Japan International Cooperation Agency (JICA)
Ministry of Mines, Energy and Hydraulics (MMEH)
Agency of Senegal for Rural Electrification (ASER)
The Republic of Senegal

The Study on Photovoltaic Rural Electrification Plan in the Republic of Senegal

Pilot Project

March 2002

KRI International Corp.
The Institute of Energy Economics, JAPAN

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Currency Exchange Rate

(February 2002)

US$＝¥ 133.74

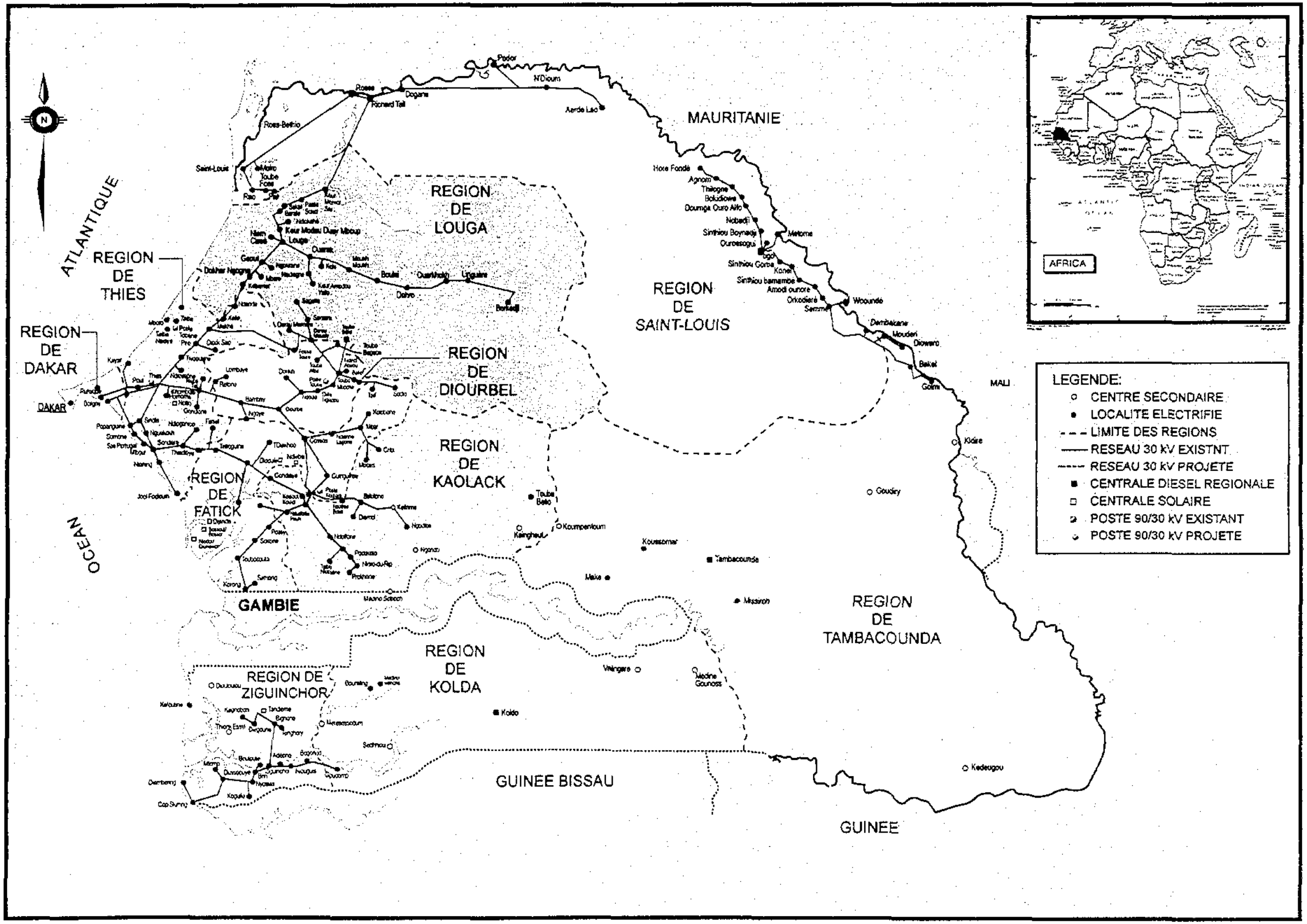
US$＝7.54 FF

Euro＝US$ 0.87

(Euro＝6.56 FF)

FF＝100 CFA (FF: French francs)

