The Federal Republic of Nigeria
Federal Ministry of Power and Steel (FMPS)
Federal Ministry of Science and Technology (FMST)
Energy Commission of Nigeria (ECN)
Rural Electrification Agency (REA)

The Master Plan Study for Utilization of Solar Energy in the Federal Republic of Nigeria

Final Report

Volume 3 Pilot Project

February, 2007

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.

RECS INTERNATIONAL INC.

THE MASTER PLAN STUDY FOR UTILIZATION OF SOLAR ENERGY IN THE FEDERAL REPUBLIC OF NIGERIA

FINAL REPORT

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PREFACE

In response to a request from the Federal Republic of Nigeria, the Government of Japan decided to conduct "The Master Plan Study for utilization of solar energy in the federal republic of Nigeria" and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA dispatched the study team headed by Mr. Mitsuhisa NISHIKAWA of Yachiyo Engineering Co., Ltd. and organized by Yachiyo Engineering Co., Ltd. and RECS International Inc. to Nigeria six times from June 2005 to February 2007.

The study team had a series of discussions with the officials concerned of the Government of Nigeria and conducted related field surveys at the study area. Upon returning to Japan, the study team conducted further studies and compiled the final results in this report.

I hope that this report will contribute to the promotion of the plan and to the enhancement of amity between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Nigeria for their close cooperation throughout the study.

February 2007

Tadashi IZAWA
Vice President
Japan International Cooperation Agency

Mr. Tadashi IZAWA
Vice President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

February 2007

Dear Sir
It is my great pleasure to submit herewith the Final Report of "The Master Plan Study for Utilization of Solar Energy in the Federal Republic of Nigeria".

The Study Team that consists of Yachiyo Engineering Co., Ltd. and RECS International Inc. conducted field surveys including pilot projects in Nigeria over the period between June, 2005 and February, 2007 according to the contract with the Japan International Cooperation Agency (JICA).

The Study Team compiled this report, which proposes Master Plan and Action Plan for PV Rural Electrification, Action Plan for Research and Development of Solar Energy Technology, Action Plan for Awareness Raising of Solar Energy, etc, through close consultations with officials concerned of the Government of the Federal Republic of Nigeria and other authorities concerned.

On behalf of the Study Team, I would like to express my sincere appreciation to officials concerned of the Government of Nigeria and other authorities concerned for their cooperation, assistance, and heartfelt hospitality extended to the Study Team.

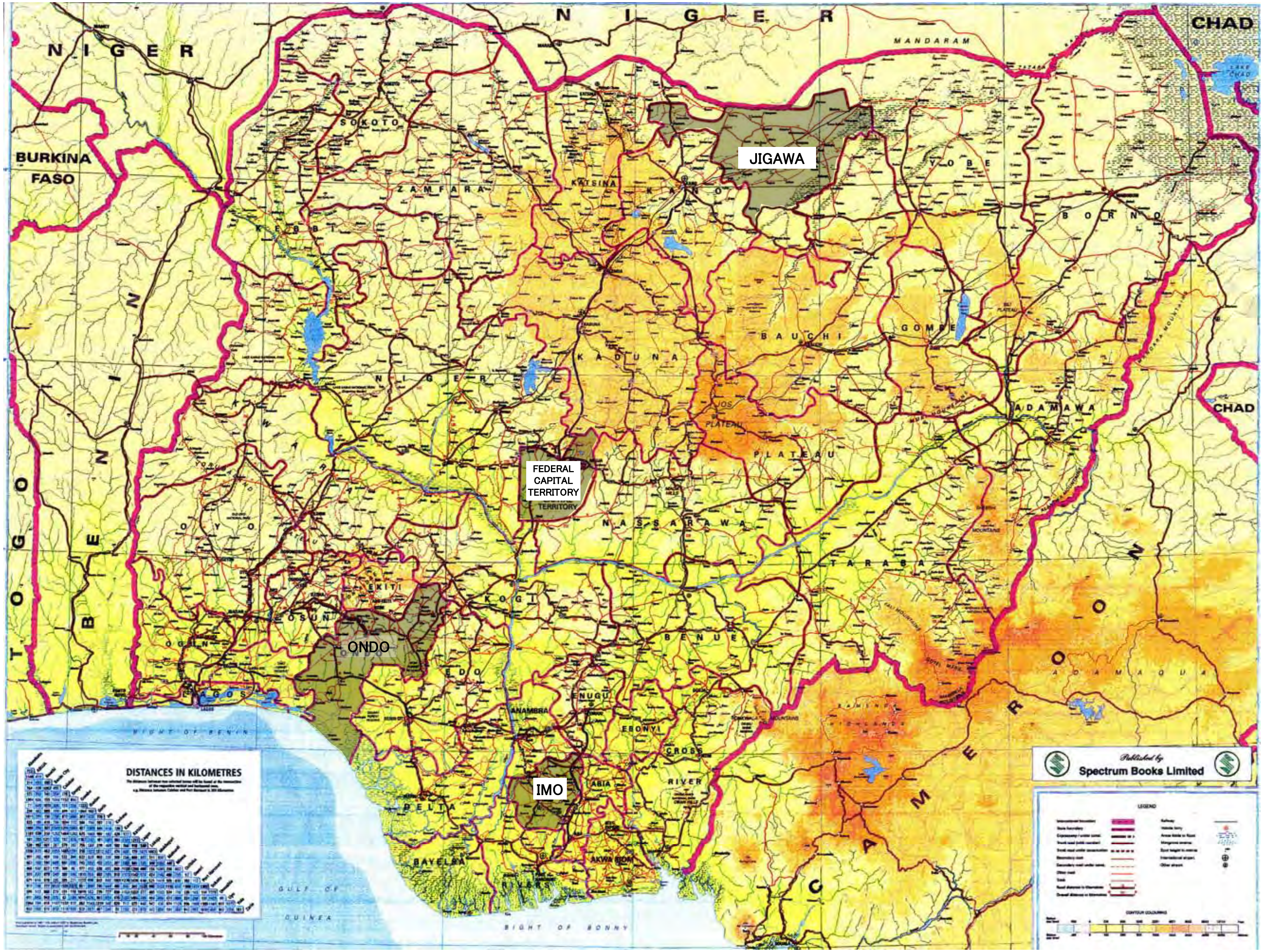
We are also deeply grateful to the Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Ministry of Economy, Trade and Industry, and the Embassy of Japan in Nigeria for their valuable suggestions and assistance during the course of the Study.

Yours faithfully,

Mitsuhisa Nishikawa
Team Leader
The Master Plan Study for
Utilization of Solar Energy in the
Federal Republic of Nigeria

THE MASTER PLAN STUDY FOR UTILIZATION OF SOLAR ENERGY IN THE FEDERAL REPUBLIC OF NIGERIA

FINAL REPORT
(VOLUME 3 PILOT PROJECT)



Study Area in the Federal Republic of Nigeria

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ABBREVIATION

BCS	Battery Charging Station
BPE	Bureau of Public Enterprises
CD	Capacity Development
ECN	Energy Commission of Nigeria)
FCT	Federal Capital Territory
FMPS	Federal Ministry of Power and Steel

(Federal Ministry of Power and Steel (FMPS) was reorganized to Federal Ministry of Energy on January 2007)

FMST	Federal Ministry of Science and Technology
IEC	International Electrotechnical Commission
IPP	Independent Power Producer
ISO	International Organization for Standards
JAEF	Jigawa Alternative Energy Fund
JICA	Japan International Cooperation Agency
JIS	JAPANESE INDUSTRIAL STANDARD
JWG	Joint Work Group
LGA	Local Government Area
LWG	Local Work Group
NEDO	New Energy Development Organization
NEPA	National Electric Power Authority
NESCO	National Electricity Supply Corporation (Nigeria) Limited
NIMET	Nigeria Meteorological Agency
NPC	National Planning Commission
O&M	Operation and Maintenance
OSEB	Ondo State Electricity Board
PDM	Project Design Matrix
PF	Public Facility
PHCN	Power Holding Company of Nigeria
PURD	Imo State Ministry of Public Utilities and Rural Development
REA	Rural Electrification Agency
REF	Rural Electrification Fund
SELF	Solar Electric Light Fund
SHS	Solar Home System
SL	Street Lighting
USAID	United States Agency for International Development
UNIDO	United Nations Industrial Development Organization
VEC	Village Electrification Committee
WB	World Bank
WHO	World Health Organization

VOLUME III PAILOT PROJECT

Chapter 1 Introduction

1.1 Objective of the Pilot Project

The Pilot Project (hereinafter referred to as "the Project") was carried out to attain knowledge which promotes to popularize PV systems in Nigeria in the future and to bring it in the Master Plan of Solar Energy Utilization (hereinafter referred to as "the Master Plan") by installing, operating, and maintaining PV systems which contribute to improve a living standard of villagers in unelectrified villages; monitoring and evaluating how they utilize the PV systems from technical and managing point of view.

For the above purpose, the JICA Study Team (hereinafter referred to as "the Study Team") selected three (3) unelectrified villages as the target villages—one (1) village each in Jigawa, Ondo, and Imo states having different weather conditions and life-style—and installed a variety of PV systems there. The activities of the Project were as follows:

1) Building up Operation and Maintenance (O&M) organizations and fee collection systems by participatory methods and monitoring how the organizations manage the Project,
2) Monitoring the maintenance records of PV systems and how the villagers utilize the systems,
3) Making and providing a PV systems manual for users, maintenance staff, and engineers,
4) Holding village meetings and making the users understand the limitation of PV systems,
5) Asking the users questionnaires about the Project and evaluating the impact on their lives by the PV systems, and
6) Attempting Capacity Developments (CDs) of counterparts in terms of the PV systems design, supervision, O&M, and management of organization.

Table 1-1 shows the Project Design Matrix (PDM[1]) of the Project.

1 PDM, which bases on the logical frame developed by United States Agency for International Development (USAID) in the late 1960s, is an outline matrix of project. The matrix consists of elements required for a project (Project Purpose, Outputs, Activities, Inputs, etc.) and shows the logical relationships between the elements. Here are "Project Purpose" means goal and/or benefit attained by the implementation of a project by the time of the end of the project, "Outputs" mean interim goals to attain the Project Purpose, "Activities" mean specific actions to achieve the Outputs applying the Inputs, "Inputs" mean human resources and/or finances required to implement the project, "Objectively Verifiable Indicators" mean indicators to judge the effectiveness of the Project Purpose and Outputs, "Means of Verification" mean data source to verify the Objectively Verifiable Indicators, and "Important Assumptions" mean uncertain assumptions being out of control by the project.

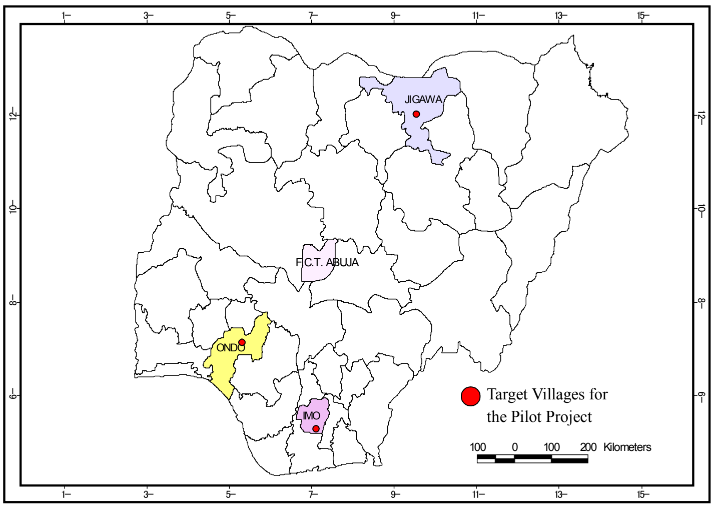
Table 1-1 Project Design Matrix of the Pilot Project

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Project Purpsoe The users understand the PV systems, and the systems are properly operated and are continuously utilized.	• The O&M organizations certainly collect the fees and maintain the PV systems. • The users understand the effect and limitation of the PV systems.	• Log book • Questionnaires	• The PV systems are not stolen.
Outputs 1. The O&M organizations function effectively. 2. The O&M organizations certainly maintain the PV systems. 3. The users utilize the PV systems properly. 4. The support systems from the counterparts are established.	1-1. The O&M organizations collect the fees and manage their finance. 1-2. The O&M organizations pay the salaries and procure the spare parts. 2. All the PV systems are utilizable. 3. The users manage the hour-of-use of the PV systems. 4. The counterparts periodically give a technical assistance.	1. Log book 2-1. Site survey 2-2. Maintenance report 3. Log book 4. Interview	• The O&M organizations monitor the PV systems. • The villagers utilize the PV systems.
Activities 1-1. Building up the O&M organizations by participatory methods 1-2. Monitoring how the O&M organizations manage the Project. 2-1. Monitoring the maintenance records. 2-2. Making and providing the PV systems manual. 3-1. Monitoring how the villagers utilize the PV systems. 3-2. Holding village meetings. 3-3. Asking the users questionnaires about the Project 4. Attempting CDs of counterparts.	**Inputs** Human resources (Japan, the Study Team) • Team leader 1 person • Solar energy utilization 2 persons • Pilot project management / participatory development 1 person Equipment • Jigawa State lot BCS:1, PF:1, SHS:40, SL:10 • Ondo State lot PF:1, SHS:60, SL:10 • Imo State lot PF:1, SHS:80, SL:10 Human resources (Nigeria, Counterparts) • Federal Ministries (FMPS, FMST, ECN), State Governments, Local Governments		• The installation works of equipment complete on schedule. **Pre-Conditions** • The villagers hope for electrification using PV systems. • The Nigerian Government supports the Project.

Source: JICA Study Team

1.2 Outline of the Pilot Project

Selecting one (1) unelectrified village each in Jigawa, Ondo, and Imo states respectively, the Project introduced PV systems composed of Public Facility (PF), Battery Charging Station (BCS), Solar Home System (SHS), and Street Lighting (SL)—Refer to Chapter 2 for the criteria of village selection. Fig. 1-1 shows the location of target villages of the Pilot Project.



Source: JICA Study Team

Fig. 1-1 Location of Target Villages of the Pilot Project

Firstly, the Study Team decided the type and specification of the PV systems based on the meteorological data and results of investigation of the target villages during the 1st and 2nd field survey, and made the technical specification and tender documents. Since a rural electrification project using PV systems[2] was implemented in Nigeria at the time of start of the Project, the Study Team consulted the above project site to decide the scale of implementation, to select the type of PV systems, and to build up O&M organizations.

Secondly, the JICA Nigeria office invited public tenders and procured the equipment for the Project during the 2nd field survey. The tender was divided into three (3) lots (Jigawa lot, Ondo lot, and Imo lot), and the delivery conditions were to complete the installation of equipment followed by the acceptance test at the site. The scale of each project was one (1) PF, eighty (80) individual PV systems (BCS and SHS), and ten (10) SLs. The final quantities of the PV systems were determined when JICA made a contract with the contractors.

Thirdly, the Study Team supervised the installation works of equipment throughout the 3rd and 4th field survey. As soon as the completion of the works, the Study Team started monitoring how the villagers would utilize the PV systems. Upon the completion of the works, the commissioning ceremonies were held at all the target villages. In Ondo state, the President (Chief Olusegun Obasanjo), Minister of FMPS, Minister of FMST, and Governor of Ondo state participated in the ceremony and celebrated the commissioning. After the ceremony, the O&M organizations started collecting the fees from the users.

Lastly, the Study Team collected the result of monitoring, asked the users questionnaires about the Project, and evaluated the Project from technical and managing point of view during the 5th field survey.

Table 1-2 shows the work schedule of the Project. The Project consisted of five (5) stages (survey, design, tender, supervision, and monitoring stages). JICA, the Study Team, and counterparts cooperated in implementing the Project as shown in the table.

2 SELF Project: Getting support form USAID and Jigawa state government, Solar Electric Light Fund (SELF), a non governmental organization based in Washington D.C., and Jigawa Alternative Energy Fund (JAEF), a non governmental organization established by Jigawa state government in 2001, cooperated in and carried out a rural electrification project using PV systems. They installed the PV systems (SHS, PV water pump, SL, PV vaccine refrigerator, etc.) in five (5) villages. USAID financed US$280,000; meanwhile Jigawa state government funded US$242,000. At present, JAEF maintains the systems.

Table 1-2 Work Schedule of the Pilot Project

	JICA	Study Team	Counterparts	Work Flow
1st Field Survey Jul. and Aug. 2005		**Selection of Project Sites** Selected the following village: ➤ Garkon Alli village in Jigawa state, and ➤ Oke-Agunla village in Ondo state		Survey
Domestic Study Sept. 2005	**Approval of Tender Documents**	**Preparation of Tender Documents** Prepared the following documents: ➤ design of PV systems ➤ technical specification, and ➤ contract agreement		Design
2nd Field Survey Oct. and Nov. 2005	**Tender Notice** Issued the tender documents for: ➤ Jigawa and Ondo lots, and ➤ Imo lot. **Tender Opening** Held the tender opening ceremony for: ➤ Jigawa and Ondo lots, and ➤ Imo lot. **Contract with Contactors** Made contracts for Jigawa, Ondo, and Imo lots.	**Selection of Project Sites** Selected Umuikoro/Opehi village in imo state. **Evaluation of Tenders / Negotiation with Bidders** Evaluated the tenders and negotiated with bidders for:Jigawa, Ondo, and Imo lots.		Survey Tender
Domestic Study Dec. 2005		**Review of Documents and Drawings** Reviewed the documents and drawings for approval.		Supervision
3rd Field Survey From Jan. to Mar. 2006	**Payment to Contarctors** Made payment to the contractor for Imo lot.	**Supervision of installation works** Supervised the installation works for Jigawa, Ondo, and Imo lots. **Capacity Development of Counterparts** Trained the counterparts by means of: ➤ teaching them the contents of tender documents, and ➤ supervising the installation works with them.		Supervision
Domestic Study Apr. 2006			**Supervision of installation works** The CPs supervised the project during the ST's absence.	Supervision
4th Field Survey From May to Jun. 2006	**Payment to Contarctors** Made payment to the contractor for Jigawa and Ondo lots.	**Supervision of installation works** Confirmed the completion of installation works for Jigawa, Ondo, and Imo lots. **Capacity Development of Counterparts** Trained the counterparts by means of: ➤ teaching them the contents of O&M manual, and ➤ supervising the installation works with them.		Supervision
Domestic Study From Jul. to Sept. 2006			**Monitoring of O&M records** The CPs monitor the O&M records during the ST's absence.	Monitoring
5th Field Survey From Oct. to Nov. 2006		**Monitoring of O&M records** Contents of monitoring: ➤ analyzing the O&M records, ➤ asking the users questionnaires about the Project, and ➤ evaluating the maintenance reports.		Monitoring

Source: JICA Study Team

Chapter 2 Target Villages

2.1 Criteria of Village Selection

Based on the 1st and 2nd field survey in July 2005 and October–November 2005 respectably, the Study Team selected three (3) villages as the target village—one (1) each in Jigawa, Ondo, and Imo states—among various unelectrified villages. Regarding the selection of target villages, the Study Team paid attention and evaluated the following points:

1) Villages were away from the existing distribution lines (further than 20 km), and they would not have any immediate plans to be electrified,
2) Villagers would approve electrification using PV systems while understanding the technical limitations of the systems,
3) Villagers had sufficient cash-income and could afford to pay a fee of the PV systems, and
4) There were residents who already used batteries in the villages. Besides, they could procure distilled water in the neighborhood and had effective means to transport the batteries.

