory Survey for Renewable Energy Promotion Program in Africa — Public Facility Electrification —

Final Report

Executive Summary

November 2009

Nippon Koei Co., Ltd.

Proact International Inc.

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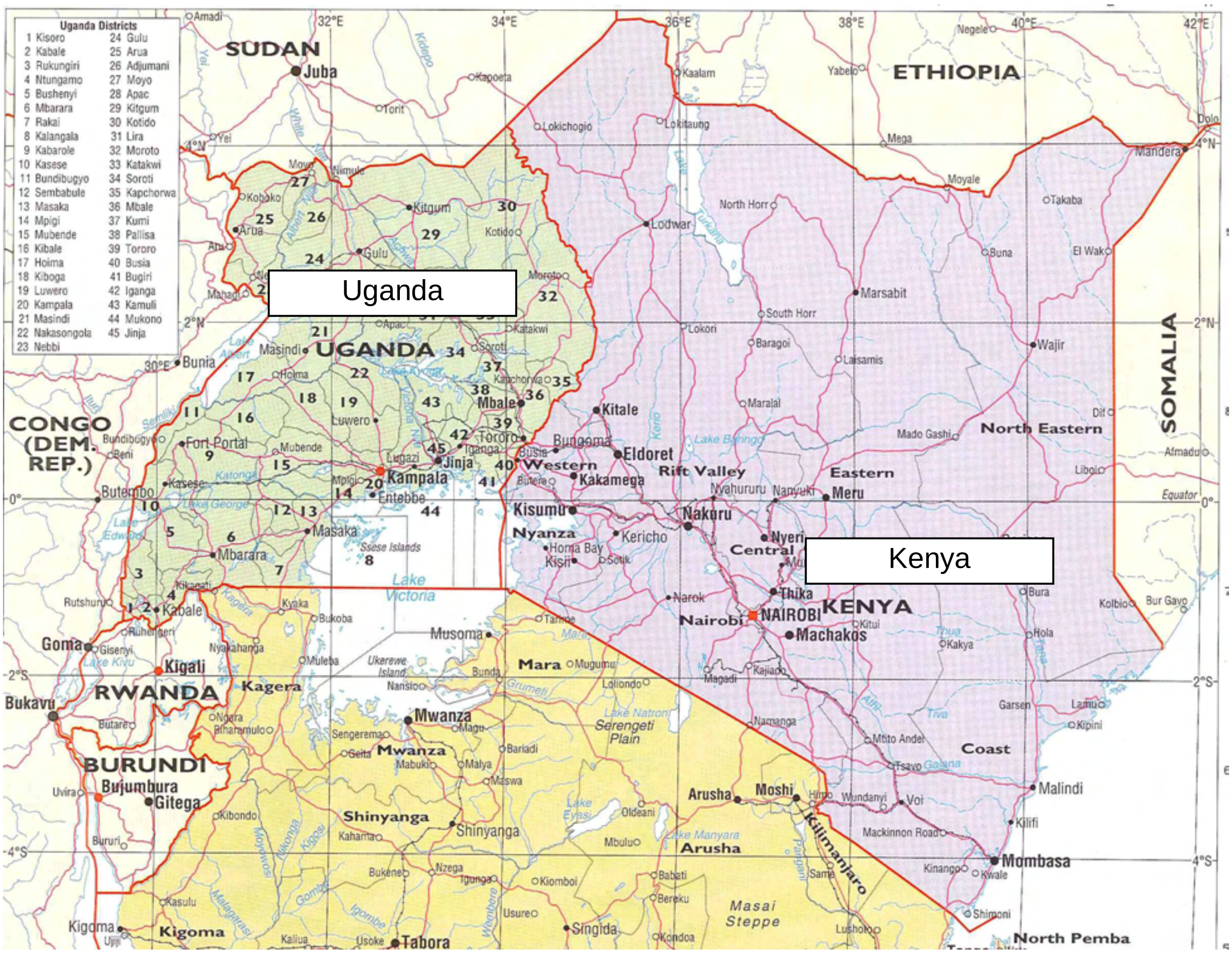
Location Map



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Abbreviation

CBO	Community Based Organization
CDF	Constituency Development Fund
CREEC	Centre for Research in Energy and Energy Conservation
CSS	Community Solar System
DWD	Department of Water Development
ERT	Energy for Rural Transformation
GNI	Gross National Income
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
IFC	International Finance Cooperation
IREMP	Indicative Rural Electrification Master Plan
JICA	Japan International Cooperation Agency
KenGen	Kenya Electricity Generating Co. Ltd.
KPLC	Kenya Power and Lighting Co. Ltd.
Ksh	Kenya Shilling
LED	Light Emitting Diode
MEMD	Ministry of Energy and Mineral Development
MoE	Ministry of Energy
MoES	Ministry of Education and Sports
MoMS	Ministry of Medical Service
MoPHS	Ministry of Public Health and Sanitation
NFE	Non Formal Education
NGO	Non-Governmental Organization
ODA	Official Development Assistance
PSDC	Private Sector Development Centre
PV	Photovoltaic
REA	Rural Electrification Agency
REA	Rural Electrification Authority
REF	Rural Electrification Fund
REM	Rural Electrification Master Plan
RESP	Rural Electrification Strategy and Plan
SHS	Solar Home System
TICAD	Tokyo International Conference on African Development
UBoS	Uganda Bureau of Statistics
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
US$	US$ Dollar
Ush	Uganda Shilling
VCR	Video Cassette Recorder

Exchange Rates (as of April 2009)

- US$ 1 = JPY 97.29
- Ksh 1 = JPY 1.258
- US$ 1 = Ksh 77.34
- Ush 1 = JPY 0.046
- US$ 1 = Ush 2,115

Electrical Terminology

・ V (Volt)	Unit of voltage
・ kV (kilovolt)	1,000 volts
・ W (Watt)	Unit of active power
・ kW (kilowatt)	1,000 watts
・ MW (Megawatt)	1,000 kW
・ Wh (Watt-hour)	Unit of energy
・ kWh (kilowatt-hour)	1,000 Wh
・ MWh (Megawatt-hour)	1,000 kWh
・ Wp (Watt-peak)	Unit of PV output[1]
・ kWp (kirowatt-peak)	1,000 Wp
・ MWp (Megawatt-peak)	1,000 kWp

[1] Maximum watt of PV module DC output under standard conditions of 1,000 W/m^2 intensity, 25 °C ambient temperature and a spectrum that relates to sunlight that has passed through the atmosphere (AM or Air Mass 1.5).

(Introduction)

1. Background

(1) Assistance in Africa

Africa is now getting the attention of the world as an economic development region following the Asian region. Investments to developing natural resources are increasing and the African economy can grab the opportunity to take off from long-term stagnation because of shortage of natural resources.

On the other hand, there are a lot of problems and issues to be resolved in Africa. African countries are the first countries to get impacts from food price hike and climate change. They set poverty reduction as a long-range goal. However, they are also requested to respond to climate change. Thus, they are expected to accomplish the development with minimum CO_2 emission and environmental impact.

Under such condition, the Government of Japan announced its policy to promote strong assistance to African countries. In the Tokyo International Conference on African Development (TICAD) IV held last May 2008, the Government of Japan announced initiative package for development in Africa including commitment to increase the Japanese Official Development Assistance (ODA) and make it double within five years. The Government of Japan also announced its policies like support to promoting renewable energy through “Cool Earth Partnership” as countermeasure against global climate change.

(2) Assistance to promote renewable energy

The Japan International Cooperation Agency (JICA) has learnt a lesson that “condition improvement for popularization and promotion in business basis” is important to familiarization with renewable energy. A study[2] held in Kenya and Uganda for four months from July 2008 showed the necessity of condition improvement for popularization and promotion in business basis as well as promoting electrification of public facilities in rural area such as schools and health facilities.

JICA conducted this study to gather basic information to formulate new projects and to confirm the appropriateness of the model of battery charging equipment attached to a public facility. This equipment is proposed in a previous study held in 2008. JICA also considers how to arrange environment to substantiate the contents of the proposal and realize the dissemination of the proposal.

2. Objectives of the Study

The Preparatory Survey for Renewable Energy Promotion Program in Africa, hereinafter referred to as “the Study” was conducted in Kenya and Uganda. This Study aims to examine the model plan of photovoltaic (PV) system proposed for accelerating its dissemination in non-electrified areas of Africa. The proposed system is to be built to provide electricity to local schools, health posts and

[2] Dissemination of renewable energy into rural communities : study on photovoltaic and small-hydro projects in East Africa, JICA, 2008

other public facilities. It is also intended to enable community people to charge their mobile phones and batteries.

Based on the results of interview survey conducted in remote areas of the two countries, the basic design, cost estimates and management scheme of the model plan are studied. Moreover, relevant information on potential areas and sites are collected. Consequently, an appropriate cooperation scheme for the proposed model plan is formulated.