CFA＝¥ 0.177



LOCATION MAP

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Abbreviation

AC	:	Alternative Current
ADER	:	Association Senegalaise pour le Development de l'Electrification Rurale
ASER	:	Agence Senegalaise d'Electrification Rurale
BCEAO	:	Banque Centrale des Etats de l'Afrique de l'Ouest
CERER	:	Centre d'Etudes et Recherches sur les Energies Renouvelables Center of Study and Research on Renewable Energy
CFL	:	Compact Fluorescent Light
CMS	:	Senegalease Mutual Credit Fund
CNCAS	:	Caisse Nationale de Credit Agricole
CNES	:	Confederation Nationale des Employeurs du Senegal
CNQP	:	Centre National de Qualification Professionelle
CR	:	Communaute Rurale
CRSE	:	Commission de Regulation du Secteur de l'Electricite
DAST	:	Scientific and Technical Affairs Delegation
DC	:	Direct Current
DFI	:	Decentralized Financing Institutions
DFS	:	Decentralized Financing Systems
D/G	:	Diesel Generator
ERIL	:	Electrification Rurale d'Initiative Locale
ESCO	:	Energy Service Company
FAO	:	Food and Agriculture Organization
FEM	:	Fonds de l'Environnement Mondial
F/L	:	Fluorescent Light
FOPEN	:	Federation des Organisations pour la promotion des Energies Nouvelles Federation of Organization for Promotion of New Energy
GDP	:	Gross Domestic Product
GIS	:	Geographical Information System
GPS	:	Geographical Positioning System
GTZ	:	Deutsche Gesellschaft fur Technische Zusammenarbeit GmbH
HVD	:	High Voltage Disconnection
IDA	:	International Development Agency
IEA	:	International Energy Association
IPP	:	Independent Power Producer
ISN	:	Institute of Senegal National Standard

LV	:	Low Voltage
MMEH	:	Ministere des Mines, de l'Enegie et de l'Hydraulique
NGO	:	Non Governmental Organization
ODA	:	Official Development Assistance
OJT	:	On the Job Training
O&M	:	Operation & Maintenance
PASER	:	Plan d'Action Senegalais d'Electrification Rurale
PCM	:	Project Cycle Management
PDM	:	Project Design Matrix
PLE	:	Plan Locale d'Electrification (LEP)
PPER	:	Programme Prioritaire d'Electrification Rurale
PPMC	:	Pilot Project Management Committee
PTIP	:	Programme Triennal d'Investissements
PV	:	Photovoltaic
RESCO	:	Regional Energy Service Company
ROE	:	Return on Equity
SEMIS	:	Services de l'Energie en Milieu Sahelien
SFD	:	Systemes Financiers Decentralises
SHS	:	Solar Home System
SPF	:	System Photovoltaique familial
UCAD	:	University of Dakar
UNDP	:	United nations Development Program
VUA	:	Village Users Association
WB	:	World Bank
WHO	:	World Health Organization

Unit

mm	:	millimeter
m	:	meter
km	:	kilometer
El.m	:	Elevation in meter
l/s	:	liter per second
m/s	:	meter per second
m^3/s	:	cubic meter per second
mm^2	:	square millimeter

km^2	:	square kilometer
mg	:	milligram
ton, t	:	metric ton
V	:	Volt
W	:	Watt
kW	:	kilowatt
MW	:	Megawatt
Wp	:	Watt peak
kWp	:	kilowatt peak
GWh	:	Gigawatt hour
kWh	:	Kilowatt hour
MVA	:	Megavolt ampere
KVA	:	Kilovolt ampere
Ah	:	ampere hour
Hz	:	Hertz
RPM	:	Revolution (revs) per minute
%	:	Percentage

Currency Unit

CFA	:	Senegalese Currency
US$	:	US Dollar
M.US$	:	Million US Dollar
Euro	:	European Currency
Yen	:	Japanese Currency

1. Objective of the Pilot Project

1.1 Problems Found from the Past PV Electrification Projects

Rural electrification with photovoltaic system only started in the 1980' in Senegal through the assistants of foreign donors such as France, Italy and Spain. The most typical PV project was the Senegal - German Project started in 1987.

SHS system was sold on credit in the Senegal - German Project, and local associations which mainly work on the agriculture sector cooperated with the project as the management organization in rural area. In addition, some management committees which consisted of village people were also organized in cooperation with SENELEC. According to the "Plans Directeurs D'électrification Urbane et Rurale", it is estimated that more than 2,000 SHS were introduced under the framework of the Senegal - German Project.

Before the devaluation of CFAF in January 1994, credit system was available and the purchase price of SHS was CFAF 185,000. However, due to the devaluation of CFAF and bad performance in the repayment, SHS procurement was only available with a lump-sum payment, and its cost between CFAF 325,000 and 500,000 as same as the commercial price.

The role of SHS diffusion was transferred from Senegal - German Project system to the private sector in the third stage. Subsequently, Senegal - German Project has focused on the standardization of the SHS. However, SHS diffusion has been stagnated due to the drastic increase of SHS price after devaluation of CFAF. In addition, only a few credit systems were available to purchase the SHS system, because most of the credits haven't collected in the Senegal - German Project. According to the past PV electrification projects, it is considered that the technical specification of SHS was almost established. The main constraints of the PV diffusion is not in the technical aspect, but in the operation and management, and financial aspect. Most of the organizations which took a role of operator fell into difficulties of charge collection. In addition, there is another problem that operators couldn't maintain the SHS in good condition, because many users scattered in wide areas.

1.2 Objective of the Pilot Project

Among the problems, identified through the past electrification projects, main constraints of PV electrification are on the operation and maintenance aspects as well as the financial aspect. Particularly, establishment of operation and management system for SHS is very difficult when SHS users are scattered in wide areas. It is concluded that the establishment of operation and management system for SHS is the most important subject for the Pilot Project, considering the above situation. In addition, the establishment of operation and management system are expected to improve the payment condition of users. According to the past projects, there were many cases to refuse payment because there were no way to fix broken SHS, and users couldn't use electricity.