Concretely, the Study Team visited the various villages recommended by the counterpart organizations in the state governments during the 1st and 2nd field surveys, and selected the villages using the above mentioned criteria. Furthermore, the Study Team evaluated the selected villages with attentions to project sustainability and development as well as benefits from the Project.

2.2 Selection Process of Target Villages and Village Descriptions

2.2.1 Target Village in Jigawa State

The Study Team investigated two (2) unelectrified villages of Jigawa state in the 1st field survey. Both of the villages were approximately 20 km away from the distribution lines, and their residents strongly requested electrification with the PV systems. In Garkon Alli village, the villagers already charged automobile batteries using a small generator and used them for the audible speaker at the PF. Because they already got used to the usage of the batteries, we judged that the village could afford to sustain and develop the Project. Therefore, we selected it as the target village.

Garkon Alli village is located in 9°30′ E longitude and 11°51′ N latitude, and in the distance of 30 minutes by car from the state capital (Dutse). It consists of approximately 400 households and 3,000 villagers. About 90% of them are farmers and owners of livestock. Most of them belong to the ethnic groups such as Hausa and Fulani, and the majority of them are Muslim. Their average annual income per household is around N40,000. The settlements are dotted in the village in the range of 650 m from south to north and of 350 m from east to west approximately. Roads are distributed in cross striped way to the four winds. There are a school, a mosque, and an Islamic school in the center of village, and many groceries and tailors are also in the business. As specific characteristics of the village, the boundaries of houses are enclosed by mud walls, and several houses made of mud are spotted on the premises.

Umuikoro/Opehi village is located in 7°5′ E longitude and 5°14′ N latitude, and in the distance of 90 minutes by car from the state capital (Owerri). It consists of approximately 1,000 households and 7,500 villagers. About 90% of them are farmers. Most of them belong to the ethnic group called Igbo (Ibo), and the majority of them are Christians. Their average annual income per household is around N200,000. The village houses are located both sides of the road from north to south in a distance of 750 m. There are some schools, several churches, and a couple of meeting places as well as a handful of groceries and tailors. As specific characteristics of the village, houses are constructed without walls, and located relatively close to each other in a form of compound.

Fig. 2-3 Panoramic View of Umuikoro/Opehi Village in Imo State

Chapter 3 Procurement of Equipment

3.1 Technical Specification of Equipment

3.1.1 Composition of PV Systems

In order to design PV systems for the Project, the Study Team referred to the technical specifications in the other pilot projects[1] in Asia and Africa done by JICA, various international standards[2], and system design manual[3] prepared by New Energy Development Organization (NEDO)

(1) System Voltage

System voltages are selected from either DC 12 V or DC 24 V according to their system outputs. The Project consisted of off-grid PV systems targeting unelectrified villages, and even its maximum output was small-scaled and less than 1 kW. Therefore, the Study Team selected DC 12 V as its system voltage because it was applicable to a variety of equipment.

(2) Circuit Type

In terms of large-scaled systems, AC electrical appliances are very often used while converting the outputs of the PV modules by inverters. However, the systems of the Project were small-scaled and did not have sufficient capacities for the use of AC appliances. Besides, to avoid breakages of equipment by mistaking AC for DC, the Study Team decided that the systems were composed only of DC circuit without inverters.

3.1.2 Equipment for PV Systems

(1) PV Module

A PV module is equipment to transform optical energy into electrical energy by means of the photo-electric effect of semiconductors. A silicon semiconductor in the module is enclosed with Ethylene-Vinyl Acetate (EVA), and the semiconductors are connected with ribbon wirings. Furthermore, the semiconductors filled with EVA resin are sandwiched between a front cover (reinforced-glass made) and back cover (film made), and rimmed with an aluminum frame.

A PV module is categorized into crystalline and amorphous according to the material kinds of silicon semiconductors. Table 3-1 shows the properties of the silicon semiconductor PV module.

Table 3-1 Properties of Silicon Semiconductor PV Module

Kind / Item	Monocrystal	Polycrystal	Amorphous
Conversion Efficiency	14–15%	11–13%	6–9%
Advantage	Widely used	High production volume	Cost reduction available
Disadvantage	High cost	High cost	Likely deteriorate

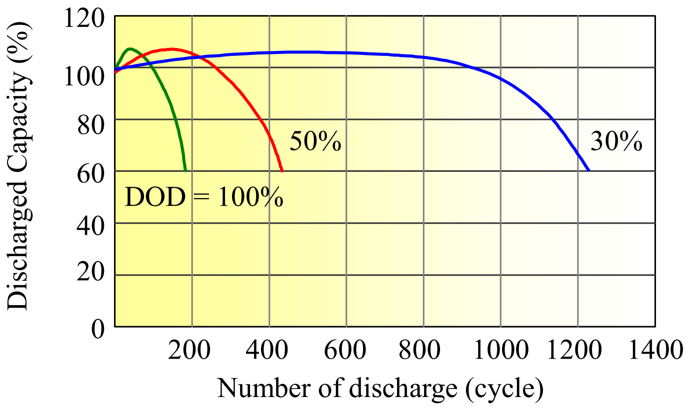
Source: JICA Study Team

1 *The Study on Rural Electrification Project by Renewable Energy in Lao People's Democratic Republic, The study on photovoltaic rural electrification plan in the Republic of Senegal, Study on the promotion of photovoltaic rural electrification in the Republic of Zimbabwe final report*, etc.
2 International Electrotechnical Commission (IEC), International Organization for Standardization (ISO), JAPANESE INDUSTRIAL STANDARD (JIS), etc.
3 *PV systems design manual,* March 2001

The Study Team did not adopt amorphous but crystalline (monocrystal or polycrystal) PV modules in the Project, because the amorphous would decrease its output caused by aged deterioration. Besides, we defined a 55 W module as the least unit since it was widely used in Nigeria and increased the number of the module in parallel according to the output of the PV systems.

(2) Battery

The Study Team used lead batteries in the Project, because they had a large capacity and were moderate-priced. Lead batteries are roughly classified into cycle and trickle use. A PV system repeats the cycles of charging electricity generated by the PV modules in the daytime and discharging it in the night. In general, batteries used for automobiles or Uninterruptible Power Supply (UPS) are float-charged at a constant voltage, and they are not appropriate for deep discharge (i.e. depth of discharge[4] is large) and the repeating of charge and discharge. Consequently, in the event that batteries for trickle use are applied to the PV systems, there is possibility that the lifetime of the batteries remarkably fall. Fig. 3-1 indicates the examples of battery discharge properties for trickle use with the depth of discharges as a parameter. In the Project, we planed to use sealed type batteries for cycle use, which electrolyte does not need to be refilled in principle. For BCS; however, we adopted batteries for trickle use (batteries for automobile), because they offer moderate-priced charging services, and the villagers can buy new ones at their own expense when the batteries complete their lives.



Source: JICA Study Team

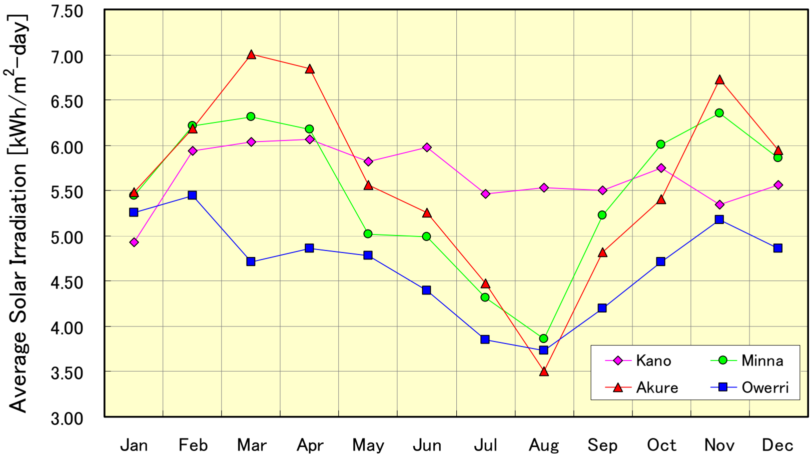
Fig. 3-1 Examples of Battery Discharge Properties for Trickle Use

3.1.3 Study on PV System Specifications

(1) Weather Condition

Nigeria is located between the north latitude of 4° and 14° and has tropical climate in the southern part. Moving toward the north, the climate turns out to be desertic, and the solar irradiation shows higher value. The annual average of solar irradiation is 5.5 kWh/m^2-day, and that of the sunshine duration is 6 hours. The monthly average solar irradiations at cities close to the target villages are 5.34 kWh/m^2-day at Kano in Jigawa state, 3.50 kWh/m^2-day at Akure in Ondo state, and 3.73 kWh/m^2-day at Owerri in Imo state respectively (Refer to Fig. 3-2 and Table 3-2), and the Study Team took these values for the design of PV systems.

4 Depth of Discharge (DOD): Ratio of the amount of electric discharge against rated capacity



Source: NIMET

Fig. 3-2 Monthly Average Solar Irradiation

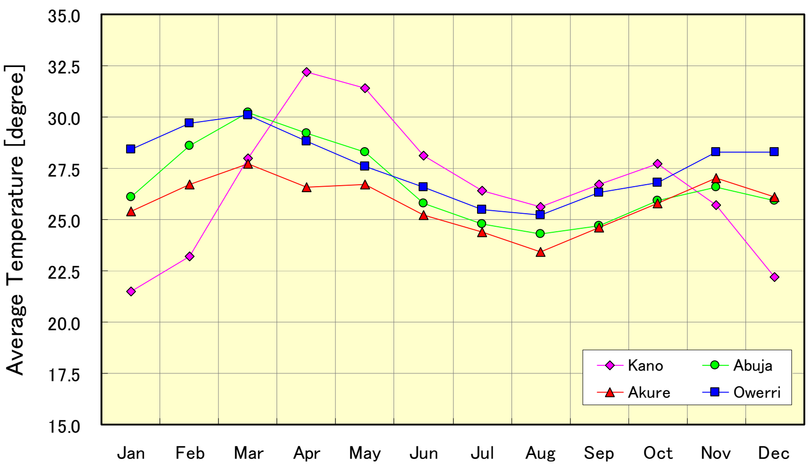
Table 3-2 Monthly Average Solar Irradiation

(KWh/m^2 - day)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean	Year
Kano	4.93	5.94	6.04	6.07	5.81	5.97	5.47	5.53	5.50	5.75	5.34	5.56	5.66	1995
Minna	5.44	6.21	6.32	6.18	5.02	4.98	4.32	3.86	5.23	6.00	6.35	5.86	6.01	1996
Akure	5.49	6.19	7.00	6.85	5.56	5.25	4.47	3.50	4.82	5.41	6.73	5.95	5.60	2002
Owerri	5.25	5.45	4.71	4.86	4.79	4.40	3.85	3.73	4.20	4.71	5.17	4.86	4.67	2002

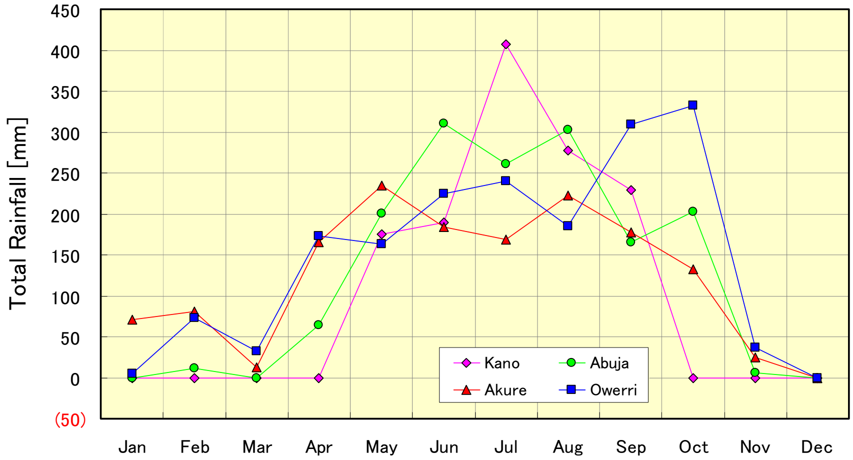
Source: NIMET

Fig. 3-3 and 3-4 represent the monthly average of ambient temperature and rainfall. The average ambient temperatures are constant and approximately between 25 and 30 ºC. Because it rains about 200 mm from March through September, the self-cleaning of PV module by rain can be expected.



Source: NIMET

Fig. 3-3 Monthly Average Ambient Temperature



Source: NIMET

Fig. 3-4 Monthly Average Rainfall

(2) SHS

a) Prerequisite

Take the minimum value of solar irradiations in Table 3-2 as the design values. Besides, assume that the maximum value of average ambient temperature is 45 °C and the running days of no solar radiation is three (3) days.

b) Estimation of Daily Consumed Ampere-hour

All loads is supposed to be DC equipment, and estimate the daily consumed ampere-hour, AH_C [Ah/day], by setting their electric power consumptions and hour-of-use as shown in Table 3-3. AH_C is given by

$$AH_C = P \cdot H / V_S = P \cdot H / 12 \qquad (1)$$

where P: Electric Power Consumption [W], V_S: System voltage [V], H: Hour-of-use [h/day]. For setting the hour-of-use, we adjust the setting and repeat trial calculations up to the following d) so as to provide estimated loads with electricity by a panel of the 55 W module.

Table 3-3 Daily Consumed Ampere-hour

Name of State	Estimated Load	Electric Power Consumption P [W]	Hour-of-use H [h/day]	Consumed Ampere-hour AH_C [Ah/day]
Jigawa state	Fluorescent light: 9 W x 2	18.0	4.0	6.0
	Radio: 5 W x 1	5.0	2.0	0.9
			Total	6.9
Ondo and Imo states	Fluorescent light: 9 W x 2	18.0	3.5	5.3
	Radio: 5 W x 1	5.0	2.0	0.9
			Total	6.2

Source: JICA Study Team

c) Calculation of Daily Required Ampere-hour

Calculate the required ampere-hour generated by the PV modules per day, AH_R [Ah/day], as below.

First, define the design coefficient K as

$$K = K_D \cdot K_T \cdot K_B \cdot K_O \qquad (2)$$

where K_D: Correction coefficient of contamination, K_T: Correction coefficient of temperature, K_B: Correction coefficient of battery circuit and K_O: Other correction coefficient. As the result of five-point observations in Japan[5], the correction coefficient of contamination K_D can be 0.98.
Then define the correction coefficient of temperature as

$$K_T = 1 + \alpha\,(T + \Delta T - 25) \qquad (3)$$

where α: Coefficient of temperature, T: Average temperature and ΔT: Temperature rise of PV module. From the properties of typical PV modules, the output of the PV modules can be expected to decrease approximately by 20% if the temperature rises by 50 °C. Therefore, the substitutions for $\alpha = -0.4\%/°C$, $T = 45$ °C, and $\Delta T = 25$ °C in the formula (3) yields $K_T = 0.82$. The correction coefficient of battery circuit K_B indicates loss caused by charging, and we assume $K_B = 0.80$ considering the general coefficient of lead batteries. The other correction coefficient K_O means loss brought from wiring and charge controllers, and we assume $K_O = 0.90$. So, we find the design coefficient $K = 0.58$ from the formula (2). Following that, calculate the daily required ampere-hour, AH_R, which is given by

$$AH_R = AH_C / K \qquad (4)$$

Table 3-4 shows the result of calculation.

Table 3-4 Daily Required Ampere-hour

Name of State	Consumed Ampere-hour AH_C [Ah/day]	Design Coefficient K	Required Ampere-hour AH_R [Ah/day]
Jigawa state	6.9	0.58	12.0
Ondo and Imo states	6.2	0.58	10.8

Source: JICA Study Team

d) Selection of PV Module

Divide the solar irradiation, SI_A [kWh/m^2-day], set in a) above by 1,000 to find the sunshine duration of the sites converted into 1,000 W/m^2, H_{SR} [h/day]. Then divide AH_R given in c) above by H_{SR} to find the output current of PV module, I_{PV} [A], which is written as

$$I_{PV} = AH_R / H_{SR} = AH_R / (SI_A / 1000) \qquad (5)$$

Table 3-5 shows the result of calculation.

Table 3-5 Output Current of PV Module

Name of State	Solar Irradiation SI_A [kWh/m^2-day]	Conversion Value [W/m^2]	Required Ampere-hour AH_R [Ah/day]	Output Current of PV Module I_{PV} [A]
Jigawa state	5.34	1,000	12.0	2.3
Ondo state	3.50	1,000	10.8	3.1
Imo state	3.73	1,000	10.8	2.9

Source: JICA Study Team

Meanwhile, we find the output voltage of the PV modules, V_{PV} [V], which is given by

5 *PV systems design manual*, March 2001

$$V_{PV} = V_S \cdot K_c + \Delta V_D + \Delta V_L \qquad (6)$$

where V_S: System voltage [V], K_c: Coefficient of full charge, ΔV_D: Voltage drop of diode [V], and ΔV_L: Voltage drop of wiring [V]. Substitute for V_S = 12 V, K_c = 1.24, ΔV_D = 0.7 V, and ΔV_L = 12 V x 2.5% = 0.3 V (according to the Nigerian standards) in the formula (6), and we get V_{PV} = 15.9 V. Table 3-6 indicates the typical specifications of a 55 W PV module and calculated value of required ampere and voltage. From the table, it can be seen that both the current and voltage are below the rated values of the PV module, and therefore, the required number of the module is one (1) panel for the system.