3. Study Team

The study team consists of the following three experts:

- Mr. Katsuhiko OTAKI: Team Leader / Public Facility Electrification Expert
- Mr. Deepak Bahadur BISTA: PV (Photovoltaic) Power Generation Expert
- Mr. Ryosuke OGAWA: Village Social Survey Expert

4 Record of Major Activities

The overall schedule of the Study is shown below.

	2009/4	2009/5	2009/6	2009/7	2009/8	2009/9	2009/10	2009/11
Site Survey	Kenya	Uganda						
Report					* Draft Final Report			* Final Report

Scopes of the Study are shown below.

- Examine the current situation of rural electrification, public facility in rural areas and electrification plan in the future
- Study the non-electrified areas in rural areas and the public facilities in said areas
- Research on other donors' activities related to rural electrification
- Conduct village social survey on electrification needs and facility management at the potential areas (managers of facility and ordinary villager)
- Undertake basic design and project cost estimates of hybrid PV generation system
- Study the management scheme of hybrid PV generation system for public facilities
- Review the basis for selection of potential areas for electrification project

(Current Situation of Rural Electrification)

5. Current Situation of Rural Electrification

(Kenya)

In Kenya, rural electrification was done under the Ministry of Energy (MoE). The Rural Electrification Authority (REA) was established in 2007, and at present, carries out full-scale operation of projects since early 2009.

It was found that 63% of the population in Kenya is covered by a power grid. However, the electrification ratio on household basis in the rural areas is determined to be only 10%. The difference in ratios is due to the expensive fees required for grid connection in areas with an available power grid.

The Government of Kenya is targeting to improve the coverage rate from 63% to 100%. It also intends to improve the electrification ratio for public facilities, e.g. trading centres, schools, health facilities, public water supply facilities and administrative offices, to 100% by 2012. Ultimately, its aim is to provide the people with power benefits by 2030[3].

The draft final Rural Electrification Master (REM) Plan, which was under preparation since 2007, was submitted in May 2009.

(Uganda)

In Uganda, grid and off-grid rural electrification are regulated as the government's responsibility in the Electricity Act published in 1999. The Rural Electrification Fund (REF) was established in 2001 as financial support to rural electrification projects. The REA, meanwhile was established in 2003 to manage the rural electrification projects using the REF.

The Rural Electrification Strategy and Plan (RESP) prepared in 2001 is a framework plan based on the Electricity Act 1999. RESP shows that the government provides necessary subsidy for rural electrification projects using the REF.

In Uganda, the electrification ratio on household basis is considered at 10% in the national level. However, it is determined to cover only 3% of the rural areas[4].

At present, the method to promote various electrification projects through the initiatives of private sector is adopted for rural electrification. The Government of Uganda is targeting to improve the ratio in rural areas to 10%, through investments from the private sector for three kinds of projects, namely 1) extension of the power grid of the Uganda Electricity Board (UEB) through investments from the private sector, 2) electrification by mini-grid generated from diesel generators or renewable energy, and 3) electrification by PV system.

[3] Rural Electrification Authority Strategic Plan 2008-2012
[4] Indicative Rural Electrification Master Plan Report, January 2009

6. Rural Electrification Project by Donors

(Kenya)

The Community Power Centre (Energy Kiosk) program by UNIDO is a notable project in Kenya. The project installs off-grid power generation systems like PV, mini-hydro, biomass and wind power in non-electrified villages and verifies the possibility of energy supply by renewable energy. Also, the project aims to improve the living standard by developing local industry and providing charging services to mobile phones and lanterns. The program has already started demonstration projects in a lot of sites in Kenya. The concept of the project by UNIDO is similar to this project. It is, therefore, imperative to analyze in detail the contents and results of this project, and to consider the possibility of complementing each together.

(Uganda)

The largest rural electrification project in Uganda is ERT by the World Bank. The program aims to promote the rural electrification and development of information and communication technology sector. It is being implemented under corroboration with REA with the target of achieving 10% rural electrification ratio of RESP in electrification sector. The program implements and supports various kinds of projects related to energy development and utilization like power source development, grid extension and off-grid electrification including public facility electrification.

The IREMP which was completed in 2009 is being prepared as part of ERT. The IREMP shows specific drafts of rural electrification projects aimed at reducing the project cost to minimum considering factors like extension plan of transmission lines, population and geological conditions, and financial sources for the projects.

The distribution and installation of PV system to schools, health facilities and water supply facilities have been conceived in ERT phase II (ERT 2) which started in July 2009. A total of 2,054 PV systems with a combined capacity of 1.50 MWp will be installed in ERT 2[5].

The present rural electrification ratio in Uganda is crucially low while ERT covers only 10% of the public facilities needed to be electrified by the PV system. Thus, the hope of rural electrification and public facility electrification in REA is by JICA and other donors.

7. Situation in Non-electrified Villages and Electrification Needs

Generally, it seems that trading centres are developed along the main roads of the villages visited by the Study Team in Kenya and Uganda. A trading centre is an area where mainly small shops are gathered. Usually, a number of households near the trading centre consists a village.

About 200 or 300 households per village is a reasonable coverage for the tentative design of a battery charging facility. However, it is necessary to survey the actual village size before designing each facility.

Main source of income in the villages is agriculture and most of the farmers raise livestock. Based

[5] Project Appraisal Document No. 47183-UG, the World Bank, May 2009

on the survey conducted by the Study Team, most livestock raising is not large scale and mainly for domestic consumption. Fishery is also an important activity in villages near the Victoria Lake and its neighboring islands.

Energy demand including demand alternated by electricity in the future is charging mobile phones, lights and radios in rural areas. Presently, those in non-electrified villages go to other villages and pay for the charging of their mobile phones. These can be regarded as among the major electrification needs. It can be concluded that mobile phone use is now popular in the rural areas[6] since the Study Team found that most adults have mobile phones and that a lot of prepaid card dealers exist in non-electrified villages. Furthermore, it was observed that there are mobile charging businesses in many rural areas.

The fee for charging per mobile phone is generally Ksh 20 in Kenya, and Ush 500 in Uganda. Frequency of charging is generally every three days.

Based on the field survey, it seems that there are only a few users of rechargeable lighting devices in rural areas. It was also found that rechargeable lanterns and torches are available at ordinary general shops, suppliers of PV equipment, or supermarkets. Moreover, most households that have cash income consume four or five liters of kerosene everyday for lighting. Based on the above, it can be considered that there are needs for rechargeable devices. However, merits of these devices, especially rechargeable LED lantern, are not widely known.

Electrification needs for lighting are slightly smaller than those required for charging mobile although none responded to the query regarding energy consumption for lighting. Needs for mobile charging are rapidly becoming common electrification requirements. Meanwhile, lighting needs are supplied through kerosene or other conventional means. Hence, electricity is not indispensable and benefits of lighting devices are not widely known. Therefore, needs for lighting appear not so significant. However, such needs using electricity should be considered because villagers currently consume expensive kerosene daily and electric lights are expected to cause more benefits against kerosene lighting.

Electric lighting is essential considering benefits such as reasonable price, brighter outputs, less possibility of fire, no smoke produced, less CO_2 emission, and others.

[6] It is so difficult to determine the exact number of subscribers or penetration ratio considering prepaid account is popular and no ID card is required to avail SIM cards.

(Current Situation of Public Facilities and Electrification Plan)

8. Current Situation of Public Facilities

(Medical and Health System in Kenya)

Medical and health facilities in Kenya consist of national, provincial and district hospitals, health centres, and dispensaries. The hospitals are under the Ministry of Medical Service, while the health centres and dispensaries are under the Ministry of Public Health.

There are 6,194 medical and health facilities. About 51% of these are public and 49% are private, as founded by the Faith Based Organization (FBO). Most of these facilities are classified as dispensaries[7]. According to government policy, at least one health centre shall be established per division, with the district acting as the administration unit. Meanwhile, it also states that a dispensary shall be established per location and administered under a division.

A clinical officer who graduated from a 4-year course and several nurses are assigned in health centres, where simple surgeries are performed. At the dispensaries, meanwhile, mainly medical care, dispensing of prescribed drugs and promoting of health or sanitary knowledge are carried out by a few nurses and other staff.

(Education System in Kenya)

The education system in Kenya is managed by its Ministry of Education. Its schooling standards adopt the 8-4 system. People study in primary schools (Standard 1 to 8) for eight years and in secondary schools (Form 1 to 4) for four years. There are 26,104 primary schools and 6,485 secondary schools in Kenya as of 2007[8]. (Among these, 8,041 are private primary schools and 2,240 are private secondary schools[9].)