The Pilot Project was designed with following conditions, based on the "concession system" and "privatization of the eclectic industry" advocated by the Government of Senegal.

- Private company (Operator) is installed in the operation and management system
- Limited area (1 to 2 village) would be selected for target area. Then the Pilot Project supplies the service to certain number of users.

2. Site Selection

(1) Three Candidate Sites

At the preliminary stage of the present JICA Study, the Senegalese Government presented three candidate sites for implementation of Pilot Project. These three sites are located in Fatick, Thies and in Kaolack Regions respectively. The location map of these three sites are shown in Figure 2.1.

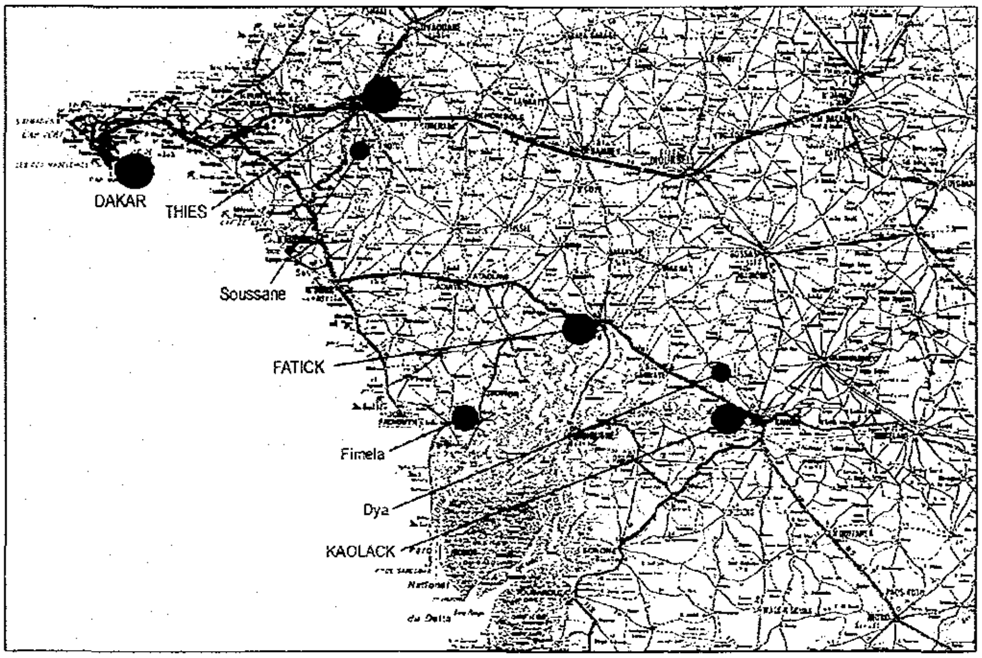

Figure 2.1 Location Map of Three Candidate Sites

These sites consisting of one central village and a relatively smaller village were selected so that the correlation between the size of the village (population and surface area) and the functions for operation and maintenance would be confirmed through the implementation of the pilot project.

The overall outline of these villages is shown in the table below.

Table 2.1 Outline of Candidate Sites

Fatick			
Sous Prefet	**Fimela**		
Communauté Rurale	**Fimela**		
Village	**Mar Lothie**	**Mar Soulou**	**Mar Fafako**
Population	1,550 (1999)	886 (1999)	2,172 (1999)
Number of Concessions*	197	39	186
Distance from Grid	3 km	5 km	6 km
Economic Activity	Agriculture, Livestock, Fishery, Remittance	Agriculture, Livestock, Fishery, Remittance	Agriculture, Livestock, Fishery, Remittance
No. of Existing SHS			11
Thies			
Sous Prefet	**Ngoekokh**	**Fissel**	
Communauté Rurale	**Malicounda**	**Ndiaganiao**	
Village	**Mbouleme**	**Soussane**	
Population			
Number of Concessions*	53	12	
Distance from Grid			
Economic Activity	*Agriculture, Livestock, Fishery*	*Agriculture, Livestock*	
No. of Existing SHS			
Kaolack			
Sous Prefet	**Sabassor**		
Communauté Rurale	**Dya**		
Village	**Dya**	**Ngothie**	
Population	785	1,550	
Number of Concessions*	67	34	
Distance from Grid	7 km	N.A.	
Economic Activity	Agriculture, Livestock	Agriculture, Livestock	
No. of Existing SHS	SHS 1 and stand alone generator 1		

* Concession is defined as a collectivity of households in which same family is sharing the spaces. Usually, there is an elder chief of the family (chief of concession) and his sons are having independent households within one concession.

Source: FAO (1999), *Recensement National de l'Agriculture et Système Permanent de Statistiques Agricole, and others*

(2) Socio-economic Situation of Three Candidate Villages

At the initial stage of the first field survey, brief socio-economic survey was conducted in order to appraise the present socio-economic situations of these three candidate sites so that the most appropriate selection of Pilot Project site would be realized. The outcome of this survey is under processing.

(3) Selected Project Site

In selecting the Pilot Project Site, the following criteria were applied.

a) Future grid extension plan; the area where there is no grid extension plan.within ten years,

b) Household income and expenditure level; the households' capacity to pay for initial and operation & management costs.