Table 3-6 Specification of PV Module

Name of State	Output [W]	Current I_{PV} [A]	Voltage V_{PV} [V]
Specification of 55 W Module	55	3.15	17.4
Jigawa state	—	2.30	15.9
Ondo state	—	3.10	15.9
Imo state	—	2.90	15.9

Source: JICA Study Team

e) Selection of Battery

Calculate the capacity of batteries, C_B [Ah/day], which is given by

$$C_B = AH_C \cdot D_{NSR} / (K_L \cdot DOD / 100) \qquad (7)$$

where AH_C: Ampere-hour consumption [Ah/day], D_{NSR}: Running days of no solar radiation [day], DOD: Depth of discharge [%], and K_L: Coefficient of loss caused by wiring and charge controllers. Substitute for AH_C given in b), D_{NSR} = 3 days, K_L = 0.9, and DOD = 50% in the formula (7), and we get C_B as shown in Table 3-7.

Table 3-7 Battery Capacity

Name of State	Consumed Ampere-hour AH_C [Ah/day]	Running Days of No Solar Radiation D_{nsr} [day]	Depth of Discharge DOD [%]	Coefficient of Loss K_L	Battery Capacity C_B [Ah]
Jigawa sate	6.9	3	50	0.9	46.0
Ondo and Imo states	6.2	3	50	0.9	41.4

Source: JICA Study Team

f) System Specifications

Finally, select the charge controllers and wiring which have sufficient capacities against the load current. Table 3-8 shows the specifications of main equipment for SHS.

Table 3-8 Specifications of Main Equipment for SHS

Item \ Name of State	Jigawa state	Ondo and Imo states
PV Module	Crystalline 55 W x 1 unit	
Charge Controller	12 V, 4.5 A x 1 unit	
Battery	Sealed type for cycle use, 50 Ah x 1 unit	
Breaker	10 A, bipolar x 1 unit	
Cable	6 mm^2, 2.5 mm^2	
Installation Configuration	Pole-mounted type	
Lighting	12 V, 9 W Fluorescent light x 2 units	

Source: JICA Study Team

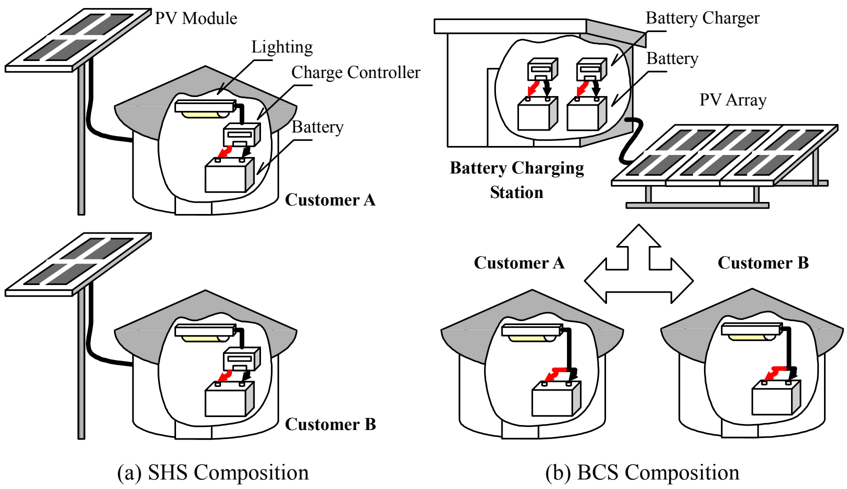
g) Installation Method of PV Module

The target villages of the Project are located between the north latitude of 6° and 12°. In general, a PV module is set up with the same tilt angle as the latitude of its site. According to data measured in Japan[6]; however, the optimum tilt angle which brings the highest annual solar irradiation is slightly lower than its latitude, but it is preferable that the modules shall be set up at a tilt angle between 10° and 15° at least to prevent rain water from remaining on the difference in level between their front cover and aluminum frame. Therefore, we unify all the tilt angle at 15°, and their directions shall be due south.

(3) BCS

a) Comparison of System Composition

Fig. 3-5 indicates the comparison of the system compositions of SHS and BCS. A SHS is composed of a PV module, charge controller, battery, and lighting (load). In the case of a PV system with BCS on the other hand, PV modules are not installed at each household, but batteries are charged by the PV array installed at BCS. The customers convey the batteries to their house respectively, and they use the batteries as power source for loads. When the voltage of the batteries falls after use for several days, the customers bring them into BCS and charge them.



Source: JICA Study Team

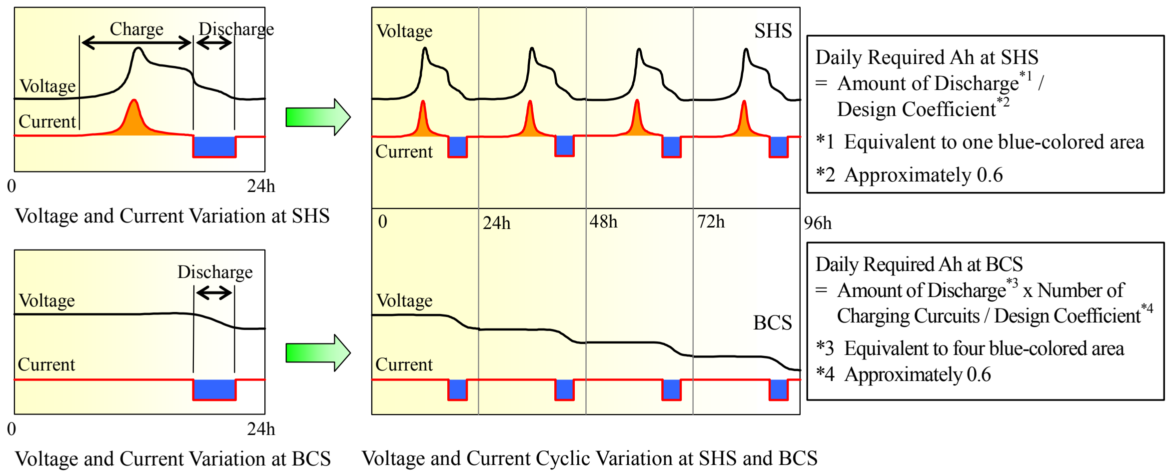
Fig. 3-5 Comparisons of System Compositions between SHS and BCS

b) Comparison of System Operation

Fig. 3-6 shows the comparison of system operational examples between SHS and BCS. In SHS, the PV modules generate electricity with the sunshine in the daytime, and the voltage of batteries rises. When lighted up after dark, the batteries start discharging electricity and the voltage of the batteries falls slightly. Assuming that the PV modules generate the same amount of discharge, the voltage constantly remains at a certain level. In terms of BCS on the other hand, the voltage of batteries gradually falls by lighting loads in the night. The customers need to recover the voltages by bringing the batteries into BCS when their equipment does not work because of the low voltage—in this example, charging cycle is supposed to be four (4) days. Now, the electric energy required for the

6 *PV systems design manual*, March 2001

PV modules per day is needed to pay attention. In terms of SHS, the system can continue to run if the PV modules can generate the amount of charge (equivalent to one orange-colored area in the figure) balanced with the amount of discharge (equivalent to one blue-colored area in the figure). In the case of BCS on the other hand, the system can not sustain unless the battery is adequately charged—i.e. the battery has to be charged with the energy corresponding to "the charging cycle multiplied by the amount of discharge per day (equivalent to four blue areas in the figure)." to recover its voltage. Besides, BCS station needs the capacity of generation sufficient to "the amount of charge multiplied by the numbers of charging circuits." Therefore, a large number of the PV modules is installed at BCS station (i.e. the capacity of PV array is large).



Source: JICA Study Team

Fig. 3-6 Comparison of System Operational Examples between SHS and BCS

c) Study on Target Areas of BCS Implementation

Table 3-9 indicates the example of BCS design for the electrification of approximately twenty (20) households on the condition of the solar irradiation of Jigawa, Ondo, and Imo states. From this, it can be seen that the PV array capacity is 990 W—eighteen (18) panels of a 55 W PV module which are equivalent to eighteen (18) SHS houses—to electrify twenty (20) households in Jigawa state, whereas the capacity becomes 1,320 W in Ondo state—twenty-four (24) panels of a 55 W module which are equivalent to twenty-four (24) SHS houses—and 1,265 W in Imo state—twenty-three (23) panels of a 55 W module which are equivalent to twenty-three (23) SHS houses.

Table 3-9 Example of BCS Design

Item	Jigawa state	Ondo state	Imo state
Solar Irradiation [kWh/m^2-day]	5.34	3.50	3.73
No. of Electrified Households [house]	20	20	20
Charge Cycle [day]	5	4	4
PV Array Capacity [W]	990	1,320	1,265
Battery Capacity [Ah)	80	80	80

Source: JICA Study Team

Furthermore, during the 1st field survey, the villagers and Local Work Group (LWG) members strongly requested that the scope of procurement in the Project would include the expenses of equipment and materials installed at the customers' houses (batteries, indoor wiring, and lighting fixtures, etc.) and installation costs for indoor wiring. As a result of the consideration, the Study Team concluded that the above expenses and costs would be included in the scope of procurement in order to accelerate the sustainable development of BCS. Consequently, the economical advantage of BCS compared with SHS fell, and the meaning of the BCS construction in Ondo and Imo states having inferior solar irradiation conditions, became quite low. From the above, we concluded that BCS should be implemented only in Jigawa state showing relatively a better solar irradiation condition, and we would monitor the O&M of the BCS.

d) Prerequisite

In addition to the same prerequisite of the SHS design as mentioned before, we need to design the number of target households, the number of charging circuit, and battery capacity in terms of BCS. This time, assume that they are twenty (20) households, four (4) circuits, and 80 Ah respectively.

e) Estimation of Daily Consumed Ampere-hour per household

Assume that daily consumed ampere-hour and hour-of-use are the same as SHS, and ampere-hour consumption is also 6.9 Ah/day as well as SHS.

f) Calculation of Daily Required Ampere-hour per household

Consider a coefficient of loss, K_L, caused by wiring and charge controllers, and we assume K_L, = 0.9. Divide the daily consumed ampere-hour, AH_C [Ah/day], found in e) above by K_L, to get the daily required ampere-hour, AH_R [Ah/day], which is given by

$$AH_R = AH_C / K_L \qquad (8)$$

Then calculate the interval of charging, DC [day], which is written as

$$D_C = (C_B \cdot DOD / 100) / AH_R \qquad (9)$$

where C_B: Battery Capacity [Ah], DOD: Depth of Discharge [%]. Table 3-10 shows the result of calculation.

Table 3-10 Daily Required Ampere-hour and Interval of Charging

Consumed Ampere-hour AH_C [Ah/day]	Coefficient of Loss K_L	Required Ampere-hour AH_R [Ah/day]	Battery Capacity C_B [Ah]	Depth of Discharge DOD [%]	Interval of Charging D_C [day]
6.9	0.9	7.7	80	50	5

Source: JICA Study Team

g) Study on Interval of Charging

Divide the number of days per month, D_M [day], by the interval of charging, D_C, given in f) above and multiply the quotient by the number of target households, N_H [house], and we find the frequency of charging, N_R [time], which is written as

$$N_R = (D_M / D_C) \cdot N_H \qquad (10)$$

Then divide N_R by the number of charging circuits, N_B [circuit], to get the monthly frequency of charging per circuit, N_C [time/circuit], which is written as

$$N_C = N_R / N_B \qquad (11)$$

Table 3-11 shows the result of calculation.

Table 3-11 Frequency of Charging

No. of Days per Month D_M [day]	Interval of Charging D_C [day]	No. of Target Households N_H [house]	Frequency of Charging N_R [time]	No. of Charging Circuit N_B [circuit]	Frequency of Charging N_C [time/circuit]
30	5	20	120	4	30

Source: JICA Study Team

h) Load at BCS

Assume that loads at BCS are only lightings (13 W x 2 units) and a radio (5 W x 1 unit) and their hour-of-use are both five hours, so we find the load is 13 Ah/day.

i) Calculation of Daily Required Generating Ampere-hour

Find the required generating ampere-hour which the PV array at BCS needs to generate per day. First, calculate the ampere-hour required for charging batteries, AH_B [Ah/day], by the product of the required ampere-hour per household, AH_R, calculated in f) above; interval of charging, D_C; and number of charging circuit N_B. We get

$$AH_B = AH_R \cdot D_C \cdot N_B \qquad (12)$$

Then Add the load, AH_S [Ah/day], given in h) to AH_B and divide the sum by the design coefficient K (same as SHS), and we find the daily required generating ampere-hour, AH_G [Ah/day], which is given by

$$AH_G = (AH_B + AH_S) / K \qquad (13)$$

Table 3-12 shows the result of calculation.

Table 3-12 Daily Required Generating Ampere-hour

Required Ampere-hour AH_R [Ah/day]	Interval of Charging D_C [day]	No. of Circuit N_B [circuit]	Ampere-hour for Charging AH_R [Ah/day]	Load at BCS AH_S [Ah/day]	Design Coefficient K	Generating Ampere-hour AH_G [Ah/day]
7.7	5	4	154	13	0.58	288

Source: JICA Study Team

j) PV Module Selection

We find the output current of the PV modules, I_{PV}, as well as SHS, as shown in Table 3-13.

Table 3-13 Output Current of PV Module

Solar Irradiation SI_A [kWh/m^2-day]	Conversion Value [W/m^2]	Required Generating Ampere-hour AH_G [Ah/day]	Output Current of PV Module I_{PV} [A]
5.34	1,000	288	54.0

Source: JICA Study Team

From the typical specifications of a 55 W modules, the numbers of the module in parallel and in series are shown in Table 3-14.

Table 3-14 Specification of PV Module

Item	Output [W]	Current I_{PV} [A]	Voltage V_{PV} [V]
Specifications of 55 W Module	55	3.15	17.4
BCS	—	54.0	15.9
Number. of PV Modules in parallel/ series	—	18 (in parallel)	1 (in series)

Source: JICA Study Team

k) Battery Selection

As well as SHS, we find the battery capacity of the load at BCS, C_B: [Ah], as shown in Table 3-15.

Table 3-15 Battery Capacity

Load at BCS AH_S [Ah/day]	Running Days of No Solar Radiation D_{nsr} [day]	Depth of Discharge DOD [%]	Coefficient of Loss K_L	Battery Capacity C_B [Ah]
13.0	3	0.5	0.9	86.7

Source: JICA Study Team

l) System Specifications

Finally, we select the charge controllers, battery chargers and wiring which have sufficient affordability and capacities against the load. In the Project, we install the charge controllers in the circuit at each customer to prevent the batteries from over-discharging. Table 3-16 shows the specifications of main equipment for BCS.

Table 3-16 Specifications of Main Equipment for BCS

Item	Specifications
BCS	
PV Module	Crystalline, 55 W x 18 units
Charge Controller	12 V, 4.5 A x 1 unit
Battery Charger	12 V, 20 A x 5 units (including 1 spare)
Battery	Sealed type for cycle use, 100 Ah x 1 unit
Breaker	Bipolar, 30 A x 2 units, 20 A and 10 A x 1 unit each
Cable	25 mm^2, 6 mm^2, 2.5 mm^2
Installation Configuration	Stand type
Lighting	12 V, 13 W Fluorescent light x 2 units
Customer (per household)	
Charge Controller	12 V, 4.5 A x 1 unit
Battery	Vented type for trickle use, 80 Ah x 1 unit
Breaker	10 A, Bipolar x 1 unit
Cable	6 mm^2, 2.5 mm^2
Lighting	12 V, 9 W Fluorescent light x 2 units

Source: JICA Study Team

m) Installation Method of PV Module

We place the PV array with steel angles on concrete foundations. Besides, the PV array needs to be surrounded with a security fence to protect the array from thefts and animal entries. As well as SHS, the tilt angle of the array is set at 15°, and their direction is due south.

(4) Public Facility

a) System Composition

The target PFs are a mosque in Jigawa state, a health care center in Ondo state, and a public meeting hall in Imo state. Although their main loads are lightings, the study team installed a PV vaccine refrigerator for preserving vaccines at the health care center. We examine the system compositions while separating the lightings and the PV vaccine refrigerator.

b) Study on Lighting Equipment

We study the specifications of the systems with the same procedure as well as SHS. Table 3-17 and 3-18 show the consumed ampere-hour of the estimated loads and the specifications of main equipment, respectively. In terms of the settings of the number of the supposed lightings and hour-of-use, we repeat the trial calculations in consideration of their lighting layouts. Then, we adjust that the PV array becomes approximately 300 or 400 W.

Table 3-17 Daily Consumed Ampere-hour

Name of State	Estimated Load	Electric Power Consumption P [W]	Hour-of-use H [h/day]	Consumed Ampere-hour AH_C [Ah/day]
Jigawa state	Fluorescent light (11 W x 12)	132.0	4.0	44.0
	Radio (5 W x 1)	5.0	4.0	1.7
			Total	45.7
Ondo state	Fluorescent light (11 W x 10)	110.0	3.5	32.1
	Radio (5 W x 1)	5.0	4.0	1.7
			Total	33.8
Imo state	Fluorescent light (11 W x 10)	110.0	4.0	44.0
	Radio (5 W x 1)	5.0	4.0	1.7
			Total	45.7

Source: JICA Study Team

Table 3-18 Specifications of Main Equipment for Public Facilities

Item \ Name of State	Jigawa state	Ondo state	Imo state
PV Module	Crystalline, 55 W x 6 units		Crystalline, 55 W x 8 units
Charge Controller	12 V, 20 A x 1 unit		12 V, 30 A x 1 unit
Battery	Sealed type for cycle use		
	350 Ah x 1 unit	300 Ah x 1 unit	350 Ah x 1 unit
Breaker	20 A, bipolar x 1 unit		30 A, bipolar x 1 unit
Cable	$25mm^2$、$6\ mm^2$、$2.5mm^2$		
Installation Configuration	Stand type		
Lighting	12 V, 11 W Fluorescent light x 12 units	12 V, 11 W Fluorescent light x 10 units	12 V, 11 W Fluorescent light x 12 units

Source: JICA Study Team

The installation configuration of the PV array is with stand type as well as BCS. Besides, the tilt angle of the array is 15°, and their direction is due south.

c) Study on PV Vaccine Refrigerator System

The PV vaccine refrigerator to preserve vaccines which is installed at the health care center in Ondo state shall be tested and certified by World Health Organization (WHO)—Standard No. E3/RF.4.