Usually, night prep classes are held for Standard 6 students or above. However there are no night prep classes in schools without lighting facilities. Because of this, some students transfer to schools with electricity before reaching Standard 6. The main purpose for transferring is to prepare for KCPE[10], where an important examination is taken at the end of Standard 8, before being accepted in secondary schools. Enrollment ratio in secondary schools is around 40 to 50%[11]. Some students enroll in technical training institutes after graduating from primary school.

(Medical and Health System in Uganda)

Medical and health systems in Uganda are managed by its Ministry of Health. Medical and health facilities consist of national referral hospitals, district hospitals (one facility per 500,000 population), health centre IV (county level, one facility per 100,000 population), health centre III (sub-county level, one facility per 20,000 population), health centre II (parish level, one facility per 5,000

[7] There are 4,767 medical or health facilities in 2004 in 2004. Among them, 562 hospitals, 691 health centers and 3,514 dispensaries as of 2004 according to Health Management Information System"(Ministry of Health, 2005).
[8] Statistical Abstract 2008, Kenya National Bureau of Statistics
[9] Ministry of Education
[10] Kenya Certification of Primary Education
[11] Comparing the number of students of Standard 8 in last year and Form 1 in this year based on "Statistical Abstract 2008" (Kenya National Bureau of Statistics)

population) and health centre I (village level, 1 facility per 1,000 population)[12]. There are 3,237 facilities[13] except for health centre I. These consist of 114 hospitals, 160 health centres IV, 955 health centres III and 2,008 health centres II. Health centre I does not have its own building.

Number of staff depends on the facility. According to the standard requirements, health centres IVs have medical officers who graduated from a 6-year course, while health centres III have clinical officers who graduated from a 4-year course. Nurses, midwives and security guards are also assigned for said facilities.

(Education System in Uganda)

The education system in Uganda is managed by its Ministry of Education and Sports. It adopts the 7-4-2 school system. Students study in primary school (Primary 1 to 7) for seven years, O-level (Ordinary) secondary school course (Senior 1 to 4) for four years and A-level (Advanced) secondary school course (Senior 5 to 6) for two years. There are 14,728 primary schools and 2,644 secondary schools in Uganda as of 2007[14]. Some secondary schools offer only O-level courses. Enrollment ratio in secondary schools is around 59%[15]. Most primary schools are established as public schools, however, almost half of the secondary schools are private schools[16]. After graduating from primary school or O-level secondary course, some of students enroll in technical institutes. Conditions for enrolling in technical institutes vary for each institute.

9. Condition of Non-electrified Public Facilities

(Kenya)

District hospitals or high-level facilities are mostly electrified. However some district hospitals were just upgraded from being dispensaries in 2007, when the number of districts increased. Thus, such district hospitals were not yet electrified. More than half of the health centres and dispensaries are not electrified[17]. Some health facilities are electrified by PV systems or diesel generators, through the support of donors' activities. However many of said facilities could not utilize the generated electricity at present due to the failure of the system or cost of buying fuel. Similar to health facilities, most education facilities are not electrified in the rural areas[18].

(Uganda)

About 1% of health centres IV, 34% of health centres III and 65% of health centres II are not electrified[19]. Moreover, some of the existing PV systems are not functioning well due to system

12 Health Sector Strategic Plan II 2005/06 - 2009/2010, Ministry of Health
13 Statistical Abstract 2008, Uganda Bureau of Statistics
14 Statistical Abstract 2008, Uganda Bureau of Statistics
15 Comparing the number of students of Primary 7 in 2006 and Senior 1 in 2007 based on "Statistical Abstract 2008" (Uganda Bureau of Statistics)
16 "Annual School Census 2007" shows 2,029 of 14,728 primary schools (13.8%) and 1,282 of 2,644 secondary schools (48.5%) are privately owned.
17 Electrification status of 3,008 medical or health facilities, except in Nairobi Province, is available and among these, 1,507 facilities are not electrified according to "Rural Electrification Master Plan Draft Final Report" (March 2009).
18 Electrification status of 6,115 educational facilities, except in Nairobi Province, is available and among these, 3,364 facilities are not electrified according to "Rural Electrification Master Plan Draft Final Report" (March 2009). Electrified ratio of primary school seems to be lower than one of secondary school, because there are more primary schools in rural area.
19 " Indicative Rural Electrification Master Plan Report" (Ministry of Energy and Mineral Development, January 2009) shows

failure and insufficient capacity to meet the demands. About 54% of the secondary schools, 82% of the primary schools, including pre- and post-primary schools, are located in “deep rural” areas. Only 27.0% of secondary schools and 4.6% of primary schools are connected to a grid at present, while 22.5% secondary schools and 47.1% primary schools remain as off-grid (more than 1km from grid), even after completion of electrification based on the “Indicative Rural Electrification Master Plan”.

10. Electrification Needs of Public Facilities in Rural Areas

Dispensaries and health centres in Kenya, and health centres IV/III/II in Uganda are considered as the target public facilities for the project. Doctors graduating from six-year course are not assigned to these facilities except health centre IV in Uganda. Clinical officers who completed a four-year course and other staff are assigned at health centres in Kenya and health centres III in Uganda. These facilities provide medical/health services including simple surgeries. Dispensaries in Kenya and health centres II in Uganda offer services like medical care, dispensing of prescribed drugs, and dissemination of health or sanitary information by nurses and other staffs.

In such health facilities above, there are needs for power supply for refrigeration of vaccines and blood supplies. Deliveries carried out at night time or emergency services and security also require lighting. There are also electrification needs for television, VCR and DVD players to present programs to promote health knowledge.

At present, small PV systems cover such demands at some facilities. Other facilities meanwhile either have no or less capacity PV systems to supply the demand for refrigerators (presently operated by LPG) and lighting (presently through kerosene or flash torch). Some facilities utilize gasoline/diesel generators to cover such demands.

Primary and secondary schools are considered as the target public facilities for the project. There are needs for power supply for computers and printers in staff’s offices and computer training rooms. Lighting is likewise found necessary for staff’s offices and classrooms. Televisions are also required in dining rooms of students’ dormitories and lighting is needed for night prep classes at primary and secondary schools.

Some schools respond to such needs by procuring PV systems, kerosene lamps or flash torches. However, there are still more schools that have no computer training rooms and night prep classes due to unavailable electricity. Accordingly, it is not appropriate to estimate the required PV system capacity considering the existing facilities/equipments. Hence, the estimation should consider facilities/equipments to be used in the near future. Enough capacity of PV systems will bring various benefits not only by providing power to facilities/equipment but also for students traveling to schools from their homes. They will also no longer transfer to boarding schools if night prep classes will be offered in electrified schools. Moreover, excellent teachers will then be willing to be employed in said schools if electricity becomes available to the villages.

At present, secondary schools are considered as the target facility with first priority followed by boarding primary schools conducting night prep classes.

only 10% of health centers (IV/III/II) are grid connected including mini-grid, 37% of health centers are standalone electrification including PV system and 53% of health centers are not electrified.

There are high electrification needs at water pumping facilities and trading centres.

It is expected that the method of utilization of public facilities discussed above will not change after electrification. However, some changes will occur due to utilization of televisions and VCRs, and the extended operational hours of lighting for security purposes. Additional effects are also expected from having excellent teachers/officers who will then be willing to work for longer hours, and from students realizing that transferring to other schools is no longer necessary.

11. Electrification Plan for Public Facilities in Remote Areas

Many donors and NGOs have been building PV systems at public facilities, schools and health centres in remote rural areas. In this study, JICA is exploring a new idea of combining a PV institutional system and a battery charging system that is open to community people of Kenya and Uganda. This hybrid system is named Community Solar System (CSS).

It is clear that the objective of developing PV institutional systems is to improve social services, education, health care, water supply, etc. which are being provided by the local public facilities. In addition, the development of PV battery charging facilities with PV institutional systems to provide mobile phone charging service to community people for immediate benefits of their daily life is conceived to be feasible. Furthermore, these battery charging facilities will promote the change of rural lighting from conventional kerosene lamps to rechargeable lamps that use fluorescent tubes or LEDs, which is viewed as a promising scenario for poverty eradication in non-electrified areas.

The battery charging facility can be developed independently. However, the CSS is expected to work more effectively because of synergy effects between PV institutional system and battery charging system. This approach is quite different from the conventional approach of distributing Solar Home Systems (SHSs) into remote non-electrified communities. However, it does not reject SHS which is useful but a little more expensive. Rather, it will pave the way for the dissemination of SHS.

If kerosene lamps are replaced with rechargeable lamps, the rural household economy will not be affected by surging fuel prices. Also, the rural people will become free from risks of fire and health hazards caused by smoke. Furthermore, carbon dioxide emissions will be reduced. Thus, the dissemination of energy efficient and long-lasting LED into the rural areas together with battery charging facilities would share the same goal with the Lighting Africa Project that is supported by the World Bank and IFC. Japan, being the front runner in PV panels, LEDs and rechargeable batteries, is expected to play a leading role in pioneering the initiative of deploying CSSs in remote non-electrified areas of developing countries.