Based on the criteria above, Mar Lothie and Mar Soulou in Fatick Region were selected firstly and Mar Fafako was added afterwards. The main reasons are such that the selected three villages are located on the island, as shown below on Fig. 2.2. They would be reached only by an engine boat in 30 minutes from the town of N'Dangane, which is connected to the power grid network of SENELEC. And it is expected that cash income can be secured as a whole, because fishery activities are rather popular, and there appears to be villagers engaged in navigation, spending most of the year overseas. Then, further socio-economic survey was implemented for the villages that were selected as a project site. At the same time, public consultations were held in the pilot site in order to explain JICA project, SHS system's function and its use to village people as well as to have a dialogue with the villagers.

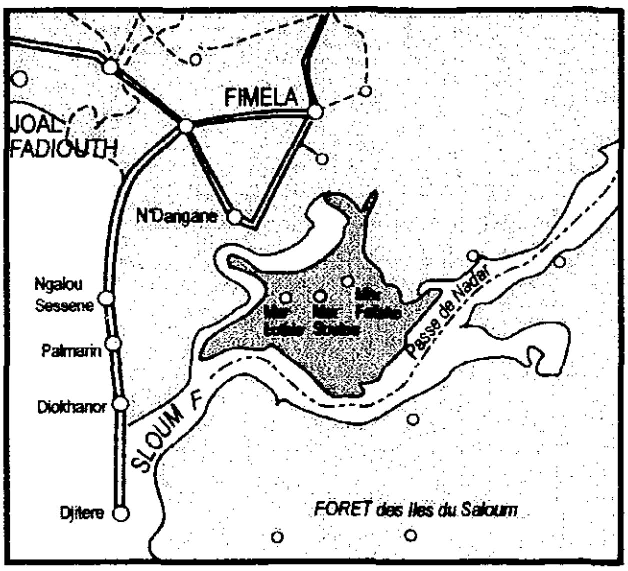

Figure 2.2 Pilot Project Site Map

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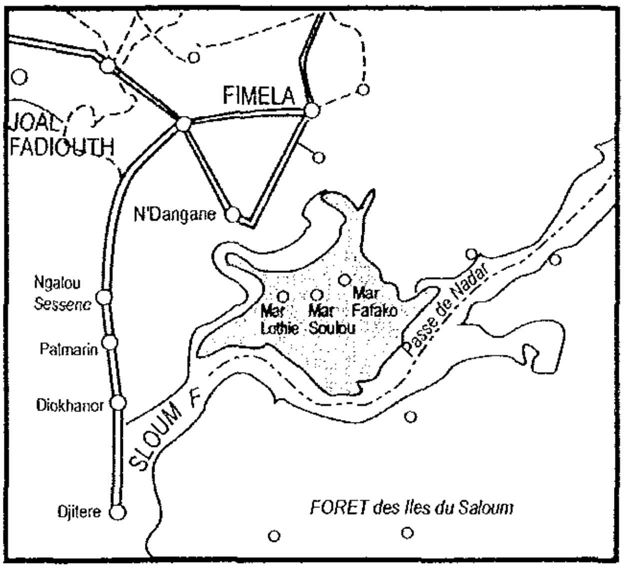


Figure 2.2 Pilot Project Site Map

3 Design and Implementation Schedule of the Pilot Project

(1) Schedule of the Pilot Project

The Pilot Project roughly divided into two stages, one was preparation stage and the other was implementation stage. The design, tender, and installation of SHS were carried out in the preparation stage (from January to December 2000), and the operation and maintenance of SHS were carried out in the implementation stage (from December 2000 to October 2001). Operational condition of the SHS was surveyed by the Operator thorough the monthly maintenance. Comparison between capacity of SHS and user's demand, and devising a countermeasure for the constraints of maintenance and management system were carried out at midterm and final evaluation. The schedule of the Pilot Project is as follows;

Period	Contents
Phase 1 Field Survey (Jan. to March 2000)	Site selection, Design of the Project (Project purpose, activities, etc), Design of SHS and options, Recruitment of the participants,
Phase 2 Field Survey (June to July 2000)	Preparation of the selection criteria for Operator, Tender of the SHS, Drawing up the operation system
Phase 3 Field Survey (Sept. to Oct. 2000)	Final selection of the participants, Establishment of the VUA, Installation of the SHS (from Nov. 2000)
Phase 4 Field Survey (Nov. to Dec. 2000)	Making a contract between Operator and user, Start the project activities such as fee collection, maintenance and management), Hold the 1st Seminar (Explanation of the project for the participants, Establish the maintenance and management system)
Phase 5 Field Survey (June 2001)	Mid term evaluation of the Pilot Project, Hold the 2nd Seminar (Extraction of the constraints and study the countermeasures)
Phase 6 Field Survey (Oct. 2001)	Final evaluation of the Pilot Project, Hold the 3rd Seminar (Future subjects, lesson learned)

(2) Planning

Planning procedure of the Pilot Project consisted of three stages. Field survey in Mar Island was carried out in February 2000 as the first stage. Then problem analysis was carried out in the Project Cycle Management (PCM) workshop as second stage. Based on the results of field survey and problem analysis, the Pilot Project and specification of SHS was designed.