The refrigerator system shall be composed of PV modules, batteries, charge controllers, refrigerators, and wiring. The system specifications of the refrigerator can not be determined because their capacities are different according to the suppliers. Consequently, in the Project, we decide the requirement of the system as shown in Table 3-19, and the suppliers shall recommend the other requirement.

Table 3-19 Requirement of PV Vaccinne Refrigerator

Item	Requirement
PV Refrigerator	Certified by WHO
PV Module	Crystalline, 55 W x more than 4 units
Charge Controller	12 V x 1 unit
Battery	Sealed type for cycle use x 1 unit
Breaker for Wiring	Bipolar x 1 unit
Cable	25 mm^2, 6 mm^2, 2.5 mm^2

Source: JICA Study Team

The PV modules described above have to be the same modules of the lightings, which can be installed with the PV array for the lightings of PF in parallel.

(5) Street lighting

In terms of street lightings, we designe the systems which can run only with one (1) unit of the 55 W module. The procedure of their designs is the same as SHS's. Their estimated consumed ampere-hour and the specifications of their main equipment are as shown in Table 3-20 and 3-21 respectively.

Table 3-20 Daily Consumed Ampere-hour

Name of State	Estimated Load	Electric Power Consumption P [W]	Hour-of-use H [h/day]	Consumed Ampere-hour AH_C [Ah/day]
Jigawa state	Fluorescent light (25 W)	25.0	4.0	8.4
Ondo and Imo states	Fluorescent light (20 W)	20.0	4.0	6.7

Source: JICA Study Team

Table 3-21 Specifications of Main Equipment for Street Lighting

Item \ Name of State	Jigawa state	Ondo and Imo states
PV Module	Crystalline, 55 W x 1 unit	
Charge Controller	12 V, 4.5 A x 1 unit	
Battery	Sealed type for cycle use, 60 Ah × 1 unit	Sealed type for cycle use, 50 Ah × 1 unit
Breaker	10 A, bipolar × 1 unit	
Cable	6 mm^2	
Installation Configuration	Pole-mounted type	
Lighting	12 V, 25 W Fluorescent light x 1 unit	12 V, 20 W Fluorescent light x 1 unit

Source: JICA Study Team

3.1.4 Technical Specification of the PV systems

Considering the technical specification of the equipment for the Project described above, the Study Team prepared the technical specifications of the PV systems (Refer to Appendix 1). The scope of work defined by the specifications covered the procurement and delivery of equipment, installation work, maintenance work (periodical maintenance done by the contractor), and training (technical training of the PV systems targeting the O&M staff of VEC done by the contractor).

The technical specifications consists of the body, technical data sheet, and price schedule. The technical data sheet, which is used at the technical evaluation in the tenders, is a format to require the bidders to submit the specifications of proposed main equipment such as the PV module, charge controller, and storage battery, etc. for the purpose of judging whether the proposed equipment meets the technical specification or not. Meanwhile, the price schedule, which is used in the price evaluation in the tenders, is a format to require the bidders to quote each unit price of the items covered by the scope of work such as the equipment, installation work, maintenance work, and training.

3.2 Schedule of Procurement and Installation of Equipment

During the 2nd field survey, JICA Nigeria office invited public tenders to procure equipment for the Project, and the Study Team assisted JICA to evaluate the bids, to negotiate with the bidders, and to make a contract with the contractors. The tender was divided into three (3) lots for Jigawa, Ondo, and Imo states. The result of tenders is summarized in Table 3-22.

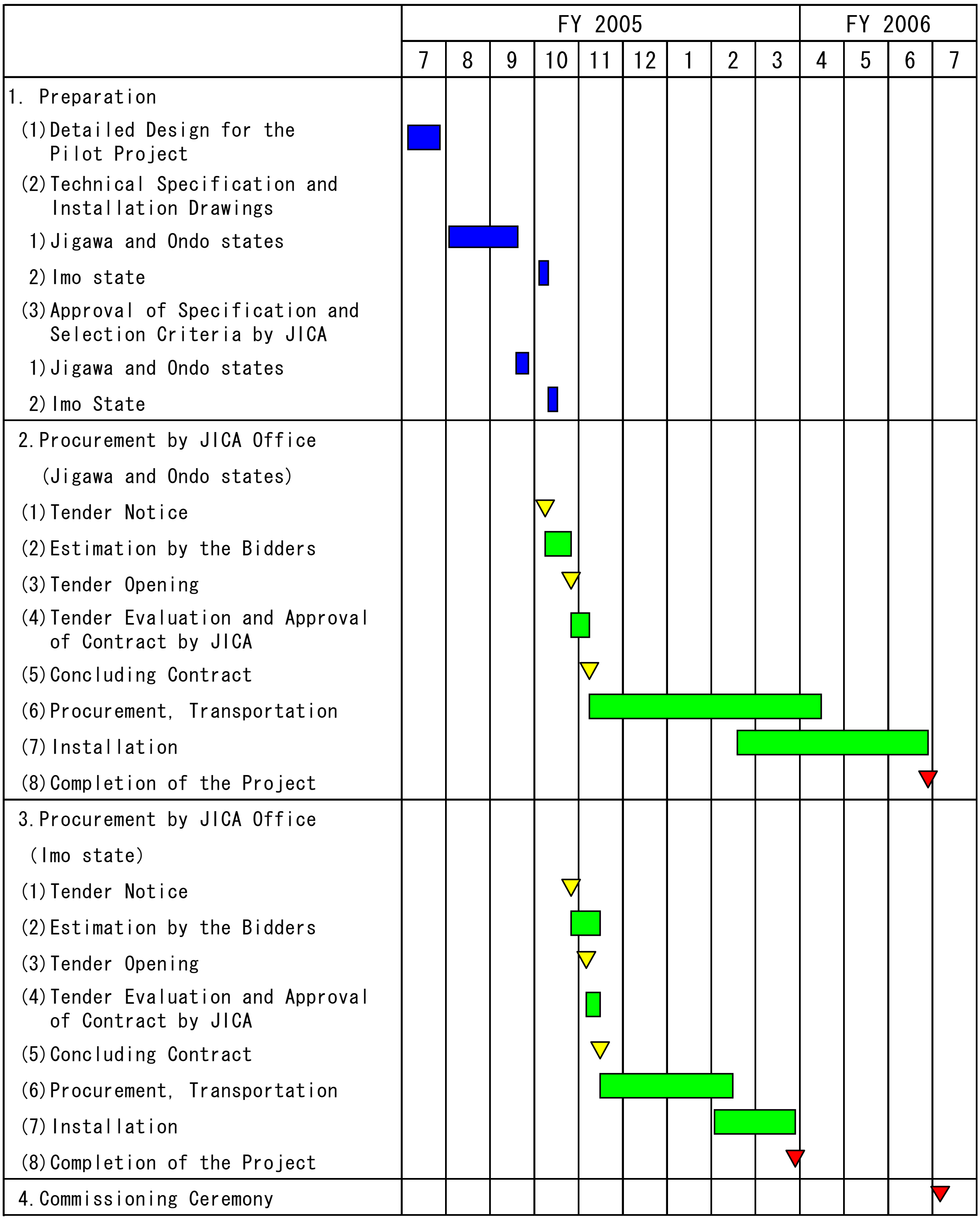
Table 3-22 Tender Results of Procurement of Equipment for the Pilot Project

Name of Village, State	Contractor	Type	Quantity	Remarks
Garkon Alli, Jigawa state	Alpha Consortium Ltd.	BCS	1	• Tender notice and opening were held on Sept. 28, Oct. 25, 2005 respectively. • Eight (8) bidders passed the technical evaluation out of thirteen (13). • Made a bulk contract (for both Jigawa and Ondo lots) on Nov. 11, 2005.
		PF	1	
		SHS	40	
		SL	10	
Oke-Agunla, Ondo state	Ditto	PF	1	• The tender schedule was the same as Jigawa lot. • Seven (7) bidders passed the technical evaluation out of thirteen (13). • PF included a PV vaccine refrigerator.
		SHS	60	
		SL	10	
Umuikoro/ Opehi, Imo state	International Energy Services Ltd.	PF	1	• Tender notice and opening were held on Oct. 20, Nov. 7, 2005 respectively. • Eight (8) bidders passed the technical evaluation out of ten (10). • Made a contract on Nov. 16, 2005.
		SHS	80	
		SL	10	

Source: JICA Study Team

After the contracts, the Study Team required the contractors to submit the drawings/documents for approval in accordance with the technical specification; however, they did not submit the required drawings/documents at all. As a result, the procurement and delivery schedule greatly delayed. In addition, we often found that some of the equipment which the contractors had delivered did not meet the technical specification and contractors failed to delivery the contracted quantity of products. The problem caused the further delay of the schedule. Although we initially intended to complete the installation of equipment at all the three (3) target villages early in March 2006, the delay of the work schedule forced JICA to modify contracts to postpone the commissioning dates. Lastly, the installation works were completed late in June 2006 in Jigawa and Ondo states, and late in March 2006 in Imo state, respectively. Table 3-23 shows the work schedule of procurement and Installation of the Project

Table 3-23 Work schedule of procurement and Installation of the Pilot Project



Source: JICA Study Team

Fig. 3-7, 3-8, and 3-9 show the status of the installations in the target villages. In additon, the technical specification of main equipment for the Porject and PV systems locations are attached as Attachement 2 and Attachment 3, respectively.

1) BCS Station (external): The villagers constructed the house by themselves.

2) BCS Station (internal): The number of charging circuits is five (5) with a rated current of 20 A. The storage batteries are vented-type with a capacity of 88Ah.

3) PV array: The array for BCS has a nominal maximum output 1,080 W comprised of eighteen (18) units of 60 W module (front). Meanwhile, the output of the array for PF is 360 W comprised of six (6) units of 60 W (back). The arrays face due south and their tilt angles are 15°.

4) PF (mosque): Twelve (12) units of 15 W fluorescent lights are installed inside. They use an audible speaker as a DC load (10 W).

5) SHS: The PV module is as the same as for BCS (60 W). Two (2) units of 15 W fluorescent lights and a DC outlet are installed inside. The storage battery is sealed type with a capacity of 65 Ah.

6) SL: The light is sodium light with an input of 18 W. The light turns on and off automatically and can be used for 6 hours a day (4 hours from sunset and 2 hours before sunrise). The PV moduel is as the same as for BCS (60 W), and the storage battery is as the same as for SHS (65 Ah).

Fig. 3-7 Status of installation of the PV systems at Garkon Alli Village in Jigawa State

1) Center of Oke-Agunla Village: The houses are located along the street from north to south. The poles for SHS and SL are installed beside the houses.

2) PF (health care center): Ten (10) units of 15 W fluorescent lights and a PV vaccine refrigerator are installed inside.

3) PV array for PF: The PV modules are the same as in Jigawa (60 W), and ten (10) units of module are installed. Six (6) of them are used for lighting, and four (4) of them are used for a PV vaccine refrigerator.

4) PV vaccine refrigerator: The refrigerator is certified by WHO and has a storage capacity of 38.7 liter. The inside of it is divided into freezer and cold storage.

5) SHS: The specifications of the equipment are as the same as in Jigawa.

6) SL: The specifications of the equipment are as the same as in Jigawa. Considering the solar irradiation, the light turns on and off automatically and can be used for 4 hours a day (3 hours from sunset and 1 hours before sunrise).

Fig. 3-8 Status of installation of the PV systems at Oke-Agunla Village in Ondo State

1) PF (meeting hall): Twelve (12) units of 11 W Compact fluorescent lamps (CFLs) are installed inside.

2) PV array: The array has a nominal maximum output 496 W comprised of eight (8) units of 62 W. The array faces due south and its tilt angles is 15°.

3) Lighting for SHS: The lighting (CFL) has expected lifetime of 5,000 hours and more.

4) Junction Box for SHS: The box contains the charge controller (6 A) and Molded-Case Circuit Breaker (MCCB). The charge controller has indicators which show the voltage level of the storage battery.

5) SHS: The PV module is as the same as for PF (62 W). Two (2) units of CFL and a DC outlet are installed inside. The storage battery is sealed type with a capacity of 60 Ah.

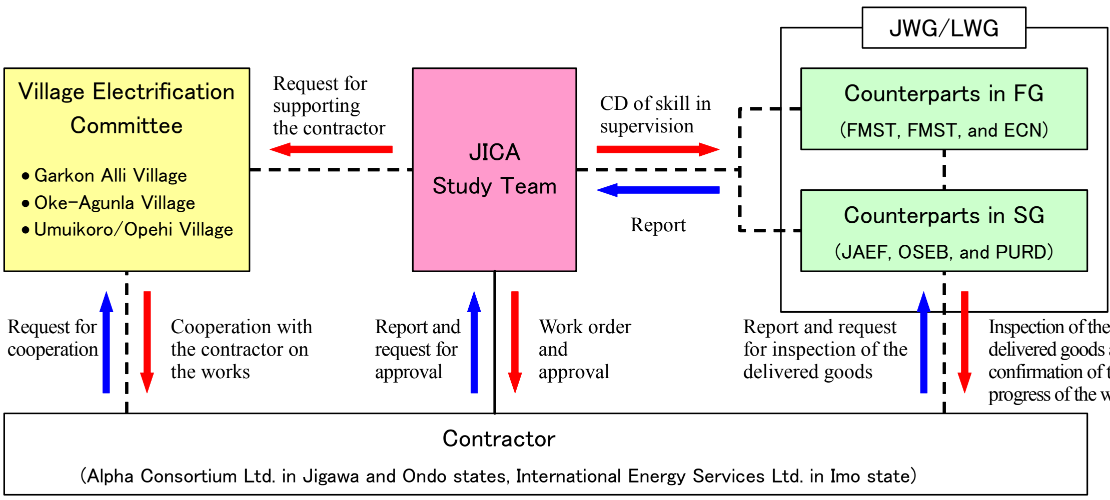
6) SL: The PV module is as the same as for PF (62 W), and the storage battery is as the same as for SHS (60 Ah). The lighting is a fluorescent light with a capacity of 20 W. The light turns on and off automatically and can be used for 4 hours a day (4 hours from sunset).

Fig. 3-9 Status of installation of the PV systems at Umuikoro/Opehi Village in Imo State

3.3 Supervising Organization of Installation Work

The Project was implemented in three (3) states (Jigawa, Ondo, and Imo states). However, the target villages are located 380 km north-northwest (Jigawa state), 310 km southwest (Ondo state), 430 km south form the capital (Abuja), and it took us whole day to travel from Abuja to the target villages. In addition to that the installation works should be carried out in three (3) villages at the same time, the delay of the schedule of procurement and delivery of equipment resulted in shortening the installation work periods and made it more difficult to supervise the works.

Under such circumstances, the Study Team requested the counterparts in the federal government (FMPS, FMST, and ECN) at JWG[7] meeting to assign a person in charge in each target village of the Project and then arranged that the person would visit the village when needed and would supervise the works in cooperation with the counterparts in each state (JAEF in Jigawa state, OSEB in Ondo state, and PURD in Imo state). Additionally, the Study Team requested the counterparts in each state at LWG[8] meeting to visit the target village periodically, and to inspect the products and materials delivered by the contractor, and to supervise his work. At each village, we requested VEC to support the contractor. Fig. 3-10 shows the supervision organization of the Project.



Source: JICA Study Team

Fig. 3-10 Supervising Organization of the Pilot Project

7 Joint Work Group (JWG): A working group established in Abuja for the purpose of promoting the Master Plan Study. JWG consists of the Study Team, FMPS, FMST, ECN, and REA (REA joined in JWG from 4th field survey).

8 Local Work Group (LWG): A working group established in each Jigawa, Ondo, and Imo state. for the purpose of promoting the Master Plan Study. LWG consists of the Study Team, counterparts in the federal government, and counterparts in each state (JAEF in Jigawa state, OSEB in Ondo state, and PURD in Imo state)

Chapter 4 Operation and Maintenance Systems

4.1 Establishment the Operation and Maintenance Organizations

4.1.1 Roles of the Operation and Maintenance Organizations in the Pilot Project

For the O&M of installed PV systems as well as for the fee collections from the users, the Village Electrification Committee (VEC) was established at each target village of the Project. The roles and responsibilities of VEC are as follows:

1) Recording the technical data available from the installed PV systems in the Project,
2) Repairing and exchanging related equipment and materials when being broken and expired,
3) Supervising the appropriate use of installed equipment and materials,
4) Collecting the fee from the users for maintenance and management cost,
5) Saving the collected fees in a bank account and keeping books properly, and
6) Paying a salary for the staff.

4.1.2 Establishment of the Operation and Maintenance Organizations in Each State

The Study Team selected the target villages for Project during the 1st field survey in July–August 2005 and the 2nd field survey in October–November 2005, and then organized the 1st village meetings during the 2nd field survey with an aim to establish an O&M organization of PV systems. The village meetings were held at each target village in collaboration with each state government. Many villagers participated to it for discussion, and the VEC was established in each target village for the O&M of installed PV systems. Table 4-1 shows the period of the implemented village meetings.

Table 4-1 Period of the Implemented Village Meetings

State	Village	State Government	1st Village Meeting
Jigawa	Garkon Alli	JAEF	18–21 October, 2005
Ondo	Oke-Agunla	OSEB	27–30 October, 2005
Imo	Umuikoro/Opehi	PURD	6–9 November, 2005

(1) Jigawa State

In Jigawa state, Jigawa Alternative Energy Fund (JAEF), which used to be supported by USAID to manage the rural electrification project using PV systems (called SELF project), is in charge to execute the O&M that relates to alternative energy projects such as village electrification in the farming villages. The Study Team visited the project sites of SELF (a non governmental organization from the USA) during the 1st field survey, and confirmed that the JAEF staff visited their site at regular base and managed the project properly by supplying spare parts and providing technical supports.

After discussion with JAFF, the Study Team came to the point of establishing the O&M committee at village level under the supervision of JAEF which has good working experience and knowledge of rural electrification using PV systems. Taking into account of the scale of the Project, the Study Team promoted the establishment of a village-level organization with two (2) technicians, one (1) fee collector, and one (1) watchman/security guard.

(2) Ondo State

In Ondo state, Ondo State Electricity Board (OSEB), a state electrical agency, is the counterpart organization for the Study Team and is responsible for the O&M of PV systems at state level. However, it is assumed that OSEB had limited experience and knowledge regarding the PV systems. Considering this circumstance, the Study Team supported the establishment of a reliable institution at state level as well as a small-scale organization in the village where the Project would be implemented.

(3) Imo State

As similar situation with Ondo state, the Imo State Ministry of Public Utility and Rural Development (PURD) is the counterpart organization for the Project at state government level, aiming good O&M of the Project. However, PURD had limited experience and knowledge of rural electrification using PV systems. Considering to this circumstance in Imo state, the Study Team supported the establishment of a reliable institution at state level as well as to establish a small-scale organization in the selected village.