This project is conceived to realize the following benefits:

- Public facilities are improved through the use of electricity for lighting, vaccine refrigeration, office equipment, etc.;
- Local people can easily charge their mobile phones, rechargeable lamps, car batteries in their respective community;
- Provision of high level social services will continue through secured funds for PV system maintenance collected from charging service fees; and

- Many battery charging system users will interact with each other and, thereby, acquire knowledge about PV which, in turn, will help in PV market expansion.

Many villagers exchange and share information about rechargeable lamps and other equipment when they come to the battery charging facility. For example, a rechargeable LED lantern, which is not known in remote areas, can spread quickly if such information exchange mechanism exists. Thus, the battery charging facility should be recognized to work not only for income generation but also for market development.

(PV System Sizing)

12. Installed Model Systems

(Kenya)

The generated power is mainly used for lighting, and PV module and related component of the system are installed at each building within the same facility as individual power source based on specific requirement. Prior to tendering, the size of the PV system is determined based on a detailed survey of load demands, load types, utilization pattern, size of rooms, and other related data. From the above table, it is understood that the capacity of each system differs depending on the size and power requirement of each facility.

In the case of health centres, the smallest building consists of four to five rooms. Almost all health centres have small LPG-generated refrigerators for storing vaccines. Unfortunately, due to distribution/management problems, said units are no longer functioning in some of the health centres. The distributed vaccination refrigerators have a rated capacity of 85 W, which can also be operated by connecting to the power grid or with a 12 V DC system.

The system installed by MoE at public facilities varies according to the requirement of each building, and is thus provided as a separate individual unit. The system voltage at DC side is 12 V, which is converted to AC for power supply. If the system capacity is bigger than what the single charge controller or inverter can handle, the number of required components is increased to meet the capacity of the system and load demand. The day of autonomy taken is three days for system sizing of the capacity of a battery bank with allowable maximum discharge of 20%.

(Uganda)

In Uganda, through the cooperation of World Bank, the ERT program is developed and applied. It is intended for Ministry of Education and Sports (MoES) installation of PV systems at schools in rural off-grid areas.

The PV systems for rural health centers are also installed through ERT program. Under the program, 632 health facilities in 20 districts were surveyed from March to June 2004. It defined the required capacity of the system for each particular unit within the same facility. To determine the capacity of each unit within the same facility, the number of patients, covered area, and location of the facility are also considered. From this, the capacity of the systems is chosen to match the requirements depending on specific conditions and location of the facility, regardless of the similarity in the overall size of the buildings.

13. Design of Off-grid PV System and Design Tool

Unlike grid-connected PV systems, off-grid PV systems are closed systems that store electricity generated by PV in batteries and use it when necessary for lights and other appliances. Therefore, the first step of the system design is to estimate the daily electricity loads. Then, the necessary capacity of PV modules (solar array) and batteries (battery bank) can be calculated.

It is important that in case of closed system without back-up, the designed generating and storage capacity should have a relatively large margin. Hence, the system should have enough redundancy and can cope with unexpected situations such as surges in electricity demand or long cloudy days, to provide stable electricity supply. The Community Solar System that will be built in remote areas of developing countries also needs to have large redundancy, taking into account the risk of poor maintenance.

The system designer needs to be careful about overestimation because the staff of targeted public facilities tends to express their desires, not fair thoughts, on the number of electrical appliances and their usage. If the designer uses these figures in the load estimation, the capacity of PV system may be much larger than what is actually needed and the load factor will remain pretty low. This often leads to criticisms by outside people. To avoid these problems, it is recommended to use the average, and not the maximum figures, on the number of appliances and hours of usage.

The size of solar array depends on the solar radiation of the construction site. Therefore, it is necessary to obtain the solar radiation data before system design. The capacity of the battery bank varies depending on the length of period (days of autonomy) in which power supply continues even when PV power generation is impossible due to long cloudy and rainy days or system failure.

The battery charging facility is planned to provide services to the following three types of rechargeable batteries:

(1) Mobile phones (Recharge with 240 V AC adaptors)
(2) Rechargeable lamps (same as above)
(3) Automotive batteries (Direct connection with PV modules)

The final consideration is that the total capacity of the solar array and battery bank is determined as multiples of the capacities of the selected PV module and battery.

When implementing this scenario or building the Community Solar System, the system design is conducted by applying the process indicated above. Daily loads are to be calculated using the actual data of targeted public facilities. However, the size, layout and electricity demand of these facilities varies a lot depending on regional conditions, both in Kenya and Uganda. Therefore, it is difficult to show a standard design. Rather, it is more effective to develop a versatile “design tool” that can automatically calculate the necessary size of PV modules, inverters and batteries using the value of estimated loads and meteorological data. The tool can be used not only in Kenya and Uganda, but also in many other developing countries. The design tool requires the following:

14. Basic Condition for System Design

(Solar Insolation and Days of Autonomy (No-sun Days))

The national annual average horizontal solar insolation of Kenya is between 4 to 6 kWh/m^2/day (i.e., from 4 to 6 hours of solar insolation). For system sizing, an average value of 5 kWh/m^2/day (5 hours of solar insolation) is adopted.

In Uganda, the national annual average horizontal solar insolation is between 4.4 to 5.5 kWh/m^2/day and a system sizing value of 5.0 kWh/m^2/day is adopted, except for the southwest and mountain regions where the adopted value is 4.0 kWh/m^2/day.

For system sizing purposes, the average value of 5 kWh/m^2/day (5 hour of solar insolation) is adopted.

In the PV system, it is a fact that power generation is not usually possible at night and during bad weather days. Thus, the need to supply power shall be as per demand basis. It is therefore required to consider days without sun and power storage, for smooth system operation. For a lighting system, power storage is considered for three days in general. In Kenya, the practice is to consider no sun for three to four days, as also adopted by REA. The same practice is also considered in Uganda.

(System Voltage)

The present system voltage in Kenya is 12 V DC. In case of Uganda, 24 V DC is applied to health centres and 12 V DC to schools. In both countries, AC power supply system is 240 V, 50 Hz. To maintain the standards in this plan, the present adopted system voltage is also adopted for system sizing.

(Storage Battery)

In Kenya, open-type large capacity vehicle battery manufactured within the country is used in most cases. These are improved type of battery for PV system, which have a short life and require several replacements for a long span to obtain smooth and reliable system operation. In the case of Uganda, considering transportation and maintenance, the sealed type of storage battery is generally used. Depending on maintenance methods, utilization pattern and conditions of storage battery life varies system by system.

The capacity of the battery is 72 hours (for 3 no-sun days) excluding battery correction factor. Normally, the rated battery capacity is indicated at either 10 or 20 hours rate (hr). To select the battery, it is imperative to understand the battery capacity either at calculated hour or at rated capacity indicated by the manufacturer. Therefore, the calculated capacity is changed to rated capacity for better understanding. Battery factor differs depending upon type and manufacturer; therefore, it is required to adopt the exact value at the time of installation. For simplicity, the average battery rate factor of 1.3 is applied to understand the capacity at 20 hours rate and rounded up to adjust to market availability.

(Lighting Load)

LED lamps are drawing attention recently as the lighting of the new generation because of their high energy efficiency and long life. Research and development of LED lamp is continuing, and its commercial application has already started. It is advantageous to use LED lights with PV systems. Due to their high price, LED lamps are not widely used at the moment. However, with efficient LED, PV systems can be smaller in size if compared with the case of using traditional fluorescent lamps. The savings in the PV system development cost may offset the cost of LED lamps. For the case of rechargeable lamps, smaller size batteries can be used with LED, or the charging intervals can be longer if same size batteries are used.

Furthermore, fluorescent lamps need to be replaced when they expire. Since replacement lamps are difficult to buy in remote areas, this decreases the sustainability of the PV system. In contrast, LED lamps have very long life and replacement will be no longer necessary, which will dramatically improve the PV system's sustainability. With such advantages, it is important to endeavor using LED lamps with the PV systems in remote areas.

In this report, two cases of system sizing are described:

- **Case I**: The presently installed related components in public facilities are adopted as a system. The PV modules are either made in Europe, U.S., India or China, however, the price in the local markets is expensive because of the small sizes of procurement lots. Batteries made in local or neighboring countries are adopted and the depth of discharge of the battery is assumed to be 50%.
- **Case II**: Equipment is the same as that adopted in Case I, however, lighting loads are not assumed to be fluorescent light, which is commonly used in Kenya and Uganda, but LED lamps which are energy-saving and long life. Hence, the system size is downsized for reference. Lighting loads in Case II is estimated to be 70% of those in Case I.