In the PCM workshop, only the problem analysis was carried out by the participants from MMEH, NGOs, local consultants in rural electrification sector, and members of the JICA study team. Because the idea of the "business model" wasn't drawn up in that period, problems regarding management by the local organization were discussed based on the experience of past projects such as GTZ rural electrification project and result of field survey in Mar Island.

Based on the results of problem analysis, MMEH and JICA study team designed the Pilot Project. The idea of the "business model" was included in this period. The project design was summarized on the Project Design Matrix (PDM) shown in Table 3.1.

Project purpose and output of the Pilot Project is as follows;

[Project Purpose]

Operation and management system for SHS is established in Mar Island.

[Output]

1 SHS units are installed to the households which want to be electrified with the SHS system.
2 User utilizes the SHS manuals.
3 Electricity fee are collected from users in schedule.
4 Maintenance and repair of SHS are well carried out.
   4-1 Operator carries out the regular maintenance of SHS.
   4-2 Operator maintain the broken SHS.
5 SHS works in line with a specification.

(3) Pricing for the Fee for Service

The regular payment of the users for the pre-condition of "Fee for Services" is computed on the following assumptions. These assumptions are to be verified in the operation stage.

- No. of system unit: 150 Units
- Unit price of the system: 450,000 FCFA (The initial cost is fully financed by JICA.)
- Initial payment of the subscriber: 45,000 FCFA (The initial payment is equal to 10% of the above amount.)

- Estimated O & M cost

Manager	0.1 M/M	500,000 FCFA/month
Accountant	0.2 M/M	200,000 FCFA/month
PV Engineer	0.3 M/M	200,000 FCFA/month
Local Technician	1.0 M/M	50,000 FCFA/month
Fee collection & book keeping	0.2 M/M	200,000 FCFA/month
Total	Monthly expense	240,000 FCFA/month
	Annual expense	2,880,000 FCFA/year

- Renewal period

PV Panel	20 years
Charge Controller	10 years
Battery	4 years

The regular payment has been calculated on such a condition that the number of system units to be installed be initially estimated at 150. In this calculation, renewal cost (the system price after 20 years be assumed to be gradually reduced to 50% of the current price.), and expenses for the daily operation & maintenance cost, are taken into account. Finally, 100 units of the system was purchased, 95 of which were installed at the site. The remaining 5 units are regarded as spare parts and are planned to be used in a adequate manner for the operation and maintenance purpose.

There are many elements, which will influence the sustainable management of the pilot project, such as personnel expenses, O & M expenses, etc., among which fee collection is the most significant factor. As a matter of fact, the sustainable management of the pilot project depends, to a large extent, on provision of the good services of electricity with users, adequate fee collection and proper fund management. These matters are to be verified through the operation of the pilot project.

(4) Operation and Management System

1) Organization structure of the Pilot Project

The Pilot Project is implemented by the three organizations such as Pilot Project Management Committee (PPMC), the Operator, and Village Users Association (VUA). PPMC consists of MMEH, ASER and JICA Study Team. The Operator is taken charge by the private company which has the main office in Dakar. The Operator dispatches one technician to the project site permanently. The Operator also dispatches more advanced technicians as the occasion demands. The Operator employed one villager in Mar Lothie as a local technician.

VUA is a representative of the users. The project site consists of the three villages, namely Mar Lothie, Mar Soulou and Mar Fafaco. However, users of Mar Lothie and Mar Soulou have a VUA, because the participants from Mar Soulou are only four subscribers. And users of Mar Fafaco belongs to the other VUA. Each VUA is established on 5 and 6, October 2000 thorough the village meeting.

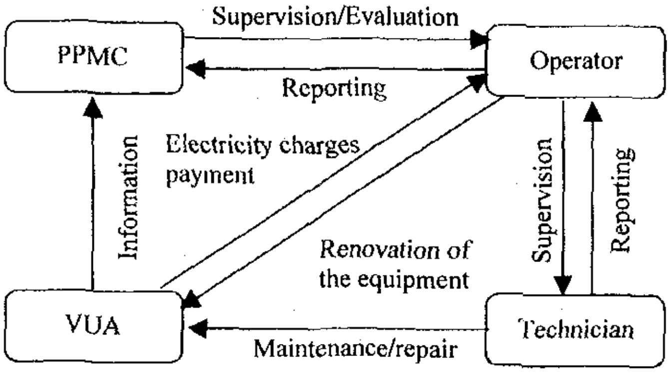
2) Role and responsibility of each organization

The respective role of the stakeholder for the Pilot Project is shown below.

1. Pilot Project Management Committee (consisted of MEMI, ASER, JICA Study Team)
   1) To supervise the activities of both operator and VMO.
   2) To collect and analyze the data from Data Loggers installed in Mar Island.
2. Operator
   1) To maintain the installed SHS system at least once a month. Maintenance is conducted based on the maintenance manual prepared by PPMC (see Table 3.2).
   2) To monitor the appropriateness of SHS system utilization of each user when maintenance is conducted.
   3) To instruct and rectify the inappropriate usage of SHS system, if any.
   4) To collect the electricity fee from the users.
   5) To repair the SHS system, if necessary.
   6) To divide the collected charges into the fund for battery replacement and fund for the other activities by operator such as transportation fee, salary for technicians, etc. These funds are deposited in the bank accounts which managed by the operator.
   7) To replace the batteries when life of the batteries are terminated (Necessary cost for the replacement is paid from the deposited fund for battery replacement).
   8) To recall the SHS system from the users who don't pay the charges more than limited period provided by the PPMC regulations. (Necessary cost for recalling and uncollected electricity fee are collected from the initial payment of user)