Thereafter, the Study Team organized the 2nd village meeting during the 3rd field survey in January–February 2006 and held several discussions with the members of established VEC and with many participants in the villages. The main contents of the discussions included followings: explanations about the equipment for the Project which were planned to be installed from March 2007, details about the O&M system, election of staff for the Project, accounting of monthly fees and subsidies, and use of the Log Book. Based on these discussions, all stakeholders of the Project determined the O&M system and the staff members at each target village.

4.2 System and Staff of the Operation and Maintenance Organizations

4.2.1 Jigawa State

In Garkon Alli village, the village board elected a person in charge of rural development, then decided to establish a VEC under his supervision, taking the implementation of village electrification project for granted. As shown in Fig. 4-1, 4 O&M staff members were employed in the Project under supervision of the VEC.

(1) Village Electrification Committee

As shown in Fig. 4-1, the VEC consisted of twenty (20) villagers and it would promote the future electrification plan in the village. Major job descriptions are listed as below:

- In Garkon Alli village, the BCS was constructed and the batteries of twenty (20) beneficiaries were expected to be charged almost everyday alternately. Due to this circumstance, the VEC should supervise the function of BCS and take care of its maintenance with intention to strengthen the management system of BCS facility,
- The every member of VEC should pay jointly the fee which related to the use of SHS at elementary school and Islamic school,
- The maintenance cost of SHS and BCS system should be collected and be kept in bank account via the accountant of the village,

- After analyzing the report prepared by O&M staff, the committee should communicate to the contractor via JAEF during the guarantee period—first one (1) year only—and would request maintenance work whenever necessary,
- After guarantee period, the committee would be responsible for the O&M under the guidance of JAEF, meanwhile necessary knowledge and experience would be accumulated in the committee,
- Every detail about the repair and exchanging materials should be well recorded, and should be reported to JAEF each time, and
- Since the use of mosque and SLs would be maintained with the subsidy of local government, all the data related to the received subsidy would be recorded properly[1].

(2) Operation and Maintenance Staff

Two (2) technicians, one (1) watchman/security guard, and one (1) fee collector were employed with following job description:

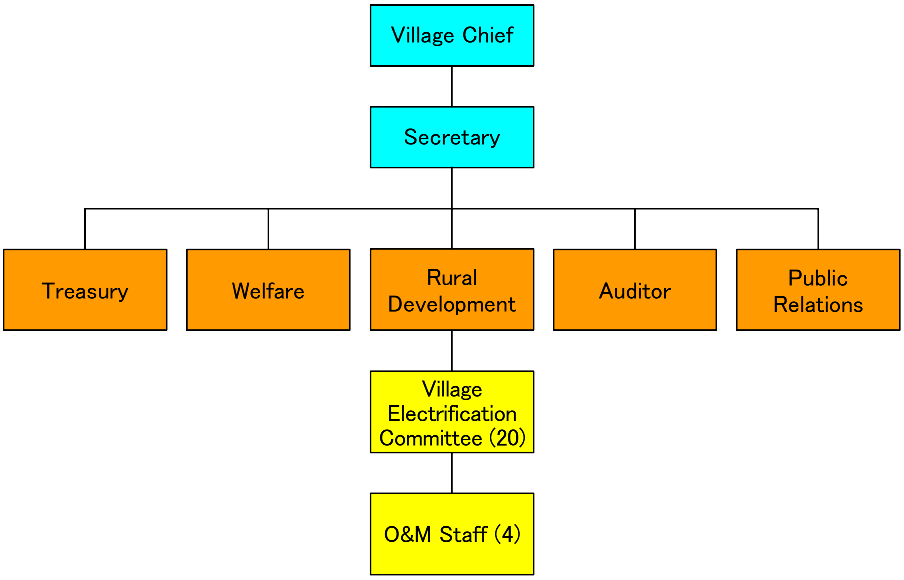
- Two (2) technicians were permanently stationed at BCS facility. They were responsible for charging the batteries for the BCS users, and were responsible to execute the maintenance job of the SHS appropriately, and would keep the maintenance records of each beneficiary on the Log Book,
- As for watchman/security guard, he went around SHS and BCS facilities in nighttime in order to avoid accidents such as robbery,
- The fee collector was in charge of collecting maintenance cost periodically from SHS and BCS users, and will keep records, and
- Overall, maintenance of PF and SLs should be carried out.

(3) JAEF

The role of JAEF in this study is as follows:

- Upon the request from the covered villages in the pilot project, JAEF should carry out field work and take necessary measure,
- JAEF staff visit all concerned locations every month to monitor and guide the activity contents of VEC, and
- JAEF should maintain good communication with VEC, and examine the outcome of repair and exchanging materials on the occasion of monthly visit. After verification, JAEF should send the copy of records and job contents to FMPS.

1 Regarding to the subsidy, Kiyawa local government promised to contribute the subsidy to the village during the 4th field survey in May–June 2006. Since July 2006, the subsidy has been paid by the local government. The agreed amount of subsidy was N15,000 per month including the salary of O&M staff members. During the 5th field survey in October–November 2006, the Study Team found that the amount of subsidy was actually N14,000 and the local government did not paid for one month. The Study Team submitted a letter towards FMPS to urge the local government for proper payment of promised subsidy.



The Village Electrification Committee at Garkon Alli village

1 Alhassan Ademu	6 Adamu Idris	11 Alhaji Idris	16 Rablu Salihu
2 Malem Shitu Liman	7 Saidu Chiko	12 Alhaji Ibrahim	17 Shaaibu Usma
3 Shehu Damfulani	8 Yusif Jinjiri	13 Ibrahim Alhassam	18 Shahu Isah
4 Yais Abdwhhatti	9 Idris Jibrim	14 Mallam Jibrim	19 Sule Gumu
5 Maianwala Shaaibu	10 Ahmed Mohamed	15 Saadu Ibrahim	20 Mati Khimstomer

Opeartion and maintenance staff

1 Mr. Muhuisla Shaaibu – Engineer
2 Mr. Ibrahim Bukar – Engineer
3 Mr. Halidu Yau – Watchman
4 Mr. Idris Jibrim – Fee collector

Source: JICA Study Team

Fig. 4-1 Structure of Village Electrification Committee at Garkon Alli Village

4.2.2 Ondo State

As shown in Fig. 4-2, a new VEC was established in the Project at Oke-Agunla village. The Ondo State Electrical Board (OSEB) is in charge of supervision for this committee.

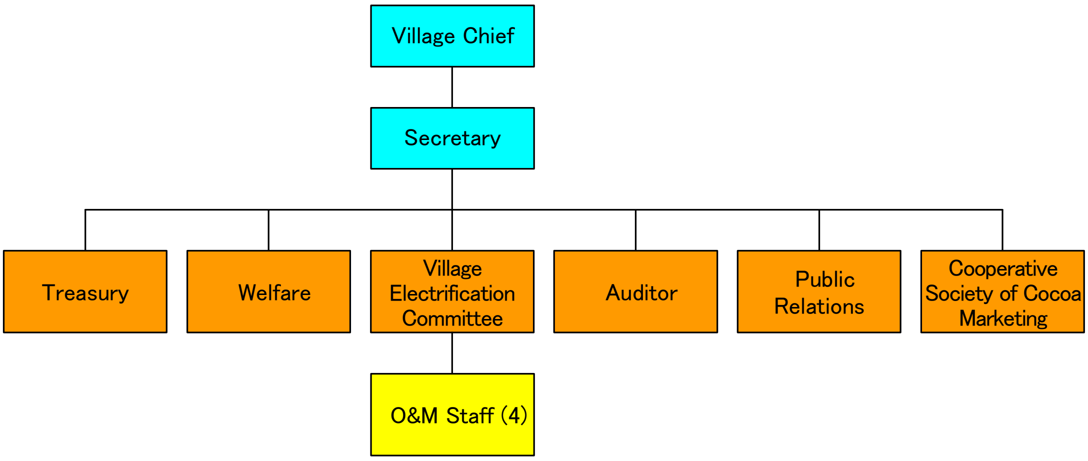
(1) Village Electrification Committee

- The maintenance cost of SHS system should be collected and be kept in bank account via the accountant of the village,
- After analyzing the report prepared by the O&M staff, the committee should communicate to the contractor during the guarantee period—first one (1) year only—and should request maintenance work whenever necessary,
- After guarantee period, the committee should be responsible for the O&M under the guidance of the OSEB, meanwhile necessary knowledge and experience should be accumulated in the committee,
- Every detail about the repair and exchanging materials should be well recorded, and should be reported to the OSEB each time, and

- Since the use of PF and SLs should be maintained with the subsidy of local government, all the data related to the received subsidy should be recorded properly.

(2) Operation and Maintenance Staff

Two (2) technicians, one (1) watchman/security guard, and one (1) fee collector were employed with the same job description as Jigawa state except for the part regarding BCS.



Operation and maintenance staff

1 Mr. Ayodele Ohowookre – Technician
2 Mr. Pastior Faith Michael – Technician
3 Mr. Rufus Odere – Watchman
4 Mr. Owolake Owoyemi – Fee collector

Source: JICA Study Team

Fig. 4-2 Structure of Village Electrification Committee at Oke-Agunla Village

(3) OSEB

As for the role in the OSEB, it is similar to the role of JAEF in Jigawa state.

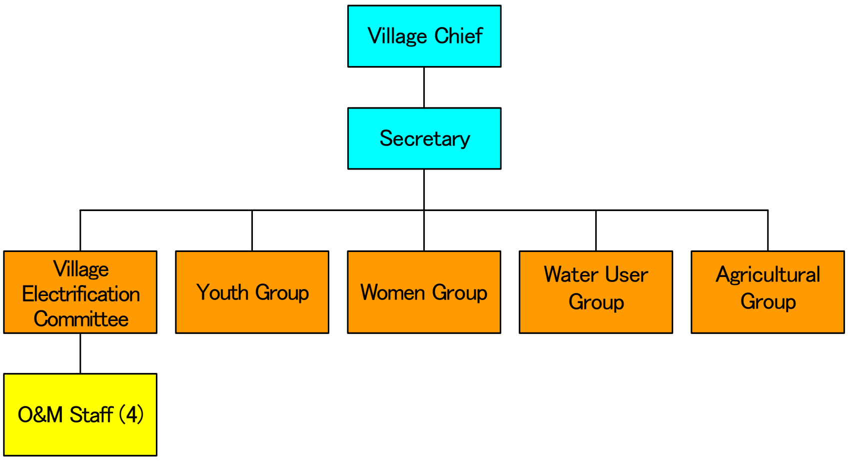
4.2.3 Imo State

As shown in Fig. 4-3, a new VEC was established in the Project at Umuikoro/Opehi village in Imo state. The Public Utilities and Rural Development (PURD) is in charge of supervision for this committee.

(1) Village Electrification Committee

The expected roles of the committee are the same as in Ondo state except following:

- After analyzing the report prepared by O&M staff, the committee will communicate to the contractor via the PURD during the guarantee period—first one (1) year only—and will request maintenance work whenever necessary.



Operation and Maintenance staff

1 Mr. Reginald Nwaeke – Technician
2 Mr. Matea Nkwocha – Technician
3 Mr. Hector Iroegbu – Watchman
4 Mr. Alexander Okere – Fee collector

Source: JICA Study Team

Fig. 4-3 Structure of Village Electrification Committee at Umuikore/Opehi Village

(2) Operation and Maintenance Staff

Two (2) technicians, one (1) watchman/security guard, and one (1) fee collector were employed with the same job description as Jigawa state except for the part regarding BCS.

(3) PURD

As for the role of PURD, it is similar to the role of JAEF in Jigawa state.

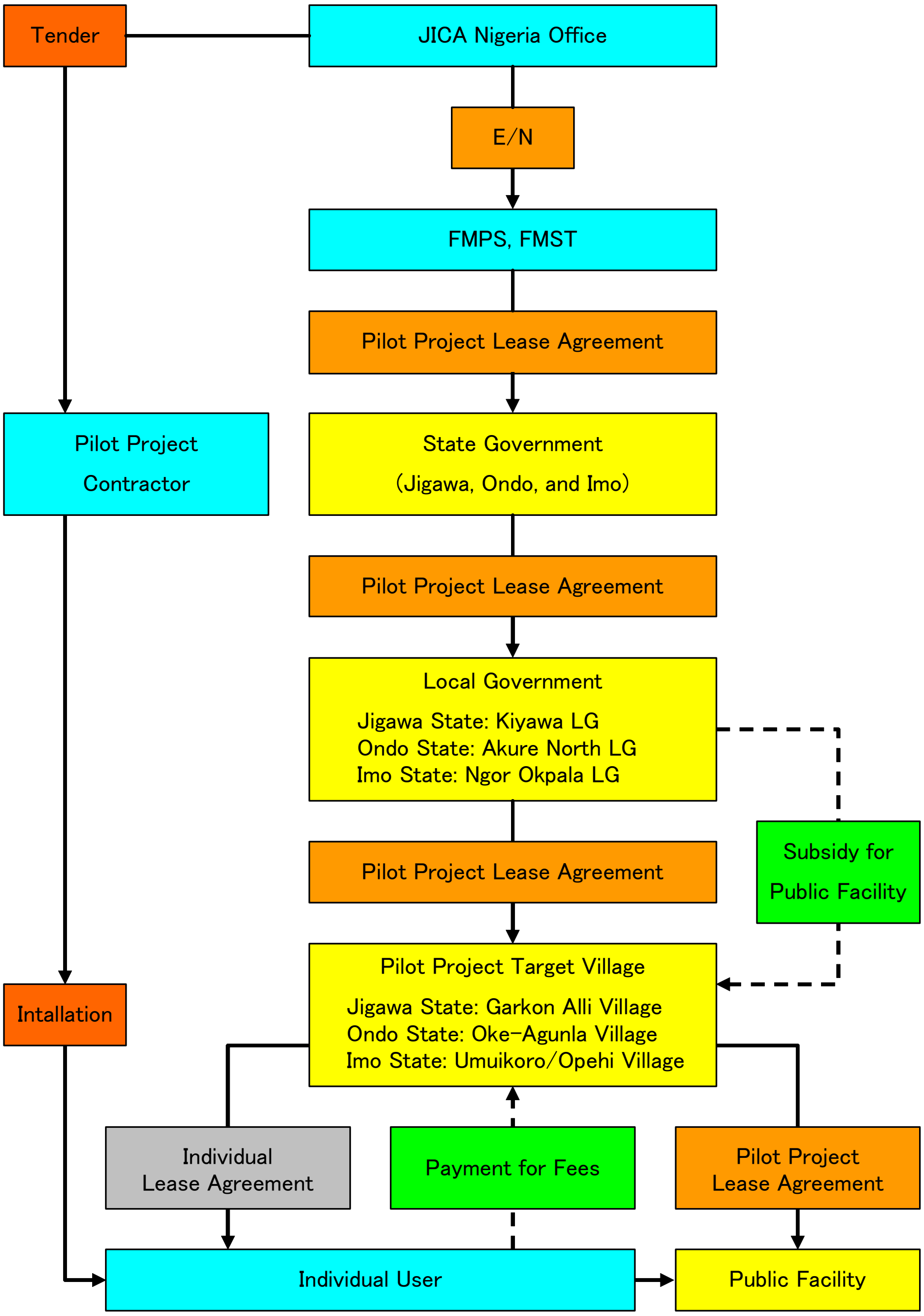
4.3 Lease Agreements of the Pilot Project Equipment

4.3.1 Legal Ownership of the Pilot Project Equipment

For the equipment for the Project, JICA Nigeria office noticed the tenders and selected the contractors who would carry out the procurement, transportation and installation of the equipment in the Project. Since the equipment is legally an asset of the JICA Nigeria office, it was lent for indefinite period to the beneficiaries via the below-mentioned organizations.

1) From JICA Nigerian office to FMPS
2) From FMPS to each state government
3) From each state government to each village
4) From each village to each user

Fig. 4-4 shows the flow chart of the lease agreement of the Project equipment.



Source: JICA Study Team

Fig. 4-4 Flow Chart of the Lease Agreements of the Pilot Project Equipment

4.3.2 Lease Agreements of the Pilot Project Equipment among the Federal and State Governments

In respect of the equipment for the Project, the Study Team prepared the draft of a lease agreement in terms of receipts of the equipment during the monitoring and warranty period and thereafter for the sustainable use. The Study Team proposed it to FMPS and FMST that they would entrust Jigawa, Ondo, and Imo state governments of the whole of the Project extended by JICA Nigeria office.

The followings are the summary of proposed lease agreement (See Appendix 4 for details):

1) The equipment for the Project should remain as an asset of JICA Nigeria office for indefinite period and should be exclusively and solely mad use of by the above VEC, and those individual users selected by the VEC of the said village,
2) For the sustainable use of the equipment, they should be provided to the following areas via the federal governments of Nigeria and Jigawa, Ondo, and Imo state governments:
   - Garkon Alli village, Kiyawa local government area, Jigawa state
   - Oke-Agunla village, Akure North local government area, Ondo state
   - Umuikoro/Opehi village, Ngor Okpala local government area, Imo state
3) Above mentioned villages should establish the VECs, and they should be responsible for its O&M for the use of the equipment,
4) The VECs should be responsible for collection of the fees for the use of the equipment,
5) The VECs should liaise with the state government for any difficulties beyond the capacity of the village organization,
6) The O&M organizations at state level should correspond to the maintenance requests from the VECs in prompt, and
7) The local government should pay the subsidy to the VECs for the maintenance of PFs.

4.3.3 Lease Agreements of the Pilot Project Equipment for the Individuals

The Study Team prepared an individual the draft of a lease agreement to the individuals of the above mentioned villages in order to clarify the legal ownership and the user's rights in case of lease agreement of the equipment for the Project for indefinite period. After the discussions in the villages, all stakeholders of the Projects agreed that fixed amount of monthly payment would be made directly to the village organization for the use of individual facilities in the Project for their sustainable use. The followings are the summary of proposed lease agreement for individual lessee:

1) The ownership of the equipment for the Project which is legally an asset of JICA Nigeria office should remain indefinite period,
2) In order to maintain sustainable use of the PV system, the fixed amount should be paid to the VEC (the name subject to agreement) of the village in which the lessee reside as monthly charge for the lease of the equipment,
3) The collected amount of payment made by the individual lessees should be used for the purpose of O&M of the pilot project as well as the salary of employed staff members in the Project,
4) Due to the failure of monthly payment for three consecutive months by the lessee, the VEC should take action as necessary, for example, the transfer of entire system to other individual as the VEC (the name subject to agreement) should make such decision for new lease agreement, and
5) The lessee will be able to transfer the lease of equipment for the Project to the resident residing within same village in which the lessee resides, but not outside of the village. The lessee shall notify the VEC his/her intention of the transfer in advance.