Table 14-1 summarizes the system sizing parameters to calculate the system capacity.

Table 14-1 System Sizing Parameters

Item	Value	Unit	Remark
Average solar insolation hour	5	hour	Possible insolation to have at earth surface converted to hourly basis (1,000 W/m^2×5 h/day=5 kWh/m^2/day)
Days of autonomy (No-sun day)	3	day	Possible occurrences of no-Sun days
PV module efficiency	80	%	Lifetime eff. and power reduction due to temp. rises and dirt's
Inverter efficiency	90	%	Conversion eff. of inverter (DC to AC) (may vary by manufacturer)
Charge controller efficiency	95	%	To protect from over charge and discharge (may vary by manufacturer)
Battery efficiency	90	%	Charge discharge loss and self discharge
Max of depth of discharge (DOD)	50	%	Max. possible discharge (of improved car and sealed type battery)
DC system voltage (School, Health center & Charging facility in Kenya)	12	V	Supply voltage is AC 240 V, 50 Hz
DC system voltage (Health center in Uganda)	24	V	
DC system voltage (School & Charging facility in Uganda)	12	V	
PV module voltage	17	V	Depends upon type of module selected (at standard conditions)

Prepared by JICA Study Team

15. System Design Plan

Besides the system sizing parameters, there are also other factors which affect the size of the system and its smooth operation. Public facilities such as schools and health centres have different purposes, and their requirement, utilization pattern and size of facility need to be considered to meet their demands. For this, system sizing is done by assuming the average demand and utilization pattern. Besides the required capacity for public facilities, the required system capacity for charging facility is calculated. In case the public facilities and charging facility can be installed at the same site, the system size of the charging facility is added to that of the public facilities.

If LED lamps are used, it will then be possible to reduce the capacity of PV and storage batteries, which will also directly affect the cost of the total system. There are no definite plans to provide access to LED lamps for local people at present, although it will be possible to utilize LED lamps in case Japan implements equipment supply.

(School of Kenya)

The assumed loads are summarized in **Table 15-1**. The system capacity, size and number of components are shown in **Table 15-2** and **Table 15-3**.

Table 15-1 Assumed Loads of Secondary School (Kenya)

Subject	Load (W)	Qty.	Load sub-total (W)	Use (h/day)	Daily load (Wh/day)	Remark
For main building			**1,440**		**3,700**	**Sub-total**
Class room	120	4	480	3	1,440	(20 W x 6 lamps) x 4 room
Laboratory	20	2	40	3	120	20 W x 2 lamps
Principal office	20	1	20	1	20	20 W x 1 lamp
Vic-principal office	20	1	20	1	20	20 W x 1 lamp
Staff office	20	2	40	1	40	20 W x 2 lamps
Administration office	20	1	20	1	20	20 W x 1 lamp
Library	20	2	40	3	120	20 W x 2 lamps
Entrance hall & corridor	10	4	40	3	120	10 W x 4 lamps
Computer for office work (including printer)	350	2	700	2	1,400	Normally running hour is short, it is also use to prepare question papers and printing
Security lights	10	4	40	10	400	Outdoor lights
For dormitory			**160**		**960**	**Sub-total**
Boys dormitory	10	4	40	2	80	10 W x 4 lamps (around 90 student)
Girls dormitory	10	4	40	2	80	10 W x 4 lamps (around 90 student)
Security lights	10	8	80	10	800	Outdoor lights for 2 buildings
For dining hall and kitchen			**310**		**1,210**	**Sub-total**
Kitchen	20	3	60	3	180	Including preparation & cleaning
Dinning hall	20	3	60	3	180	Including cleaning
Security lights	10	4	40	10	400	Out door lights
TV (holidays and free hours)	150	1	150	3	450	At dining hall
For staff quarter			**130**		**340**	**Sub-total**
Bed room	10	2	20	2	40	2 bed rooms
Living room	10	1	10	2	20	Common use
Kitchen	10	1	10	2	20	Common use
TV/Radio	80	1	80	3	240	Common use
Entrance	10	1	10	2	20	10 W x 1 lamp

Prepared by JICA Study Team

Table 15-2 System Capacity, Size and Number of Components for School (Kenya, Case I)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,704	Wp	And above
Battery (12V, @20hr) with base/box	1	1,900	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	1,000	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	221	Wp	And above
Battery (12V, @20hr) with base/box	2	300	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	15	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	558	Wp	And above
Battery (12V, @20hr) with base/box	1	700	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	500	W	Capacity of each
Charge controller (12 V DC)	1	40	Amp	Capacity of each
For staff quarter				
PV module	1	157	Wp	And above
Battery (12V, @20hr) with base/box	1	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	10	Amp	Capacity of each

Prepared by JICA Study Team

Table 15-3 System Capacity, Size and Number of Components for School (Kenya, Case II)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,386	Wp	And above
Battery (12V, @20hr) with base/box	1	1,600	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	1,250	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	155	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	453	Wp	And above
Battery (12V, @20hr) with base/box	1	500	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	30	Amp	Capacity of each
For staff quarter				
PV module	1	143	Wp	And above
Battery (12V, @20hr) with base/box	1	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	10	Amp	Capacity of each

Prepared by JICA Study Team

(School of Uganda)

The assumed loads are summarized in **Table 15-4**. The system capacity, size and number of components are shown in **Table 15-5** and **Table 15-6**.

Table 15-4 Assumed Loads of Secondary School (Uganda)

Subject	Load (W)	Qty.	Load sub-total (W)	Use (h/day)	Daily load (Wh/day)	Remark
For main building			**1,680**		**4,420**	**Sub-total**
Class room	120	6	720	3	2,160	(20 W x 6 lamps) x 6 room
Laboratory	20	2	40	3	120	20 W x 2 lamps
Principal office	20	1	20	1	20	20 W x 1 lamp
Vic-principal office	20	1	20	1	20	20 W x 1 lamp
Staff office	20	2	40	1	40	20 W x 2 lamps
Administration office	20	1	20	1	20	20 W x 1 lamp
Library	20	2	40	3	120	20 W x 2 lamps
Entrance hall & corridor	10	4	40	3	120	10 W x 4 lamps
Computer for office work (including printer)	350	2	700	2	1,400	Normally running hour is short, it is also use to prepare question papers and printing
Security lights around building	10	4	40	10	400	Outdoor lights
For dormitory			**200**		**1,040**	**Sub-total**
Boys dormitory	30	2	60	2	120	(10 W x 3 lamps) x 2 bed rooms
Girls dormitory	30	2	60	2	120	(10 W x 3 lamps) x 2 bed rooms
Security lights	10	8	80	10	800	Outdoor lights for 2 buildings
For dining hall and kitchen			**310**		**1,210**	**Sub-total**
Kitchen	20	3	60	3	180	Including preparation & cleaning
Dinning hall	20	3	60	3	180	Including cleaning
Security lights	10	4	40	10	400	Outdoor lights
TV (holidays and free hours)	150	1	150	3	450	At dining hall
For staff quarter			**260**		**680**	**Sub-total**
Bed room	20	2	40	2	80	(10 W x 2 lamp) x 2 buildings
Living room	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
Kitchen	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
TV/Radio	80	2	160	3	480	80 W x 2 buildings
Entrance	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings

Prepared by JICA Study Team

Table 15-5 System Capacity, Size and Number of Components for School (Uganda, Case I)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	2,035	Wp	And above
Battery (12V, @20hr) with base/box	1	2,300	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	1,000	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	240	Wp	And above
Battery (12V, @20hr) with base/box	2	300	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	15	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	558	Wp	And above
Battery (12V, @20hr) with base/box	1	700	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	500	W	Capacity of each
Charge controller (12 V DC)	1	40	Amp	Capacity of each
For staff quarter				
PV module	2	157	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

Table 15-6 System Capacity, Size and Number of Components for School (Uganda, Case II)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,618	Wp	And above
Battery (12V, @20hr) with base/box	1	1,800	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	1,000	W	Capacity of each
Charge controller (12 V DC)	2	60	Amp	Capacity of each
For dormitory				
PV module	2	168	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each
For dining hall and kitchen				
PV module	1	453	Wp	And above
Battery (12V, @20hr) with base/box	1	500	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	30	Amp	Capacity of each
For staff quarter				
PV module	2	143	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

(Health Facility of Kenya)

The assumed loads are summarized in **Table 15-7**. The system capacity, size and number of components are shown in **Table 15-8** and **Table 15-9**.