   Remarks: The roles from 1) to 3) are filled by the technicians employed by the operator. This technicianstays in the project site during the project period. The roles 4) to 6) are filled by the head office of the operator, and role 7) and 8) are filled by experts who dispatch to the Mar Island from the head office of the operator.
3. Village User's Association (VUA)
   1) To instruct and rectify the users who don't pay the charges.
   2) To monitor and enlighten the users through the monthly meeting.
4. User
   1) To attend the meeting held by PPMC.
   2) To clean the SHS system in line with the user's manual.
   3) To pay the electricity fee as scheduled.
   4) To cooperate the surveys conducted by PPMC.

The relationship between each organization is as follows;



Due to the governmental organization, MMEH and ASER couldn't participate in the commercial activities. Therefore, the Pilot Project adopted the contract system that the PPCM doesn't make a direct contract with users. The contract regarding electricity charge collection and maintenance services are made between the Operator and each user. The contract is officially made on December 2000, after the installment of SHS is completed. Contract papers between between Operator and user is shown in Attachment A.

4. SHS Specification

4.1 Summary

Based on meteorological data and expected power demands of lighting and 12V B/W TV the following specification was established. Considering large extended family system in Mar-island the three types of appliance kit was offered, enabled maximum 6 rooms was possible to light (see bellow).

a) Out put: DC12V

b) Autonomous operation capacity: Continuous 3 rainy days with listed loads.

c) PV panel : power max. 55W single crystal (SX55, Solarex,USA)

d) Battery : Solar Grade 12V 110AH/ C10, 120AH C/20, 145/AH C/100 (Type:M14sol, Accus National, Morocco)

e) Charge regulator : 10A (AtonlCinside SLR1010, Uhlman Solareleelecronic Gmbh, Germany)

f) Voltage converter : 3/6/7.5/12V (Uhlman Solareleelecronic Gmbh, Germany)

g) Fluorescent lamp : 8W (Thi-Lite,U.S.A) and 11W (SolsumESL,Steca, Germany)

h) LED lamp : 0.7W (SolsumESL,Steca, Germany)

i) Load : shown below the table

LOAD	TYPE 1	TYPE 2	TYPE 3
F/L LAMP, 8W (supplied as a kit)	5	3	2
LED LAMP, 0.7W (supplied as a kit)	none	none	4
Socket for TV (DC. B/W)	none	1	1
Socket for Radio	1	1	1

4.2 System Sizing and Components Selection

(1) Photovoltaic Module .

a) Crystal modules was selected

Almost all of big PV projects in the world selected crystal module instead of amorphous so far because, amorphous silicon create power degradation through the years. To assure the reliability of the system the project eliminated from the bidding.

b) Over 55W of output module was selected

Most former studies on rural electrification by SHS in Senegal have used a photovoltaic module of 50 Wp to adapt life style in remote area. Recent technical innovation brought increment of power for a unit of PV cell and the difference in price between 50 Wp module and 55 Wp module become small. Therefore, 55Wp PV module would become a major for 50Wp class of SHS inthe market. The study team chose a photovoltaic module of 55 Wp. The technical specification of PV Module has been specified in order to be sure that suppliers offer the PV modules in good quality. The specifications of a PV module have mainly specified Type of Cell, Peak Watt, Performance at High Temperature Condition and Outdoor Exposure Resistance.

According to the system sizing, and in order to keep enough allowance of power supply, the tender document required 55 Wp PV Modules. Energy consumption was estimated initially as shown in Table x.1 for the proposed service. According to the estimated daily load consumption of 130 Wh/day, module size was calculated as follows.

$$130\,[\text{Wh/day}] \div \frac{4\,[\text{kWh/m}^2\,/\,\text{day}]}{1000\,[\text{W/m}^2]} \div 0.65 = 50\,[\text{W}]$$

Where, four (4) [kWh/m^2/day] is estimated worst average daily irradiation through a year in Mar Island, 1000 [W/m^2] is standard irradiance and 0.65 is total loss factor.

Multiplying 1.1 to this result as safety factor, the module size was determined as 55 Wp.

LOAD		TYPE 1	TYPE 2	TYPE 3
F/L LAMP	8W	3	3	3
F/L LAMP	8W	3	2	3
F/L LAMP	8W	3	2	none
F/L LAMP	8W	3	none	none
F/L LAMP	8W	3	none	none
LED LAMP	0.7W	none	none	8
LED LAMP	0.7W	none	none	8
LED LAMP	0.7W	none	none	8
LED LAMP	0.7W	none	none	8
TV	12W	none	4	3
radio	5W	2	3	4
total energy consumption [Wh]		130	119	104
expected energy generation [Wh] : rainy season		154	154	154
expected energy generation [Wh] : dry season		214	214	214
expected energy generation [Wh] : annual		182	182	182

c) Peak power must not be inferior to 90% of the nominal peak power.