The lease agreement should be agreed upon between the VEC and the lessee of the individual facilities (See Appendix 4 for details). In case of broken equipments, the lessee should inform to the VEC which will eventually inform to JICA Nigeria office via the state government and FMPS.

4.4 Financial Management for Operation and Maintenance Costs

Several types of PV systems were installed in the Project. In Jigawa state, there were SHS, BCS, PF and SL, and in Ondo and Imo states, there were SHS, PF and SL. The villagers have been using those PV systems under the supervision of the VEC (See the installed numbers of each system at Table 3-22). Installed equipment was provided under the lease agreements, so the users of PV systems did not cover the initial investment costs. They should; however, pay the expenses for the O&M towards the sustainable uses.

4.4.1 Requirements for Setting the Monthly Fees of PV System Utilizations

(1) Village with SHS

1) Costs

In the Project, the Study Team estimated that PV module would have its physical durability of 20 years. The anticipated costs during this period are calculated for the system as follows:

a) Initial investment

Followings are assumed for the 55 W SHS:

- PV module (Silicon crystal, one panel)
- Battery (50 Ah, sealed type, deep cycle use, one unit)
- Charge controller (12 V, 4.5 A, one unit)
- Steel pole and support device for the module
- Wiring materials, etc.

b) Salaries for O&M staff

- N60,000/person/year

c) Equipment renewal cost (batteries, controller, etc.)

- Battery replacement will be done in every several years, but depends on the frequency to be used. It is expected that each user will be responsible for the renewal of battery.
- Controller renewal after 10 years (once in a period of 20 years)

d) Repair cost

- Approximately 2% of the initial investment of the whole system annually

e) Miscellaneous cost

- Approximately 1% of the initial investment of the whole system annually

2) Revenues

In one SHS, each user has its own source of electricity, and these therefore, electricity charge does not need to be collected according to its use. A fixed fee shall be collected form each user.

(2) Village with BCS

The users of BCS need to carry their batteries to the station every couple of days to charge it. Despite of the extra work for charge, the initial investment for the BCS is the lowest among the introduced PV systems.

1) Costs

It is set at 20 years, the same as in the case of the SHS. The anticipated costs during this period are calculated for the system as follows:

a) Initial investment

Followings are assumed for the BCS:

- PV module (60 W panel, 2 in series x 9 in parallel)
- Battery (100 Ah, sealed type, deep cycle use, one unit)
- Charge controller (12 V, 60 A, one unit)
- Battery charger (12 V, 20 A, 5 units)
- Concrete foundation with a security fence

b) Salaries for O&M staff

- N60,000/person/year

c) Equipment renewal cost (batteries, controller, etc.)

- Battery replacement will be done in every several years, but depends on the frequency to be used. It is expected that each user will be responsible for the renewal of battery.
- Controller renewal after 10 years (once in a period of 20 years)

d) Repair cost

- Approximately 2% of the initial investment of the whole system annually

e) Miscellaneous cost

- Approximately 1% of the initial investment of the whole system annually

2) Revenues

- Revenue from the user charge for battery charge (approximately every 5 days or 72 times per year)

(3) PF and SL

The PFs in the Projects were one (1) unit for the mosque in Jigawa state, one (1) unit for the health care center in Ondo state, and one (1) unit for the meeting hall in Imo state. The main loads of the PV systems at those PFs are lightings except at the health care center which had been installed a PV vaccine refrigerator.

4.4.2 Outcome of Consultations for Setting the Monthly Fees of PV System Utilizations

The VEC initiated by community is not a typical organization like ordinal companies, but is rather a non-profit organization. The VEC aims to provide benefits from the electrification for villagers, and to manage the institution sustainable way by the payment of monthly fees from the villagers. Therefore the Study Team did not analyze the profitability of electrification, but examined the rational amount of monthly fee for PV system utilizations, considering that the yearly balance of cash flow will never stay in deficit for a period of the operation (20 years). The table below shows the examined result.

Table 4-2 Examined Monthly Fees for PV System Utilizations

Unit：Naira

Name of Village, State	Fee for SHS [per month]	Battery Charge [per charge]	Fee for PFs [per month]
Garkon Alli village, Jigawa state	650	50	50
Oke-Agunla village, Ondo state	500	—	50
Umuikoro/Opehi village, Imo state	550	—	50

Source: JICA Study Team

As shown above, the prices were not beyond the payment capacity of villagers with regards to their living standards, but it was considered as relatively high prices. Therefore, during the 4th field survey, the Study Team proposed above-mentioned prices on the occasion of JWG, and discussed with the stakeholders in each state for possible options such as subsidy introduction and preferential loan. With consideration of the payment capacity of villagers, the local governments of Jigawa and Ondo states agreed to contribute certain amounts of subsidy which would cover some fees for SHS and PF. As a result, the fee for PF became free of charge, and the monthly fee for SHS was reduced. In Imo state, the Study Team and counterparts discussed the similar issue with the local government during the 5th field survey, and then the local government agreed to hire three (3) O&M staff on temporally contract base as well as to contribute the monthly fee for PFs and SLs. The table below shows the fixed monthly fees by the discussions.

Table 4-3 Fixed Monthly Fees for PV System Utilizations

Unit : Naira

Name of Village, State	Fee for SHS [per month]	Battery Charge [per charge]	Fee for PFs [per month]
Garkon Alli village, Jigawa state	650 –> **400**	50 –> **30**	50 –> **0**
Oke-Agunla village, Ondo state	500 –> **250**	—	50 –> **0**
Umuikoro/Opehi village, Imo state	550 –> **350**	—	50 –> **0**

Source: JICA Study Team

4.5 Technical Supports for Operation and Maintenance of the PV Systems

In the Projects, two (2) local technicians (with experiences of automobiles, bicycle and generator repairing) had been hired by the VEC. The Study Team gave them guidance how to determine the cause of rudimental troubles, and repair it if possible. The Study Team also instructed them to record the inspection results of PV systems, to collect monthly fees from villagers, and to procure and maintain spare parts with using the Log Book. For the local maintenance, the Study Team requested the staff members of state and local governments to visit the target villages as much as possible in order to give technical supports for the O&M of PV systems. While the 5th field survey, the Study Team checked whether local staff had handled the tasks for maintenance properly, it was found that all the necessary data had not been collected and recorded to the formats. The Study Team explained the contents to the local staff members.

For the education of technicians, the Study Team gave them lectures about the basic principles of PV system with the manual made by the Study Team, and instructed how to maintain the PV system properly. So far, the counterparts in state government and the technicians of VEC had monitored and observed the installation process done by the contractors, and consequently they have learned how to treat and handle the components of PV systems. Furthermore they participated to the workshop called "Lectures on how to use the PV systems," which was a part of the Project contract, in order to improve the O&M techniques.

On the occasions of village meetings, the Study Team also organized several demonstrations of PV systems, and gave lectures about the system treatment and the limitations of PV systems. The Study Team also prepared several PV system manuals, targeting to 1) users, 2) maintenance staff, and 3) engineers according to the technical level (See Appendix 5).

4.6 Operation and Maintenance System in the Future

During the guarantee period—first one (1) year only; till June 30, 2007 in Jigawa and Ondo states; and till March 17, 2007 in Imo state—after the PV systems installation, the contractors should procure and maintain spare parts as well as handle claims of villagers. Meanwhile the local technicians should O&M the ordinal works.

After the guarantee period, the state government in charge (JAEF, OSEB and PURD) will coordinate the O&M system of each village and will supervise the VEC. In practice, the staff of state government will visit and inspect the PV systems regularly (at least once in a month), and they will report the result of inspection to FMPS at the end of every month.

In case of technical difficulties, the VEC is supposed to make a contact with the state government for further technical supports. The Study Team also recognized the necessity of continuous technical transfers how to use the PV systems in the future. Therefore the Study Team requested to organize training courses at the target villages for the engineers of state governments and for the O&M staff members in collaboration with ECN, Sokoto and Nuska Research Centers. By the time of 5th field survey, this training course was not implemented, then the Study Team requested again at the occasion of JWG to execute it in prompt. Hereafter, it is also necessary to verify the contents of training courses in regards to the project sustainability.

Chapter 5 Capacity Development

5.1 Development of Ability for Engineering

The counterparts for the Project did not have experience in design for execution regarding PV systems except ECN and JAEF who implement design, construction, and maintenance of PV systems in Nigeria. In order to provide technical support for the target villages of the Project continuously, their ability for PV systems engineering had to be improved.

Throughout the Project, the Study Team aimed to improve the ability of engineers in the counterparts in the federal government and state governments and carried out the following transfers of skill in engineering:

1) Giving the engineers a lecture about the procedure of PV system design by means of the design examples of SHS and BCS,
2) Expounding the technical requirement for each equipment, relevant standards, way of installation, and contents of factory and field tests to the engineers by use of the technical specification of the Project (Refer to Appendix 1),
3) Explaining the outline of PV system components, and design procedure of SHS to the engineers by use of the PV systems manual (Refer to Appendix 5),
4) Performing wiring and usage of a PV system in the presence of the engineers by use of the demonstration kit which the Study Team procured as a part of the Master Plan Study,
5) Having the engineers attend lectures on how to use the PV systems done by the contractors, and
6) Handing out leaflets of PV systems and SHS handbooks prepared by JICA.

The Study Team conducted the above transfers when we came to each state for the purpose of supervision and monitoring of the Project.

Besides, JICA invited eight (8) counterparts mainly from the federal government to the training by country, which was hosted by JICA and held in Japan during the period of the Master Plan Study, and the Study Team gave them lectures on electrical engineering and PV systems design. In addition, JICA plans to hold the second training by country in Japan after the period of the Master Plan Study. The training will target the counterparts in the state governments and researchers at national research centers and concentrate on project implementation.

5.2 Development of Ability for Supervision

In order to promote village electrification projects using PV systems in Nigeria in the future, the engineers in the federal government and state governments who will play a role as implementation agency shall supervise all the stages of a project from procurement and installation to testing.

Throughout the supervision of the Project, therefore, the Study Team aimed to improve the ability of engineers in the counterparts and carried out the following transfers of skill in supervision:

1) Expounding the procedure for dealing with approval drawings, points on reviewing the drawings, and notabilities during supervision to the engineers by use of the reviewed approval drawings of the Project,
2) Instructing the engineers on computing rates of progress of engineering works, which are required to supervise the works,
3) Making a survey of the construction sites with the engineers and pointing out defects in the works, and
4) Having the engineers act for the Study Team during our absence form Nigeria.

5.3 Development of Ability for Management of Organization

The Study Team organized VECs at the target villages, which would take charge of O&M of the PV systems after the commencement of their operation. The VECs were built up under the control of the existing autonomous communities; and would conduct a daily checkup of the PV systems, keep a record of their operation, and manage the revenue and expenditure.

In order to ensure smooth management of VECs, the Study Team aimed to strengthen the ability of the concerned parties in the Project and carried out the following activities:

1) Educating the villagers to pay the fees for PV system utilization at the village meetings along with the counterparts in the federal government and state governments, and Instructing the VECs to get tough with the users who do not pay the fees and to take action against them in accordance with the lease agreement,
2) Preparing recording forms (Log Book) which make it easier to manage the revenue and expense, maintenance, and inventory; and instructing the VECs on how to fill out the Log Book,
3) Instructing VECs on how to deal with the discarded batteries and scrap, and requesting the counterparts in the state governments to observe it,
4) Requesting the counterparts in the state governments to visit the target villages periodically and to monitor whether the VECs function healthily or not
5) Showing a cash flow during the period of the Project (assume it as 20 years) to the counterparts in the federal government, and expounding the reason for setting of fees for PV system utilization to them, and
6) Negotiate the local governments together with the counterparts in the federal government and sate governments, and secure a promise of support for the Project from the local governments.

5.4 Outcomes and Issues of Capacity Development

5.4.1 Federal Government and State Governments

In order to verify the development of ability for engineering, the Study Team gave the former trainees of the JICA training in Japan an assignment and evaluated their answers. As a result, they generally understood the design procedure proposed by the Study Team in the Project. However, they did not attain the level of understanding the necessary design conditions, defining the specification of system components, preparing the drawings and specifications. In addition, they have major problems with ability of documentation, and sharing of information, etc. For the future, the engineers shall be given an opportunity to design PV systems and prepare the specifications in a similar project, and consultants or specialists will review the documents prepared by them and instruct them on how to improve the quality of documents.

As for ability for supervision, the counterparts could supervise the Project by themselves as long as the Study Team pointed out the issues to be confirmed beforehand. However, the ability to find the issues on the supervision is to do with the ability for engineering after all, so they shall experience the similar projects as much as possible.

Concerning the ability for management of organization, the counterparts have a talent for presentation and persistent negotiation by nature, and greatly played a role in educating the villagers and instructing the VECs upon request of the Study Team. However, they did not sufficiently understand the financial evaluation which is essential to plan a project. For the future, they shall develop ability for project evaluation during the period of the project implementation.

5.4.2 Local Governments

Obtaining cooperation from the counterparts in the federal government and state government, we could extract a promise of voluntary support for the Project form the local governments. The local governments subsidize the PF and SL contributing on the public interest, and also agreed to bear the salaries of O&M staff members. Consequently, the Study Team could greatly decrease the fees for PV system utilization.

However, we observed that the promised subsidy often had not been paid on time. Unless the subsidy is transferred as planed, the VCSs will run short of cash when they need to replace the batteries after several years, and then the Project can be collapsed. Therefore, the local government shall be fully aware of their influence on the sustainability of the Project.

5.4.3 Villages

As a result of the instruction to the villagers during the village meetings, the VECs could acquire skills in daily checking and understand how they fill out the Log Book. In addition, the VECs got tough against users who did not pay for the fees and disconnected the wire to prevent them from using the PV systems. Since the VECs were built up under the control of the existing autonomous communities, the village chiefs are likely to exercise leadership, and the villagers monitor each other well.

The future issue is to ensure to manage the revenue and expense and save enough money by the time of the replacement of equipment throughout the long period of theProject.

Chapter 6 Monitoring

6.1 Method of Monitoring

In order to evaluate the sustainability of the PV systems, the Study Team prepared formats of O&M records (Log Book, refer to Appendix 6) and monitored the Project. Taking into account the consistency of the records and literacy rate of the PV system users, we kept a record of O&M of the Project as follows:

1) The Study Team charged the VECs to select target SHS and BCS households—the numbers of target households shall be between ten (10) and twenty (20) respectively—to keep a record of energy consumption at SHS, BCS, and PF,
2) The O&M staff members of VECs would visit the target houses every day and keep the records on the formats,
3) The O&M staff members would start to keep the above records on date of the commencement of operation and continue to do that until the end of November 2006 (5th field survey), and
4) The O&M staff members continuously would keep the records of the revenue and expense, and the inventory of spare parts while the PV systems are utilized in the villages.

6.2 Result and Analysis of Monitoring

At the 5th field survey, the Study Team collected the Log Book from each VEC. Meanwhile, we received the completion reports of the maintenance works from the contractors, and then inspected the result of the maintenance work during the site surveys. The results of monitoring and its analysis are described as below.

6.2.1 Jigawa state

Table 6-1 shows the inspection results and Study Team's responses at Garkon Alli village.

Table 6-1 Result of Monitoring at Garkon Alli Village in Jigawa State

Item	Inspection Results	Stud Team's Responses
O&M Organization	• At Garkon Alli village, the villagers had started utilizing the PV systems at the end of June 2006; however, the users did not signed the lease agreement.	• The Study Team held a village meeting and required all the users to sign the agreement immediately.
	• The VEC had started collecting the fees for SHS utilization and battery charge in July 2006; however, they did not received the fees for the SHSs at the schools.	• The Study Team confirmed a man in charge of payment for the SHSs at the schools and required him to pay the amount which were corresponding to the fees from June 2006 to that moment.
	• The VEC did not use the required format (Log Book) to keep the records of revenue and expense, but noted the records on a notebook.	• The Study Team instructed them on how to fill out the Log Book again and required them to transcribe the records on the Log Book.
	• The VEC used a part of the collected fees as a salary for the O&M staff members.	• Not responded particularly
	• The local government transferred subsidies, but the amounts were less than what they promised. In addition, they did n not paid it for a month.	• The Study Team Send a letter to FMPS and requested them to facilitate the local government through the state government to pay the subsidies as they had promised.
	• The VECs did not procured a spare bottle of distilled water though they ran short of the water for the maintenance of batteries.	• The Study Team required them to procure the spare distilled water immediately.

Maintenance of the PV Systems	• The VEC had conducted the maintenance of the PV systems (cleaning, troubleshooting, etc.). • At BCS, tree (3) units of the battery charges had broken down, and the contractor replaced them with the new ones. In addition, one (1) spare battery for BCS was damaged.	• Using the PV systems manual, the Study Team instructed them on the troubleshooting again. • The Study Team reported the troubles to the contractor, and required them to contact JAEF and to replace the damaged battery.
Availability of the PV Systems	• The VEC kept records of energy consumption; however, the number of records were far less than what the Study Team had requested. • Several users complained that they could only use the lightings for a few hours.	• The Study Team collected the said records and analyzed them. • The Study Team judged that the users overused the systems and caused the low voltage of batteries, so we held a village meeting and encouraged all the users to save electricity.
Support form the Counterparts	• JAEF had visited the village once and more, confirmed the O&M records, and given technical support. • JAEF deposited the subsidies from the local government in a bank account under the name of JAEF.	• The Study Team requested JAEF to continue to inspect the village periodically and report the results to FMPS at the end of every month. • The Study Team made JAEF be sure to used the cash only for the Project.

Source: JICA Study Team

As a result of the monitoring, the VEC has managed the Project without major problems. From technical point of view; however, the frequent breakdown of the battery chargers at BCS station are pending issues. The Study Team interviewed the concerned parties after the site inspection, and suspected the users and O&M staff members of the breakdown by connecting/disconnecting the cables on/from the batteries without opening the breaker (MCCB) in the charging circuits and causing a short-circuit. Therefore, we requested JAEF to instruct the villagers to be sure to turn off the breakers and switches whenever they connect/disconnect the cables.

6.2.2 Ondo state

Table 6-2 shows the inspection results and Study Team's responses at Oke-Agunla village.