Table 15-7 Assumed Loads of Health Facility (Kenya)

Subject	Load (W)	Qty.	Load sub-total (W)	Use (h/day)	Daily load (Wh/day)	Remark
For main building			**880**		**2,920**	**Sub-total**
Waiting room	20	1	20	2	40	20 W x 1 lamp
Examination room	20	2	40	2	80	20 W x 2 lamps
Treatment room	20	2	40	2	80	20 W x 2 lamps
Office	20	1	20	2	40	20 W x 1 lamp
Medicine distribution and store	20	2	40	2	80	20 W x 2 lamps
Emergency operation room	20	5	100	2	200	20 W x 5 lamps
Maternity ward	60	3	180	3	540	(20 W x 3 lamps) x 2 rooms
Store room	10	1	10	1	10	10 W x 1 lamps
TV for information (with DVD/VCR)	350	1	350	3	1,050	Health information to public
Security lights	10	8	80	10	800	Outdoor lights
For refrigerator			**85**		**2,040**	**Sub-total**
Small vaccine refrigerator (12V DC)	85	1	85	24	2,040	Once cooled, low consumption
For staff quarter			**260**		**520**	**Sub-total**
Bed room	20	2	40	2	80	(10 W x 2 lamp) x 2 buildings
Living room	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
Kitchen	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings
TV/Radio	80	2	160	2	320	80 W x 2 buildings
Entrance	10	2	20	2	40	(10 W x 1 lamp) x 2 buildings

Prepared by JICA Study Team

Table 15-8 System Capacity, Size and Number of Components for Health Facility (Kenya, Case I)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,345	Wp	And above
Battery (12V, @20hr) with base/box	1	1,500	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	1,000	W	Capacity of each
Charge controller (12 V DC)	2	40	Amp	Capacity of each
For refrigerator				
PV module	1	846	Wp	And above
Battery (12V, @20hr) with base/box	1	1,000	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	N/A	N/A	W	Capacity of each
Charge controller (12 V DC)	1	60	Amp	Capacity of each
For staff quarter				
PV module	2	120	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

Table 15-9 System Capacity, Size and Number of Component for Health Facility (Kenya, Case II)

Subject	Qty.	Capacity	Unit	Remark
For main building				
PV module	1	1,087	Wp	And above
Battery (12V, @20hr) with base/box	1	1,200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	800	W	Capacity of each
Charge controller (12 V DC)	2	40	Amp	Capacity of each
For refrigerator				
PV module	1	846	Wp	And above
Battery (12V, @20hr) with base/box	1	1,000	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	N/A	N/A	W	Capacity of each
Charge controller (12 V DC)	1	60	Amp	Capacity of each
For staff quarter				
PV module	2	107	Wp	And above
Battery (12V, @20hr) with base/box	2	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	2	300	W	Capacity of each
Charge controller (12 V DC)	2	10	Amp	Capacity of each

Prepared by JICA Study Team

(Health Centre of Uganda)

The ERT program is adopted as the base for power supply by PV system categorized depending upon requirement. The study team also carried the system calculation based on the same categorization. For load calculation of Case II, 100% of the load in wards and 40% in the staff quarters are assumed as lighting load. The assumed loads are summarized in **Table 15-10**. The system capacity, size and number of components are shown in **Table 15-11** and **Table 15-12**.

Table 15-10 Assumed Loads of Health Facility (Uganda)

	AC Loads (Wh/day)								
	HC IV			HC III			HC II		
Wards	Except light	Light	Total	Except light	Light	Total	Except light	Light	Total
OPD	0	628	628	0	580	580	0	475	475
Maternity	0	922	922	0	732	732	0	436	436
General	0	941	941	0	660	660	0	390	390
Operation	0	1,700	1,700	0	900	900	N/A	N/A	N/A
Laboratory	0	172	172	0	80	80	N/A	N/A	N/A
Administration	0	882	882	0	626	626	0	240	240
Staff quarter	Except light	Light	Total	Except light	Light	Total	Except light	Light	Total
Senior medical officer	576	384	960	576	384	960	282	188	470
Doctor	474	316	790	N/A	N/A	N/A	N/A	N/A	N/A
Clinical officer	282	188	470	282	188	470	N/A	N/A	N/A
Nurse 2	588	392	980	588	392	980	588	392	980
Nurse 1B	450	300	750	N/A	N/A	N/A	N/A	N/A	N/A
Nurse 1A	258	172	430	258	172	430	258	172	430
Nurse	150	100	250	150	100	250	150	100	250
Other loads									
Refrigerator small (12V DC)			2,040			2,040			2,040
Refrigerator medium			4,800			4,800		N/A	
Information TV (with DVD/VCR)			1,050			1,050			1,050

Prepared by JICA Study Team

Table 15-11 System Capacity, Size and Number of Component for Health Facility (Uganda, Case I)

Subject	PV module (Wp)	Inverter (W)	C/C (Amp.)	Battery (Ah)	Remark
HC IV					
					Total of PV module: 8,094 Wp
Wards					
OPD	290	800	10	200	12V battery*2 capacity @20hr
Maternity	425	600	15	300	12V battery*2 capacity @20hr
General	434	600	15	300	12V battery*2 capacity @20hr
Operation	783	1,000	30	500	12V battery*2 capacity @20hr
Laboratory	80	200	10	100	12V battery*2 capacity @20hr
Administration	406	600	15	300	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	442	600	15	300	12V battery*2 capacity @20hr
Doctor	364	500	15	200	12V battery*2 capacity @20hr
Clinical officer	217	300	10	200	12V battery*2 capacity @20hr
Nurse 2	452	500	15	300	12V battery*2 capacity @20hr
Nurse 1B	346	300	10	200	12V battery*2 capacity @20hr
Nurse 1A	199	200	10	200	12V battery*2 capacity @20hr
Nurse	116	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC III					
					Total of PV module: 6,618 Wp
Wards					
OPD	268	600	10	200	12V battery*2 capacity @20hr
Maternity	338	500	10	200	12V battery*2 capacity @20hr
General	305	300	10	200	12V battery*2 capacity @20hr
Operation	415	500	15	300	12V battery*2 capacity @20hr
Laboratory	37	300	10	100	12V battery*2 capacity @20hr
Administration	289	200	10	200	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	442	600	15	300	12V battery*2 capacity @20hr
Clinical officer	217	300	10	200	12V battery*2 capacity @20hr
Nurse 2	452	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	199	200	10	200	12V battery*2 capacity @20hr
Nurse	116	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC II					
					Total of PV module: 3,025 Wp
Wards					
OPD	219	600	10	200	12V battery*2 capacity @20hr
Maternity	201	500	10	200	12V battery*2 capacity @20hr
General	180	300	10	100	12V battery*2 capacity @20hr
Administration	111	200	10	100	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	217	600	10	200	12V battery*2 capacity @20hr
Nurse 2	452	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	199	200	10	200	12V battery*2 capacity @20hr
Nurse	116	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy

Prepared by JICA Study Team

Table 15-12 System Capacity, Size and Number of Component for Health Facility (Uganda, Case II)

Subject	PV module (Wp)	Inverter (W)	C/C (Amp.)	Battery (Ah)	Remark
HC IV					
					Total of PV module: 7,116 Wp
Wards					
OPD	203	800	10	200	12V battery*2 capacity @20hr
Maternity	298	600	10	200	12V battery*2 capacity @20hr
General	304	600	10	200	12V battery*2 capacity @20hr
Operation	549	1,000	20	300	12V battery*2 capacity @20hr
Laboratory	56	200	10	100	12V battery*2 capacity @20hr
Administration	285	600	10	200	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	389	600	15	300	12V battery*2 capacity @20hr
Doctor	321	500	10	200	12V battery*2 capacity @20hr
Clinical officer	191	300	10	200	12V battery*2 capacity @20hr
Nurse 2	398	500	15	300	12V battery*2 capacity @20hr
Nurse 1B	305	300	10	200	12V battery*2 capacity @20hr
Nurse 1A	175	200	10	100	12V battery*2 capacity @20hr
Nurse	102	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC III					
					Total of PV module: 5,951 Wp
Wards					
OPD	188	600	10	200	12V battery*2 capacity @20hr
Maternity	236	500	10	200	12V battery*2 capacity @20hr
General	213	300	10	200	12V battery*2 capacity @20hr
Operation	290	500	10	200	12V battery*2 capacity @20hr
Laboratory	27	300	10	100	12V battery*2 capacity @20hr
Administration	202	200	10	200	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	389	600	15	300	12V battery*2 capacity @20hr
Clinical officer	191	300	10	200	12V battery*2 capacity @20hr
Nurse 2	398	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	175	200	10	100	12V battery*2 capacity @20hr
Nurse	102	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Refrigerator medium	2,210	800	40	1,200	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy
HC II					
					Total of PV module: 2,694 Wp
Wards					
OPD	153	600	10	100	12V battery*2 capacity @20hr
Maternity	141	500	10	100	12V battery*2 capacity @20hr
General	126	300	10	100	12V battery*2 capacity @20hr
Administration	78	200	10	100	12V battery*2 capacity @20hr
Staff quarter					
Senior medical officer	191	600	10	200	12V battery*2 capacity @20hr
Nurse 2	398	500	15	300	12V battery*2 capacity @20hr
Nurse 1A	175	200	10	100	12V battery*2 capacity @20hr
Nurse	102	100	10	100	12V battery*2 capacity @20hr
Other loads					
Refrigerator small (12V DC)	846	N/A	30	500	12V battery*2 capacity @20hr
Information TV (with DVD/VCR)	484	200	15	N/A	No autonomy

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(Charging System)

In practice, the days of autonomy for PV lighting system is three days but in charging system there is no such case considered because the batteries of individual owners can be used for many days with one charging and each individual owner can manipulate the charging days of discharged batteries and vary the day of charging for each battery. If the system is designed with storage battery, the cost of the system will be higher which will directly reflect at the charging service tariff.
Mobile phones and rechargeable lamps have small batteries that need regular charging. For convenience, it is considered that mobile phones and rechargeable lamps can be charged even in a bad weather day. Therefore, one day of no-sun day is considered in the system for mobile and small rechargeable lamps.