This specification is necessary to assure of quality of PV Modules.

d) The maximum output power at 60°C of cells junction temperature shall be higher than 85% of the nominal power

The output energy of PV Modules at high temperature is important particularly in the site of hot area in order to assure of battery charge with the PV module.

e) The voltage at the Maximum Power Point of the module at 60°C of cells junction temperature shall be higher than 16V

This voltage assures battery of being fully charged under the high temperature condition. Typical Lead Acid Batteries require 2.25[V/cell] to 2.5[V/cell] (13.5[V] to 15[V] for 12[V] batteries) for equalization charge. Therefore, the PV module has to generate voltage of higher than 15[V] during noontime.

f) The module must be fitted with waterproof cases of IP54 standard at the connection points. The cases shall be fitted with oakum-press allowing the cables to pass through. The polarity of the terminals must be clearly indicated inside the cases.

IP code is described by IP plus two digits like IP54. The number has its own meaning defined as follows. For example, a device with IP54 has protection against dust (first index) and against water spray (second index). Generally, the higher requirement for protection, the more expensive the system cost. However, at least IP54 will be required in Senegal for outdoor devices because of Sandy atmosphere in dry season and heavy rain in rainy season.

First Index	Protection Against Foreign Objects
0	Not Protected
1	50mm diameter and greater.
2	12.5mm diameter and greater.
3	2.5mm diameter and greater.
4	1mm diameter and greater.
5	Dust protected; dust deposits are not totally prevented, but their volume must not affect the function of the device.
6	Absolutely Dust Prevented

Second Index	Water Protection Against
0	Not Protected
1	Vertical Water dripping
2	Water dripping at an angle (up to 15 degrees on either side of the vertical.)
3	Spray Water (up to 60 degrees on either side of the vertical.)
4	Splashing water from all directions
5	Water Jets from all directions
6	Powerful Water Jets from all directions
7	Temporary immersion for 1 meter in water under standardized conditions of pressure and time.
8	Permanent immersion under conditions that shall be agreed between manufacturer and the user, but are more severe than for number 7.

g) Each module must be fitted with diode by-pass.

By-pass diodes are required to protect the PV module against hot-spot phenomena that is caused by partial shadings on PV modules. However, some say that damages on PV modules by hot-spot is negligible for DC systems whose voltage is lower than 24[V]. In the tender document, by-pass diode was requested to eliminate any uncertainties against "reliability".

h) Each photovoltaic module must have a plate of notification at least the following prescriptions:

- name, trademark or symbol of maker
- number or reference of the model
- peak power, short-circuit current (A), open circuit voltage (V) for STC conditions
- Serial number
- manufacturing country

In order to assure of manufacturer's responsibility, those label are required.

i) The proposed modules shall be tested by an authorized laboratory conforming to the EUR 101 and 502 (501) specifications published in the EUR 7078 and EUR 9414 reports or conforming to the corresponding of IEC specifications. An ISPRA certification (or equivalent) showing that the tests are successfully achieved shall be attached to the document.

Bidders should always be required to submit certificate by appropriate laboratory for their propositions. Because international mutual certification system seems to be now under discussion, the tender document required the bidders to submit certification above.

j) Incomprehensible things of these prescriptions, refer to the IEC61215, IEC61277, IEC61194, IEC60904 standards

Those standards are concerning certification of PV modules. Bidders were required to read and understand those standards well. By imposing the task to read and understand those standards on bidders, supply of PV modules in good quality can be expected.

(2) Support Structure of PV Module

Since the Mar-Island is surrounded in sea, the support structure should have corrosion resistance. The specification indicated the component to be used for the support structure, that is, rustproof steel, stainless steel and anodized aluminum. In addition, support structure made by wood and plastics is generally available for SHS, though, this kind of support structure were excluded in this tender because the study team took into account of its reliability.

a) The material of the support for the module should last 10 years without any serious erosion. The following material is acceptable:

- Stainless Steel
- Reinforced Steel
- Anodized Aluminum

Timber and UV protected plastics can be taken into consideration as a material of support structures. However, these materials are not recommendable because they have uncertainty for rigidity. Moreover, metals are easier to give theft proof and rigidity against wind than timber or plastics.

(3) Battery

According to the sizing battery, the study team requested 100 Ah of battery, of which capacity varies according to the discharge rate. The proposed SHS was adopted a battery rated at 20-hour rate of discharge for a maximum discharging ampere of proposed SHS was approximately estimated 5 A. 5A corresponds to 20-hour discharge rate of 100 Ah battery.

The technical specifications of battery have been defined from the aspect to make sure that the battery for the proposed system should have enough lifetimes under use of a deep cycle. Besides, because batteries are sometimes placed within the reach of user's hands, there exist some risks like tampering of the system by users, an electric shock and other accidents. The study team required preparing special battery box. In the specification, the battery characteristics like voltage, capacity, density and volume of electrolyte, self-discharge rate are defined.

a) Nominal voltage: 12V

b) Nominal capacity: minimum 100Ah

When sizing of battery for the proposed system, assumption of below was used.

- autonomy days: 3 days
- charge - discharge loss factor of battery: 0.75
- depth of discharge: 50 %
- wiring loss factor: 0.9

According to this assumption, the size of battery was caluculated;

$$\frac{130Wh}{12V} \times 3days \div 0.75 \div 0.5 \div 0.9 \approx 96.3Ah$$

On the top of this estimation, because the instantaneous current drawn from battery affects the life of battery, maximum withdrawn electricity was also taken into account. Such a high rate discharge compared to the battery capacity often causes drop of plate, which leads to the loss of lifetime.