Table 6-2 Result of Monitoring at Oke-Agunla Village in Ondo State

Item	Inspection Results	Stud Team's Responses
O&M Organization	• At Oke-Agunla village, the villagers had started utilizing the PV systems at the end of June 2006; however, the users did not signed the lease agreement. • The VEC had started collecting the fees for SHS utilization in July 2006; however, some users refused to make payment. Hence, the O&M staff disconnected a cable and kept the users from utilizing the systems. • The VEC used the required format (Log Book) to keep the records of revenue and expense, but did not fill out the forms with accuracy. • The VEC used a part of the collected fees as a salary for the O&M staff members; however, the members were not fully paid because the VEC could not collect all amount of the fees. • The local government did not pay a subsidy for the Project at all.	• The Study Team held a village meeting and required all the users to sign the agreement immediately. • The Study Team educated the villagers to pay the fees at the village meeting, and the users who had not made payment agreed to pay the fees. Therefore, the staff will reconnect the cable as soon as the said users pay the overdue fees. • The Study Team instructed them on how to fill out the Log Book again. • The Study Team checked the balance of the account of the Project and confirmed that the VEC had a remaining cash. Accordingly, we requested the VEC to discuss using the cash to fulfill the staff member's salary internally. • The Study Team visited the local government along with the counterparts; however, we could not meet the chairman to make progress on the issue. Consequently, the Study Team requested the counterparts in the state government to continue discussions on it.
Maintenance of the PV Systems	• The VEC had conducted the maintenance of the PV systems (cleaning, troubleshooting, etc.). • All systems had operated healthily.	• Not responded particularly • Not responded particularly

Availability of the PV Systems	• The VEC kept records of energy consumption; however, the number of records were far less than what the Study Team had requested. • The above record said the users had utilized the systems for longer hours than designed.	• The Study Team collected the said records and analyzed them. • The Study Team encouraged all the users to save electricity and explained the idea of the standard hour-of-use of the PV systems at the village meeting
Support form the Counterparts	• OSEB had visited the village once and more, confirmed the O&M records, and given technical support.	• The Study Team requested OSEB to continue to inspect the village periodically and report the results to FMPS at the end of every month.

Source: JICA Study Team

As a result of the monitoring, the VEC has managed the Project properly from both technical and managing point of view. At Oke-Agunla village, the technician of the O&M staff members got tough with the users who had not made payment. If they had not paid the fees for more than three (3) months, he took action to disconnect a cable and kept them form utilizing the systems. The action could have caused a conflict between the technician and users; however, the village chief strongly supports the technician so that the VEC can strictly manage the Project in accordance with the lease agreement without any conflict. This is a good example of the O&M organization which is under the control of an autonomous community.

6.2.3 Imo state

Table 6-3 shows the inspection results and Study Team's responses at Umuikoro/Opehi village.

Table 6-3 Result of Monitoring at Umuikoro/Opehi Village in Imo State

Item	Inspection Results	Stud Team's Responses
O&M Organization	• At Umuikoro/Opehi village, the villagers had started utilizing the PV systems at the end of March 2006. The VEC was supposed to start collecting the fees in August 2006; however, they did not collected fees at all • The VEC did not keep the records of revenue and expense, and inventory of spare parts at all. • Although the local government had agreed to offer a subsidy during the 4th field survey, its content had not been decided. Consequently, the VEC did not receive any subsidy from the local government. In addition, the local government had agreed to pay salaries for the O&M staff members as well, no progress was made.	• The Study Team held a village meeting to inform the villagers of the fees for the system utilization, and required all the users to pay the fees immediately. As a result of a discussion with the VECs, they decided 7th day of every month as the due date for payment and promised to collect the fees for the last three (3) months in November 2006. • The Study Team instructed them on how to fill out the Log Book again and required them to start keeping the records immediately. • The Study Team visited the local government along with the counterparts and had a meeting with the chairman. The local government finally confirmed the amount and content of the subsidy for the Project.
Maintenance of the PV Systems	• The VEC had conducted the maintenance of the PV systems (cleaning, troubleshooting, etc.).	• Not responded particularly
Availability of the PV Systems	• The VEC did not kept records of energy consumption at all. • Many users complained that they could only use the lightings for a few hours.	• The Study Team severely condemned the VEC for their irresponsibility. • The Study Team judged that the said problem was caused by the low voltage of batteries because of the low solar irradiation during rainy season and overuse of the systems by the users, so we encouraged all the users to save electricity at the village meeting.
Support form the Counterparts	• PURD had visited the village only once since the commissioning ceremony because of the car breakdown.	• The Study Team requested PURD to inspect the village periodically and report the results to FMPS at the end of every month for the future.

Source: JICA Study Team

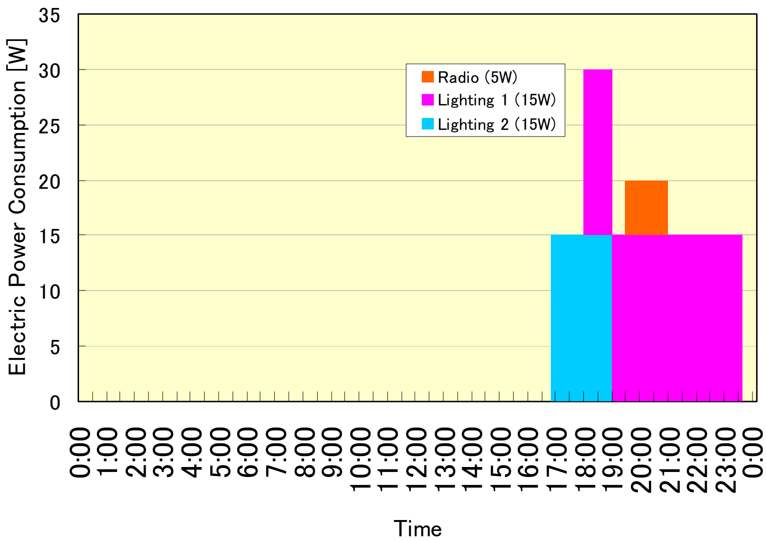
As a result of the monitoring, the VEC did not play the required role in the Project at all. In addition, the counterparts did not satisfactorily support the VEC either so that the status of the O&M at Umuikoro/Opehi village failed to be mended.

In the 4th filed survey, the content and intended use of the subsidy form the Nogar Okupala local government had not been confirmed so that the fees for the system utilization did not yet decided. Although the unsettled fees was a part of the reason of the above issue, the VEC should have collected N550 per month as the fee of SHS utilization because the Study Team had explained to the villagers that the fees would be N550 in case the local government did not subsidize the Project. Therefore, the issue was obviously caused by the such factors as the users' low sense of liability to pay the fees, VEC's low sense of responsibility, village chief's lack of leadership, the counterparts' lack of commitment to the Project. This is a typical example of how the rural electrification using PV systems turns out to be unsustainable. From now, all concerned parties shall pay attention to whether: the VEC will improve their ability for management following instructions from the Study Team, the state government and local government will continue their support of the Project, and the Project at Umuikoro/Opehi village will be sustainable.

6.2.4 Analysis of Availability of the PV systems

(1) SHS and BCS

We analyze the energy consumption data which was obtained in Jigawa and Ondo states. the Fig. 6-1 shows an example of the daily load curve at SHS in Jigawa state. The users are likely to start using the lighting at sunset. In the example, the user shortens the period of using two (2) sets of the lighting so that he/she can use one (1) set of them longer. The example is considered to be that the user properly understands the limitation of the PV system. The other data of the energy consumption also shows that the users tend to use the lightings between 18:00 and 24:00 for the purpose of spending time with their family and reading/study. In addition, they use a radio for several hours since only the radio is available as a DC load as of now.



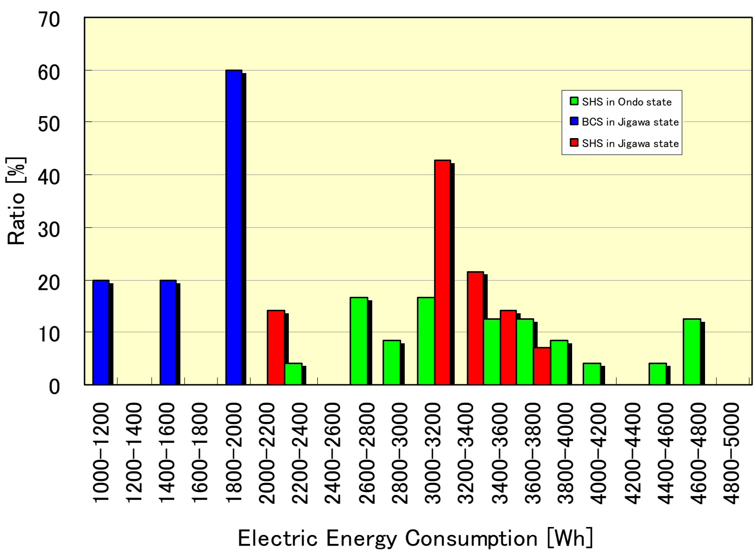
Source: JICA Study Team

Fig. 6-1 Example of Daily Load Curve

At the BCS station, they charge three (3) or four (4) batteries a day—There are five (5) charging circuits at the station. The period of the charging batteries are generally from 8:00 to 18:00—ten (10) hours.
We intended to collect the data of the battery voltages before and after charging; however, the O&M staff could not measure them because of the breakdown of the instrument.

The Fig. 6-2 shows the monthly electric energy consumption. The figure indicates the energy consumption at the BCS is relatively lower than at the SHS. For the design, we assumed the same energy consumption for both the BCS and SHS and decided the specification of equipment. The types of deliver equipment are slightly different from what we designed; however, the lightings (loads) are the same for both the BCS and SHS.

As we illustrated in Fig. 3-6, in the case of BCS, the battery voltage declines as the user utilize the energy, and charge controller will automatically disconnect the loads when the controller detects the low voltage of the battery. Meanwhile, in the case of SHS, the battery is daily charged by the PV modules, and so the voltage will not decline but remain the same level if the value of solar irradiation are higher than the design value. Therefore, the SHS users are able to utilize the loads for longer hours than assumed.



Source: JICA Study Team

Fig. 6-2 Monthly Electric Energy Consumption

The Fig. 6-3 and 6-4 show the examples of monthly energy consumption at the SHS and BCS, respectively. In Fig. 6-3, the SHS user constantly consumes energy in the range of 100 watt-hour a day. Meanwhile, in Fig. 6-4, the BCS user consumes energy about 80 watt-hour a day and can not utilize the system for a day or so in order to charge the battery.

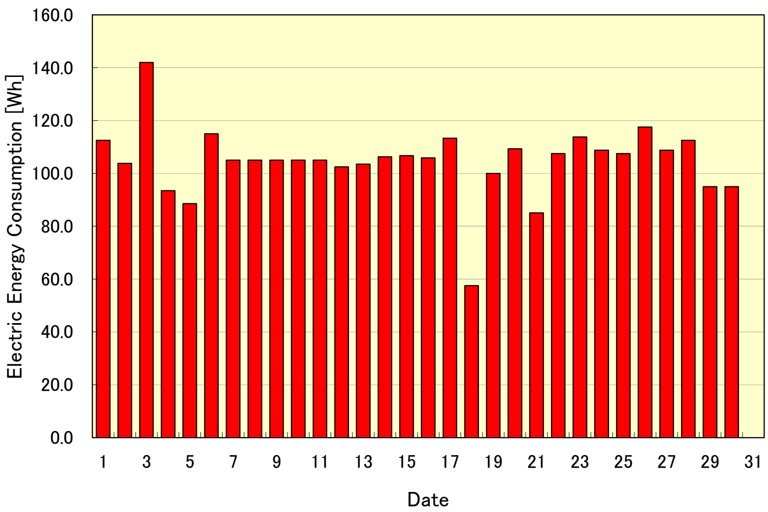
From the records of energy consumption above, the Study Team concludes that the BCS installed in the Project are inferior to the SHS in terms of quality of service, i.e. the BCS users can utilize less energy than that of the SHS users' and can not utilize the system for a day or so every time they charge the batteries. In order to raise the quality of services of BCS, we propose the countermeasures as follows:

a) Revision of Design Procedure

We newly assume the coefficient of loss, K_S , caused by the self-discharge of battery, and assume it as 0.8 to calculate the required ampere-hour[1]. As a result of the trial calculation according to the design procedure in Chapter 3, the interval of charging is as the same as before—five (5) days, but the number panels of PV module becomes twenty-one (21)—originally eighteen (18) panels.

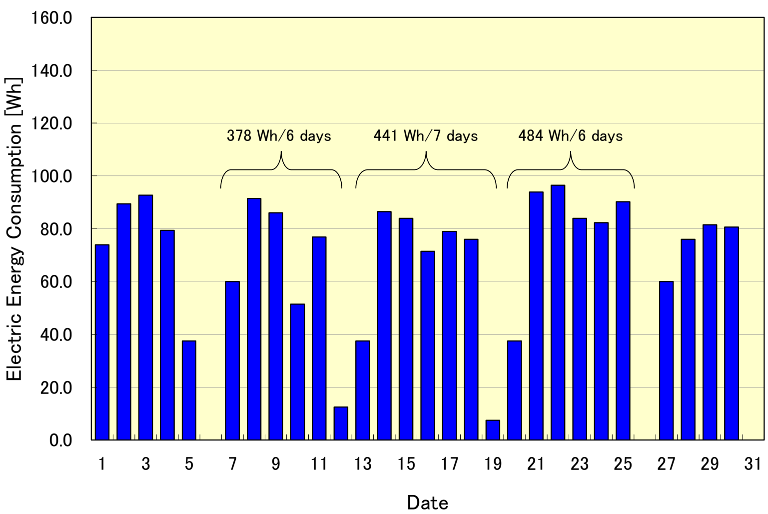
b) Revision of Battery Operation

At BCS stations, we propose to prepare the same number of batteries as that of charging circuits. The O&M staff charges all the said batteries in advance, and the users will receive the charged batteries at BCS station in exchange for the discharged batteries.



Source: JICA Study Team

Fig. 6-3 Example of Daily Load Curve (SHS)



Source: JICA Study Team

Fig. 6-4 Example of Daily Load Curve (BCS)

1 Referring to Fig. 6-3 and 6-4, we divide the energy consumption at BCS, 484 Wh/6-day, by that of at SHS, 600 Wh/6-day, to find 0.8.

(2) PF

In Jigawa state, the villagers use lightings at PF (mosque) twice a day early in the morning—one and a half (1.5) hours in total. In addition, they utilize an audible speaker as a DC load for three (3) hours a day.

In Ondo state, by using lightings at PF (health care center), the villagers can enjoy a round-the-clock medical care at the PF (health care center). They used to go to the nearest electrified village for medical care at night, but residents in nearby villages currently come to Oke-Agunla village to take a medical care. In addition, the vaccines are preserved in the PV vaccine refrigerator.

In Imo state, the villagers removed the light valves at PF (meeting hall) and left them unused since they had not completed the repair work of the hall. However, they only used the lighting at a clinic inside the hall.

As described above, the PV systems for PF contributes to the human security (e.g. healthcare, education, security, etc.) in the overall communities.

(3) SL

In all the target villages, the SLs properly operated. At night, the villagers get together under the SLs to enjoy playing a game and chatting. In Jigawa state where the majority of people are Muslim, the SLs are used as prodigious meeting places for women because they can only go out of their residences during the night.

As mentioned above, the PV contributes to improve a benefit of women in the villages.

6.3 Questionnaires to PV system Users

The Study Team asked the users questionnaires about the Project during the 5th field survey, At the village meetings, the counterparts speaking the local languages played a role as facilitator and carried out the questionnaires. The form of questionnaire and result of answers are attached as Appendix 7. We analyze the result of answers as below.

(1) Degree of Satisfaction and Understanding regarding the PV systems

Almost all the users are satisfied with the PV systems. The reasons of satisfaction are firstly “Reliable and/or Easy to use,” and are secondly “Reasonable tariff” (Refer to Fig. 2-1 and 2-2 in Appendix 7).

As for the question of “Do you understand how to use the PV systems,” most of the users in Jigawa and Ondo states reply affirmatively. However, 30% of the users in Imo state reply negatively (Refer to Fig. 2-3 in Appendix 7).

As for the question of “Do you understand that PV systems have the limitation,” 40% of the users in Imo state reply negatively (Refer to Fig. 2-4 in Appendix 7).

The reason of negative answers from the users in Imo state is that they were not eager to understand the PV system. The result of answers suggests the reason why the Project has not been managed well in Imo state.

(2) Effect of the PV systems

As for the question of "Who use the PV systems often," more than 90% of the users in Jigawa state answer "Wife." Meanwhile more than half of the users in Ondo and Imo states answer "Husband." The result in Jigawa state ensures that women mainly stay home and can not act for themselves (Refer to Fig. 2-5 in Appendix 7).

As for the question of "Did you start any business after you started using the PV systems," most of the users answer "Non." Although about 20% of them answer "House industry," as a result of interviewing some users after the questionnaire, we found that they only produced snacks and foods for their private use and did not sell products to the others. Therefore, the answer does not surely mean that they started business (Refer to Fig. 2-6 in Appendix 7).

As for the question of "What did the PV systems improve," we received answers from a husband and housewife points of view respectively. The answers of husband's perspective are too dispersed to characterize the tendency. Regarding the answers of housewife's perspective, more than half of them are "Household work and/or Child care." The result suggests that "Household work and/or Child care" are housewives' work at home (Refer to Fig. 2-7 and 2-8 in Appendix 7).

As for the question of "How much do you spend for energy before and after you started using the PV systems," the expense averagely decreases by N359 equivalent to 59% (Refer to Table 2-1 in Appendix 7).

(3) Preferred PV systems

We presented four (4) types of PV systems, which consisted of the 55 W SHS, 110 W SHS, 165 W SHS, and BCS, and asked the users to select the preferred system. In Jigawa and Imo states, the users are likely to want the SHSs with larger capacity (110 W and 165 W). Meanwhile, about half of the users in Ondo state want the 55 W SHS. The reason of the answers is that the users in Ondo state were satisfied with the existing 55 W system since all the system were usable and operated healthily without the load disconnection, while some users in Jigawa and Imo states complained that they could only use the system for a few hours (Refer to Fig. 2-9 in Appendix 7).

Three (3) users in Jigawa state and two (2) users in Ondo state choose BCS, and the number in total are equivalent to 5% of all the respondents. In terms of the quality of service, BCS is inferior to SHS; however, a few of the users want to utilize BCS because of the reasonable fees.