The assumed loads are summarized in **Table 15-13**. The system capacity, size and number of components are shown in **Table 15-14**.

Table 15-13 Assumed Loads and Numbers to be Charged in a Day

Subject	Qty. (/day)	Voltage (V)	Capacity (Ah)	Daily load (Wh/day)	Remark
For mobile phone and lantern				**1,051**	**Sub-total**
Mobile phone (700 mAh @70% discharge, 4 V)	100	4	0.49	280	300 nos. (100% of 300HH), charging every 3 days (100 nos./day), AC adapter efficiency (70%) is considered.
Rechargable lantern (4 Ah @50% discharge, 6V)	45	6	2.00	771	225 nos. (75% of 300HH), charging every 5 days (45 nos./day), converting efficiency from AC to DC (70%) is considered.
For car battery as storage				**1,260**	**Sub-total**
Car battery (70 Ah @30% discharge, 12 V)	5	12	21.00	1,260	25 nos. (8% of 300HH), charging every 5 days (5 nos./day)

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Table 15-14 System Capacity, Size and Number of Components for Charging Station

Subject	Qty.	Capacity	Unit	Remark
PV module	1	1,009	Wp	And above
Battery (12V, @20hr) with base/box	1	200	Ah	Capacity @20hr
Inverter (In 12V DC, Out 240V,50Hz)	1	300	W	Capacity of each
Charge controller (12 V DC)	1	30	Amp	Capacity of each
Charge controller (12 V DC) with Ah Meter	5	10	Amp	Capacity of each

Prepared by JICA Study Team

(Criteria for Selecting Target Areas and Public Facilities)

16. Criteria for Selecting Target Areas

The target areas of CSS are non-electrified areas without electricity grids. Those communities having grid electricity plan but with no confirmed timetable are eligible for CSS development. The communities that have both social and economic functions (core communities) would be given high priority. In this scenario, it is planned to provide PV systems to the public facilities and PV battery charging facilities in the core communities to improve their public services.

In Kenya, electricity grids have been extended considerably to cover more than half of the country. Therefore, the communities and public facilities suitable for CSS are limited. At the moment, the REA of Kenya is formulating a master plan of rural electrification and the selection of around 250 public facilities targeted for off-grid electrification until the year 2013 will be completed by June 2009. Hence, it is recommended that JICA selects the candidate sites of CSS from the REA list of public facilities.

On the other hand, Uganda has low rural electrification rate and, therefore, has many public facilities suitable for CSS development. Its grid extension has not been going well as planned and off-grid electrification of public facilities by PV is regarded as an important component of rural electrification. Many donors, including the World Bank, have been implementing PV electrification of public facilities but the number of completed sites to date is still limited. Many public facilities are left without electricity. Hence, JICA can find the candidate sites of CSS by coordinating with REA, the World Bank and other donors to find the list of public facilities that have no plan of electrification.

There are some areas in both Kenya and Uganda where JICA sets restrictions on entering due to security reasons. However, the rural electrification rate in those areas is generally low and, therefore, the need for PV electrification of public facilities is high. Thus, it is recommended that JICA pursues appropriate measures to undertake PV electrification activities even in the restricted areas while considering the security conditions of the target sites.

17. Selection of Target Facilities

High priority public facilities suitable for CSS are Secondary Schools and upper level Health Centres (“Health Centre” in Kenya and “Health Centre III” in Uganda) in non-electrified areas. Isolated Primary Schools located deep in remote areas or large boarding Primary Schools, which can be viewed as important central schools in remote areas, would be also eligible for CSS. Similarly, isolated Health Centres servicing large areas would also be eligible.

In the premises of public facilities, the battery charging facility that deals with many customers every day should be properly located so as not to disturb the main activities of the public facilities. For example, in case of schools, battery charging facilities should be located away from classrooms so as not to make any nuisance.

(Demand Estimation and Financial Analysis of Combined PV System)

18. Demand Estimation

An estimate of the demand for battery charging in a rural community is shown in Table 18-1. Rechargeable lamps have just started entering the rural market. Rechargeable lamps made in China and India can be found even in remote areas. Some donors and the REA of Uganda have expressed strong interest in rechargeable lamps. Furthermore, some people will use large-size automotive batteries so they can use many lamps and watch TV at the same time, which is common in Asia but rare in Africa. Such practice will spread over time among high income families as rural people accumulate knowledge on PV.

Table 18-1 Estimated Number of Battery Charging Customers

Item	Estimation
Mobile phone charging	Number of owners 300, Interval every 3 days, Number of users 100/day
Rechargeable lantern charging	Number of owners 225, Interval every 5 days, Number of users 45/day
Automotive battery charging	Number of owners 25, Interval every 5 days, Number of users 5/day

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19. Financial Analysis

The estimated revenue of battery charging facility is shown in Table 19-1. This study revealed that the common rate of phone recharging fee is around US$ 0.25 in both Kenya and Uganda. However, data of lamp recharging fee was not easily obtained because of limited number of rechargeable lamps used in remote areas. It is estimated that the fee will be fixed at around US$ 0.50, which would be proportional to the rate of mobile phone charging fee. In case of automotive battery charging, recharging fee falls in the range from US$ 0.50 to US$ 2.00 in Uganda.

Table 19-1 Estimated Revenue from Battery Charging

Item	Estimation	Monthly revenue
Mobile phone	Number of owners 300, 10 charging/month, Fee US$ 0.25	US$ 750
Rechargeable lantern	Number of owners 225, 6 charging/month, Fee US$ 0.50	US$ 675
Automotive battery	Number of owners 25, 6 charging/month, Fee US$ 1.00	US$ 150
Total		US$ 1,575

Prepared by JICA Study Team

On the other hand, the associated costs include operators' salary (around $50 per month for one person), rewards for committee members, spare parts such as clips and cables, and replacement costs of charge controllers and batteries. In addition, the maintenance costs of institutional PV system should be taken into account. The aggregate costs, however, will be smaller than the expected revenue and the surplus would reach a significant amount, and the management of cash surplus must be worked out carefully.

(Management of Combined PV System and Human Resource Development)

20. Basic Concept of Management

For the PV institutional system, it is important to prepare maintenance manuals and provide well-designed training for the public facilities where PV systems are installed. In addition, maintenance support by installers, provision of warranty, and information service through mobile phone will support the public facilities. It is realized that the wide use of mobile phones even in remote areas facilitate communication with PV dealers. Information on troubleshooting and spare parts obtained conveniently and promptly is vital for PV dissemination.

For the battery charging system, many users will visit and use it daily. Users bring in their phones and other equipment for recharging and pay for the service. The required works such as dealing with customers, fee collection, record keeping, accounting, etc. would be time-consuming and labor-intensive. The staffs of public facility are busy in carrying out their assignments and therefore cannot conduct these additional tasks. Thus, establishing a good management system with newly-hired operators is the key to the success of the battery charging system.

Battery charging is important for the community just like water supply and therefore should be run properly every day. Moreover, the revenue should be managed properly and used for PV system maintenance. For these reasons, it would be appropriate that the battery charging system is owned and operated by the community.

21. Relationship with Existing Battery Charging Providers

There are situations where some villagers are already operating small PV battery charging stations at the communities where community solar systems are planned. In such cases, the impacts on existing charging services should be carefully examined.

If the charging fee of the community solar system is set at the same level as the existing charging stations, they can also serve other customers who live far from the community solar system since the charging services required is the same.

In addition, community solar systems can recharge large batteries used for rechargeable lamps, which is very difficult for existing small battery stations. Sales of rechargeable lamps (lanterns) in rural areas would grow quickly if battery charging services are accessible. Thus, it would be feasible to have a community solar system focusing on customers with large-size batteries.