As a result of the further analysis of each answer, we found that many respondents chose the systems which would require them to shoulder the fees in excess of their yearly income. The result suggest that they do not only have knowledge of yearly income but also desire to have the large systems without considering the cost burden. Therefore, the answer does not surely mean that they are capable of paying the expenses of their preferred PV systems.

(4) PF and SL

As for the question of "What do you think of PF/SL," almost all the users answer "Beneficial" (Refer to Fig. 3-1 in Appendix 7).

As for the question of "How long do you want to use SL," most of them answer "8 hours" and more. Especially, all the users in Jigawa state answer "12 hours," because they patrol the village to secure the safety all night long, and consider the SLs beneficial to crime prevention if they utilize the SLs all night. However, as for the additional question of "Which do you prefer one (1) SL for 12 hours or two (2) SLs for 6 hours," all the users in Jigawa state preferred "two (2) SLs for 6 hours" (Refer to Fig. 3-2 in Appendix 7).

As for the questions of "Are you willing to pay tariffs for PF/SL" and "What is the reason of above answer," the answers are split into "Yes, because they are beneficial" and "No, the local government shall pay for them." (Refer to Fig. 3-3 and 3-4 in Appendix 7).

(5) SHS and BCS

As for the question of "What do you think of the monthly tariff of SHS," the most users answer "Inexpensive/Reasonable" (Refer to Fig. 4-1 in Appendix 7).

As for the question of "What do you think of the charging fee at BCS," the most users answer "Inexpensive/Reasonable" (Refer to Fig. 4-2 in Appendix 7).

For the users in Jigawa state, we asked the question of "Considering the monthly charge of SHS, which do you prefer SHS or BCS. " As a result, all the SHS users prefer "SHS", meanwhile the answers from BCS users are almost equally split into "SHS" and "BCS." The reasons of the BCS users are that "Reasonable tariff" or "Reluctant to carry the battery." (Refer to Fig. 4-3 and 4-4 in Appendix 7).

(6) VEC

As for the question of "Does the committee manage the Project," almost all the users reply affirmatively (Refer to Fig. 5-1 in Appendix 7).

As for the question of "Does the maintenance staff maintain the PV systems properly," almost all the users reply affirmatively (Refer to Fig. 5-2 in Appendix 7).

(7) State Government and Local Government

As for the question of "Do you think the local government and state government contribute to the Project enough," the most users reply affirmatively; however, 20% of them in Imo state reply negatively. The reason of the answers in Imo state is that the amount and content of the subsidy from the local government had not been decided at the point of the questionnaire, so some of the users were dissatisfied with it (Refer to Fig. 6-1 in Appendix 7).

As for the question of "What do you expect the local government and state government to do," the most users answer "Financial support," but the answers for the user in Jigawa state were almost equally split into "Financial support" and "Technical support." The reason of the answers is that the BCS which needs time-consuming maintenance is introduced only in Jigawa state so that the villagers seek technical support from the state government (Refer to Fig. 6-2 in Appendix 7).

Chapter 7 Conclusion

7.1 Evaluation of the Pilot Project

As a result of monitoring in Chapter 6, we evaluate the Project based on the PDM shown in Table 1-1.

7.1.1 Efficiency

From the viewpoints of the achievement, amount, and timing of Inputs of the Project, we evaluate how efficient the Outputs of the Project were achieved.

Table 7-1 shows

Table 7-1 Evaluation of Achievement of Outputs of the Pilot Project

Item	Evaluation Result
1. The O&M organizations function effectively.	The O&M organizations have functioned effectively without major problems. • The Study Team built up VECs which would take charge of the O&M of the Project by participatory methods. The VECs chose the O&M staff members, PV system users, and locations of SL by themselves. • In Jigawa and Ondo state, the VECs have collected the fees and managed the revenue and expense properly. The VEC in Imo state does not function effectively as of the moment, we can expect them to improve its function in the future. As long as the local governments continuously provide the subsidies, the financial problems will not occur in the Project. • In Jigawa and Ondo states, the VESs have paid the salaries to the O&M staff members. In Imo state, the local government promised to hire the O&M staff. • Because only a few months have passed since the commencement of the operation of the PV systems, the VECs do not have to purchase the spare parts except the distilled water in Jigawa state as of 5th field survey. They are able procure spares of the fluorescent light or storage batteries through the state governments. • The users are generally satisfied with the management of the Project by the VECs. • Because of the delayed schedules of installation works, we could only monitor the Project once until the 5th field survey. To improve the status of management by the VECs, we should have monitored the Project twice and more.
2. The O&M organizations certainly maintain the PV systems.	The O&M organizations have maintained the PV systems certainly. • All the PV systems installed in the Project are usable. • The users are generally satisfied with the maintenance of the systems by the VECs.
3. The users utilize the PV systems properly.	The users have utilized the PV systems almost properly. • The Study Team proposed the way to manage the hour-of-use of the systems, and the counterparts in the state governments and O&M staff members understood it. They have instructed the users of SHS and BCS on how to use the systems. • A part of the users utilized the systems for than the specified hours. By the educational activities by the Study Team at the village meetings, they understood the proper hour-of-use of the systems. • The users understood how to use the systems and their limitations generally. • The Study Team collected the data of energy consumption from the VECs; however, the numbers of sample were far smaller than we requested. To get hold of the user's energy consumption with accuracy, we should have gotten as many numbers of data as possible.
4. The support systems from the counterparts are established.	The support systems from the counterparts were established. • The counterparts in the state government periodically have visited the target villages and supervised the management of VECs. • The local governments financially have supported. • The Study Team built up the correspondence procedure between the federal government, state governments, and VECs. • The users are generally satisfied with the support from the state governments and local governments.

Source: JICA Study Team

As describe in Table 7-1, all the Outputs are almost achieved as of the 5th field survey.

In three (3) states having different weather conditions, ethnic groups, and custom, the Project was implemented in the scale of one (1) PF, eighty (80) individual PV systems (BCS and SHS), and ten (10) SLs, respectively. As a result of monitoring, a variety of Outputs appeared in the target villages, and we acquired the sufficient survey results to verify the deference between BCS and SHS, and effectiveness of PF and SL. Therefore, the amount of Inputs are considered to have been appropriate.

However, the delays in the procurement of equipment for the Project and installation works made us postpone the start of monitoring scheduled at the end of 3rd field survey until the end of 4th field survey. Consequently, we could only have monitored the Project once by the end of the Master Plan Study. Therefore, the problem of the timing remained to be solved.

7.1.2 Effectiveness

We evaluate how far the Project Purpose was effectively attained by the above achievements of Outputs.

As of the end of 5th field survey, the above Outputs brought about the attainment of the Project Purpose (The users understand the PV systems, and the systems are properly operated and continuously utilized), and we could attain the purpose up to a certain point, on which the PV systems are properly operated.

We will attain the remaining part of the purpose (The PV systems are continuously utilized) as long as VECs satisfactorily function by the continuous support from the counterparts and the users utilize the systems properly.

7.1.3 Impact

We evaluate the negative/positive impact caused by the implementation of the Project.

The positive impact is summarized as follows:

- Thanks to the lighting at BCS and SHS households, the users got to have more opportunities for spending time with their family, and to read/study at nigh,
- The lightings at PF brought about round-the-clock medical care, which results in the improvement of human security in the overall communities,
- The SLs were utilized as the prodigious meeting places for women, and
- The users could reduce the quantity of kerosene consumption, and their energy expense decreased.

Meanwhile, the fees of PV systems utilization can be negative impact; however, the users can set off the reduced energy expense against the fees for the system so that the fees can not be hard-impact for them. In addition, as for the environmental impact caused by the discarded batteries in the future, the batteries can not be negative impact because they are recyclable in Nigeria and the VECs are able to ask a battery collector to buy them as the Study Team instructed.

7.1.4 Relevance

We verify that the Project Purpose and Outputs are still justifiable at the time of evaluation.

Since the electrification projects using PV systems are consistent with the rural electrification policy in Nigeria, a lot of similar projects is considered to be implemented in the future. The viewpoint of the O&M in the Project Purpose and Outputs are common issues in rural electrification projects using PV systems; therefore, the Project Purpose and Outputs are still justifiable.

7.1.5 Sustainability

We evaluate if the benefits brought by the Project are sustainable after the Master Plan Study.

The Study Team built up the correspondent procedure between the federal government, state governments, and VECs. Therefore, the benefits are considered to be sustainable as long as the counterparts continue to support the Project.

7.1.6 Conclusion

Although there was a problem of the timing of Inputs, the implementation of the Project proved that a rural electrification projects using PV systems is sustainable under the following scheme:

1) A donor bears all the initial investment,
2) An O&M organization is built up under the control of an existing autonomous community and the organization takes charge of the O&M of PV systems,
3) The users of the systems pay fees corresponding amounts of money as fees for the system utilization, and
4) The governmental organizations subsidize the O&M expense of the PV systems contributing to the public interest.

From now on, we expect the VECs fulfill their responsibilities and the concerned governmental organizations continue to support the VECs so that the PV systems installed in the Project can be continuously utilized.

7.2 Lessons and Recommendations

7.2.1 Procurement of Equipment

Targeting bidders in Nigeria, JICA Nigeria Office invited public tenders and procured equipment for the Project. We describe the lessons which we learned from the tender for procurement of equipment, inspection, and supervision; and recommendations for the similar projects as below.

(1) Method of Tender

Public tenders do not result in cost reduction in Nigeria, if anything, the method of tender allows ineffective bidders in terms of procurement and construction to enter a tender and will cause a problem .Therefore, we recommend that: a purchaser shall strictly carry out a pre-qualification to prevent bidders who are unable to work on time; and the purchaser shall invite the qualified bidders to a nominative tender. At a pre-qualification, a puncher shall pay attention to the following points:

- Experiences in the similar projects (The purchaser shall confirm not only experiences but their performance by the owners' certificate, and shall verify that the bidders complete the job on schedule),
- Design documents in the similar projects (The purchaser shall judge the bidders' ability by the drawings and technical calculation sheets)

In addition, the purchaser shall hold a briefing to make the bidders understand the scope of work and contents of specification.

(2) Technical Specification

We recommend that a purchaser shall make use of the technical specification prepared by the Study Team or ones published by World Bank[1] (WB) when he/she carries out the similar project.

In the Project, the Study Team defined the specification of each equipment in detail and required the bidders to submit the technical data sheets as a part of the tender documents. At the technical evaluation, the Study Team verified whether the proposed equipment meet the specification or not based on the submitted data sheets. However, we frequently found inaccurate data in the sheets, and the contractors often changed the type of equipment at the point of delivery. Consequently, we took a long time to evaluate the tenders by means of the technical data sheets, but the method was not effective as we expected. The specification of products for PV systems are quite similar, therefore, we recommend that a purchaser shall simplify the specification as the following examples:

- PV module: Shell SM55 or equivalent
- Charge Controller: Morningstar SHS6 or equivalent

In addition, the purchaser shall require the bidders to submit the certificates, which prove the proposed products are comply with the international standards (IEC, ISO, etc.) or PV GAP Standards[2].

(3) Approval Procedures

In the Project, the contractors did not understand the drawings/documents for approval, and their negligence caused the delay in procurement and installation. A purchaser shall make the bidders understand the required approval procedures at a briefing. Additionally, we recommend that a purchaser shall take the submission of the drawings/documents for approval for the conditions of payment in the contract agreement; the purchaser shall get tough with the contractor and penalize

1 http://www.worldbank.org/、Home > Topics > Energy > RE Toolkit > Project Tools > Technical Standards and Specifications
2 PV GAP: An international NPO promoting to popularize PV systems. They publish the standards of PV system components (charge controller, storage battery, etc.) which IEC and ISO have not established as their own standards.

him for the delay if he fails to submit the by them due date.

Besides, the contractors are likely to change the specifications of delivered products unilaterally, so the purchaser make the contractor be sure to get an approval from the purchaser in any case.

(4) Factory Test Data

In the Project, we required the contractors to submit the factory test data of the PV module, storage battery, and charge controller, etc.; however, they did not understand the importance of the test results at all and took a long time to submit them. Especially, tests on the output characteristics of PV module and capacity of storage battery can not be examined at the field test after the installation, therefore, the contractor must submit the factory test data so as to prove the quality of their delivered products. We recommend that the purchaser shall take the submission of the factory test data for the conditions of payment as the same as the drawings/documents for approval.

(5) Supervision

At all three (3) target villages in the Project, the contractor never delivered the equipment and construct on schedule. Although the Study Team visited the villages in accordance with the work schedule, the contractor did not deliver it and the site survey often turned out to be vain. Besides, the quality of construction work done by Nigerian contractor can not be considered to be satisfactory; therefore, a purchaser shall supervise the construction work all the time to raise the quality of job. Accordingly, we recommend that engineers of implementation agencies (or their consultant) shall stay at the site from the delivery of equipment to field tests.

7.2.2 PV Systems Design

(1) Solar Irradiation Data

The solar irradiation data is the most important parameter for PV systems design. In the Master Plan Study, we received the data of the monthly average solar irradiations in the neighboring towns of the target villages from Nigeria Meteorological Agency (NIMET) and used it for the deign. The data is; however, horizontal solar irradiations and no data of inclined solar irradiations exists. In order to optimize the tilt angle, the inclined solar irradiations data is necessary.

For the purpose of promoting to popularize the PV systems in Nigeria, the solar irradiation data shall be enhanced and be opened to the public. In case of Japan, the Japan Weather Association opens data of inclined solar irradiations at eight-hundred and one (801) points nationwide to the public[3]. The data is calculated based on the observed sunshine duration data for thirty (30) years and are arranged every 15° in direction and every 10° in tilt angle.

From now, we recommend that FMST shall take charge of enhancing the data of monthly inclined solar irradiations and opens it to the public.

3 *PV systems design manual,* March 2001

(2) Design Procedure

In Chapter 3, we described the design procedure which is used in the Project. However, the procedures and various coefficients are not absolute, and they shall be modified in accordance with the reality in Nigeria.

We recommend that ECN and the national research centers shall monitor the Project, verify the relevance of our design procedures, and modified them as a PV systems design guideline in Nigeria.

(3) Capacity Mesurement of Batteries

The time of replacement of the batteries in the Project will be subjectively judged by the users of PV systems as "The hour-of-use of lighting shorten than before" or "The battery does not last for a few hours even though I frequently charge it."

There is no way to measure capacity of storage battery in the village, so we recommend that test equipment comprised of a constant voltage/current charger, an electronic load, a data logger shall be installed at the national research centers. Whenever they need, they collect the batteries for PV systems in the village, examine the capacity measurement, and evaluate the result to make a decision on the time of replacement of the batteries in the village. In addition, when they can get and accumulate information on the relationship between the availability and life-cycle of the batteries, they will make use of the information to improve the said guideline. Therefore, we recommend that FMST shall consider to budget the above test equipment.

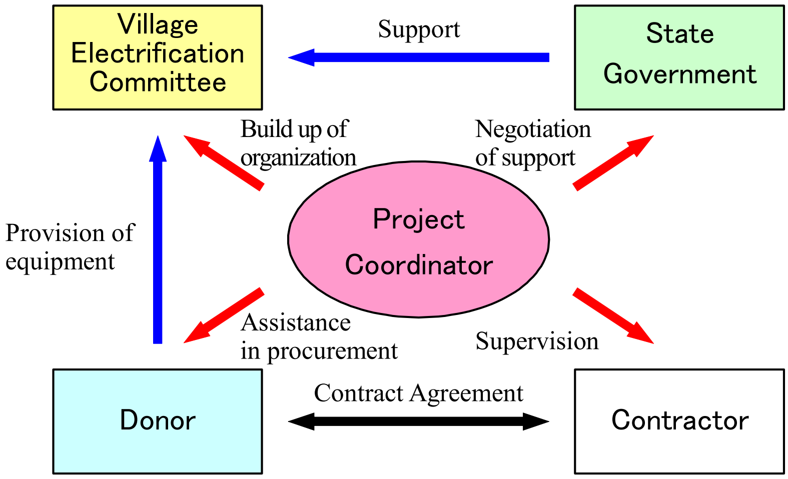
7.2.3 Project Implementation

(1) Project Coordinator

In the Project, the Study Team took charge of the PV systems design, preparation of tender documents, negotiation with the bidders, review of the drawings/document for approval, and supervision of the installation as engineers. Besides, we built up the O&M organization by participatory method as organizers.

In every field survey, the Study Team traveled with the counterparts in the federal government and state government, and worked on the negotiation with the local government or education of the VECs together. The counterparts properly fulfilled their duty while they were with us; however, they turned not to respond actively when we took them over the duties of study on the fees, negotiation of the subsidies, and left Nigeria. Next time we arrive, they often do not progress at all.

From now, we recommend that the implementation agencies shall play a role of a project coordinator as we did in the Project. Fig. 7-1 shows the role of project coordinator. FMPS/REA in the federal government or engineers in state governments (or their consultant) will take charge of it.



Source: JICA Study Team

Fig. 7-1 Role of Project Coordinator

(2) Subsidy

In the Project, the local government subsidize the O&M costs of the PV systems contributing to the public interest, and salaries of the O&M staff members. As a result, we could reduce the fees for the individual systems. According to the result of the questionnaire, the villagers are likely to request financial support, meanwhile, the local governments are willing to support the PF and SL.

However, if the local governments do not pay the subsidy fully or not transfer it on schedule, the Project are greatly influenced and can be collapsed. Therefore, the implementation agencies shall avoid a scheme of project taking it for granted that the local government always subsidize. Distinctively, as for the negotiation with the local government, all decision were made by the chairman so nothing proceeded in his absence.

(3) Project Cost

In the Project, the donor bore all the cost of the procurement and installation of equipment, and the federal government and state government did not shoulder any cost. They rendered a service to the Project. According to the evaluation of SELF project[4], the project was carried out by splitting the budget in half between SELF and Jigawa state; however, the scale of project downsized and delayed in starting operation because the budget from Jigawa state decreased and delayed in payment.

In case that the Nigerian government and a donor collaborate to implement a project, it is good to limit the commitment of the Nigerian side to a rendering of service

(4) Work Group

During the Master Plan Study, the JWG/LWG have been periodically held and functioned as a place where the concerned parties in the relevant sectors have lively a discussion and exchange of

4 Village Electrification Project in Jigawa State (September 30, 2005), SELF

opinions. From now, we recommend that FMPS and REA shall lead the group, periodically hold a this kind of meeting, and develop it as a forum at which issues on rural electrification project using PV systems are cross-sectionally discussed.