22. Organizational Development at the Early Stage

The management of battery charging system discussed earlier is very important in achieving the objectives of a community solar system. However, the community people can hardly develop an appropriate scheme without assistance. JICA is therefore proposed to be responsible for the development of management scheme as well as the system development.

During the process of planning to construction, a series of meetings will be held to discuss the development plan of a community solar system. During such meetings, guidance must be given to the community regarding the organizational development for managing the community solar system.

These activities are to be conducted by consultants that have extensive experience in business development as soft component of project.

It is recommended therefore that monitoring activities should be continued for several years after the consulting services by JICA, to reinforce the management structure. There is a possibility to utilize Private Sector Development Centers (PSDCs) in Uganda to follow up the JICA project on community solar system and develop a promising business model for community-based PV battery charging.

23. Business Model for PV System Dissemination

Rechargeable lamps and other electrical products that need PV electricity will be widely used after the installation of the community solar system. Thus, the system works to lead the PV business development in remote areas as well as to provide battery charging services to remote villagers. When the community solar systems are developed in remote areas and battery charging has become part of the villagers' lives, it is expected that PV market expansion will naturally progress based on the following mechanism:

1) First Stage - Mobile Phone Charging

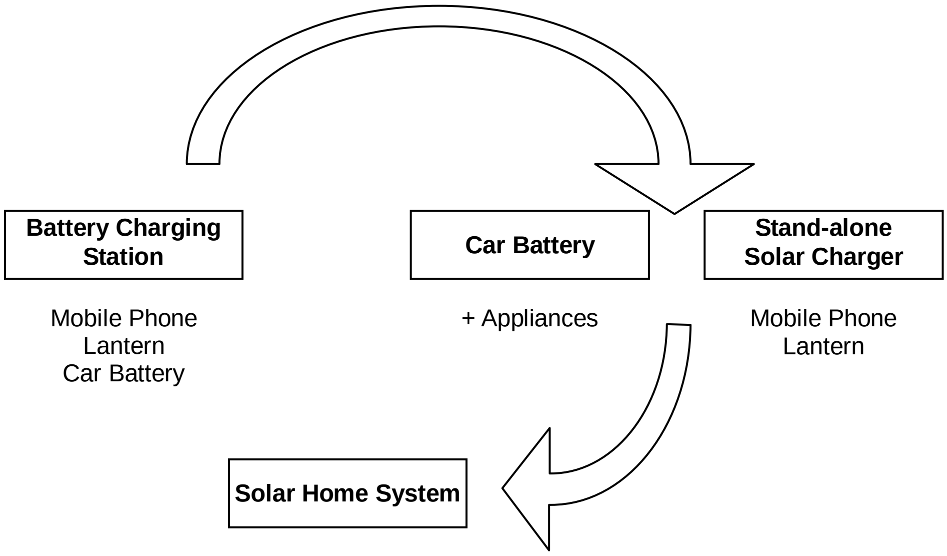
It is evident that there is a strong need for mobile phone charging services in remote communities. With community solar system, PV battery charging will spread in the community. The PV system can generate good income, which will encourage the owner of the community solar system to learn the proper use and maintenance of the PV system. The system will be sustainable and continue to provide battery charging service to the community people.

2) Second Stage - Introduction of other products with batteries

The villagers accumulate knowledge on PV application, and become interested in using electrical products that work with rechargeable batteries. They would try to use rechargeable LED lanterns that are starting to enter the local markets. PV dealers will increase their sales taking advantage of these trends. The more they use PV technology and rechargeable batteries in their daily lives, the more they learn about PV and batteries. Frequent use of the PV system for battery charging will spread knowledge of its benefits, and hence, rural people will gain confidence in the PV system. Although they were already aware of such system before, they will further gain confidence in the utilization of PV with the community solar system, which is fundamentally different. Thus, many villagers will be educated to properly use and maintain PV systems, and become potential customers of such systems.

3) Third Stage - Sales increase of high-end PV products

By using mobile phones and rechargeable lamps, many villagers become confident on PV and gain good knowledge for the sustainable use of PV. At this stage, many rural people will start developing ideas on how to use PV to improve their lives and consider purchasing PV accessories. Some high income families will buy upscale PV systems such as self-rechargeable solar lamps or solar home systems (SHS). PV dealers can increase their sales and are motivated to provide better service to cater to the increasing number of PV customers and expand such market. The favorable business cycle will emerge and evolve over time.



Prepared by JICA Study Team

Figure 23-1 Stages of PV Dissemination in Rural Communities

The business model elaborated above is different from the ordinary model that places emphasis on financial aspects and pursues the dissemination of SHS from the beginning. The new model also focuses on the flow of knowledge and information for the users, not only in monetary terms.

24. Human Resource Development

The above-mentioned business model starts with a PV battery charging system in non-electrified community, which will require an investment of several hundred dollars. Thus, financing needs for the investment will be effectively dealt with by local small financial institutions.

Sensitization on such new business and provision of information on PV dealers and PV system operation are more important than financial support. Also, it is very important to educate potential users to develop new customers of PV battery charging.

So far, user training has been conducted primarily by PV installers, which usually ends in inadequate results in remote areas. PV dealers cannot spend enough time and money for the customers who live in long distance. As a result, knowledge transfer to remote users is insufficient and PV systems cannot be operated in a sustainable way.

It is recommended to give training to those who are interested in PV battery charging business in their communities and to make them understand the basics of PV system. With such efforts, an effective information dissemination mechanism will be created in remote areas, in which the trainees will work as information providers and spread the knowledge about PV to other villagers.

(Recommendations)

1) Definition of Community Solar System in ODA Program and Start of Pilot Project

The concept of community solar system that integrates battery charging system with PV institutional system in public facilities is not yet recognized as a promising scheme to promote PV utilization in developing countries.

There is no technical difficulty in developing community solar systems, and the concept is easy to understand. Moreover, the required investment is relatively not substantial. Thus, many public and private organizations can undertake aid projects to build community solar systems. The concept contributes to the development of local communities and in the mitigation of global warming, thus, it should draw more attention and be clearly defined in the ODA program. Japan, having an edge in PV and LED technology, is expected to lead other counties in realizing the concept.

Based on this understanding, it is expected that JICA will conduct more in depth studies of the said concept and its effectiveness, and integrate it into Japan's ODA program. Wasting time for mulling this idea should be avoided. Early implementation of pilot projects is recommended to assess its feasibility, sustainability and replicability.

2) Support for New Business Model to Disseminate PV

The elaborated business model to accelerate PV development starts with a small battery charging business. The necessary investment for the venture is expected to be minimal and affordable, and therefore, local entrepreneurs who are interested in such business will emerge if funds are made available locally. Once it starts, the small business will soon generate good income from the existing strong demand for mobile phone charging and the growing need for rechargeable lamps.

In addition to the development of a local credit scheme, training is needed to be provided to local people who are interested in PV business, regarding the issues on PV technology, procurement and installation, and ways of providing battery charging services. Use of media such as newspapers and distribution of posters will be also effective. It is apparent that implementation of pilot projects using ODA funds have positive impacts to many people. Furthermore, integrating PV into the school curriculum, in vocational schools for instance, will be effective to ensure the supply of human resources for this business in the long term.

On the user side, the plan on gaining consumers' confidence in new products that work with rechargeable batteries is important. In particular, some rechargeable lamps, at the early stage of its dissemination in the market, are poor in quality and therefore may cause problems. Hence, the development of an appropriate quality certification scheme should be considered. In addition, application of LED technology to lighting equipment is recommended to improve sustainability. Measures to promote LED, such as the exemption of import duties on LED lamps, should be considered.

3) Human Resource Development in Japan

There is little demand for stand-alone PV systems in Japan, and therefore human resources that can work to develop them will remain very limited due to the lack of hands-on opportunities in the country. When JICA leads the role in building PV systems in developing countries, the bottleneck is the shortage of Japanese consultants who have experience in off-grid PV systems. Training of necessary human resources should be intentionally planned and conducted by JICA. Such training can be conducted only by JICA on a long-term basis, which private companies in Japan have no interest in undertaking. Thus, JICA strategically needs to consider how to develop domestic human resources for community solar system projects.

Application of small PV systems in remote areas is a community-oriented grassroots type project, and involvement of the local people is indispensable. Therefore, NGOs and volunteers working in Africa are expected to be more intensively involved in the projects for developing PV systems, which will augment JICA's programs.

4) International Collaboration

There are many international organizations and aid agencies involved in the projects for global warming mitigation and poverty reduction. It has become a major ODA concern to help African countries, whose demand for energy will grow in the future, in terms of development of renewable energy and achieving the improvement of living standards. The responsibilities of aid organizations are enormous. The international society is keen on this matter and pays attention to the activities of aid organizations. Thus, JICA needs to build strong relationships with other international organizations and coordinate its programs with them.