The sum of electricity withdrawn by expected appliances is 4.67 A, 4.26 A and 3.67 A in Type 1, Type2 and Type 3 respectively. 4.67 A of electric current is approximately equivalent to 20 hour rate discharging current of 100 Ah battery (5A). 100 Ah capacity of battery at 20 hour discharging rate was required for the proposed system.

It is necessary to specify the discharge hour rate of battery (HR) because battery capacity varies according to its discharge hour rate. The capacity at 100 HR (C100) is as 20 to 30 % large as that at 20 HR (C20), which affects the cost of battery. Normally, C20 should be applied for expression of nominal capacity of a battery.

c) A Lead-antimony flat or tubular plate and stationary liquid electrolyte batteries well adapted to PV systems

d) The thickness of each plate must be more than 2 mm

Most industrial deep-cycle batteries use Lead-Antimony plates rather than the Lead-Calcium used gelled deep-cycle batteries. The Antimony increases plate life and strength, but increases gassing and water loss. It is important to exclude automotive batteries because they are not suitable for delivering small current during long period or for deep cycle discharge. For this purpose, "Batteries well adapted to PV systems" were required in the tender document. Even if the tender specifies the battery as "well adapted to PV system", there are automotive batteries that can adapt to PV systems to some extent with simple modification (Some call them "semi deep cycle" battery). Those modifications are mainly about plate thickness and liquid quantity. The thicker is the battery plate, the longer discharge

e) Self-discharge rate at 25°C must not exceed 6% of the nominal capacity in one month.

The self-discharge of battery should be as small as possible in order to compensate autonomy use when sufficient irradiance cannot be obtained.

f) Tub of a battery must be thick and resistant enough to be transported and forwarded without any damage.

g) The level of the electrolyte of the battery must be easily verifiable by the user: marking of minimum and maximum on translucent tubs

The tub of lead acid battery has to be translucent for easy watering.

h) The density of the electrolyte must not exceed 1.25 kg/l at 20°C

Electrolyte density affects not only battery capacity but also the self-discharge rate of batteries. The higher is the electrolyte density, the larger is the self-discharge rate and the shorter the lifetime of batteries, and the greater is the battery capacity. Specification of electrolyte density should be chosen so that the battery has reasonable lifetime and capacity. Relatively high electrolyte density will be specified in cold area and relatively low electrolyte density will be specified in hot places. In Senegal, the ambient temperature is high, thus, the temperature of electrolyte is expected to go up high.

i) Gel electrolyte batteries are excluded.

The advantage of gel electrolyte batteries is that there is no risk of spilling acid even if they are broken or overturned. However, there are several disadvantages such that they must be carefully charged to prevent gassing that may cause damage on the battery cell or may lead to explosion. Moreover, gel batteries must avoid overcharging. If overcharged, voids can develop in the gel that will be never compensated, causing a loss in battery capacity. In hot climates, water loss can be observed that leads to short battery lifetime. Senegal has hot climate and disadvantages mentioned above is enough reason to avoid the choice of gelled batteries.

j) The volume of electrolyte must be higher 1.15 liters per 100Ah nominal capacity and per cell.

Sufficient volume of electrolyte can lead to long lifetime of lead-acid batteries.

k) Each battery must have a notice plate of at least following information:

- name, monogram or symbol of maker
- number or reference of the model
- capacity (Ah) indicating the discharge system
- manufacturing date

Labeling is one of the most important factors for the conductor of a project to see the reliability of proposed components.

l) The battery must have a permanent indication of polarity on each terminal.

The polarity marking for DC devices is important to avoid reverse connection of devices.

m) Protection cover for the battery lead connections shall be delivered with the batteries.

This is aimed at protection against drying up greasing on the battery terminal.

n) The battery shall be dry-charged and delivered with necessary electrolyte. The volume of electrolyte must be more than 1.15 liters per 100Ah of the nominal capacity C20 and per cell.

Lead-acid battery should be delivered with dry charged at manufacturer and be filled with electrolyte at the site to allow easy transportation. Instead, batteries should be fully charged at the site before being put into service.

o) The lead-calcium alloy as well as car batteries are excluded.

The advantage of lead-calcium alloy is to reduce water loss due to the low voltage of gassing. On the other hand, because of weak cohesion of active materials on plate, those batteries have short lifetime. Moreover, such batteries are not suitable for deep cycle discharge and for use under high temperature. For this reason, PV systems in Senegal should not be allowed to use batteries with lead-calcium alloy.

SHS requires batteries delivering small current for long hours and therefore batteries are required to have thicker plate. Car batteries do not bear these characteristics required by SHS.

p) The batteries shall be put in a tub fitted with a lock and must have airing holes and endure erosion, acid spray and chocks. This tub shall be designed so as to allow easy access to the battery lead connections and control of electrolyte level and good cooling system.

A battery box with lock system was specified here in order to keep the battery out of user's reach. The pilot project schemed to hire a local technician for maintenance to avoid tampering by users.

q) Incomprehensible things of these prescriptions, refer to the IEC60896, IEC61056 and NFC58510 standards.

These standards define minimum requirements of lead acid batteries.

(4) Technical Specifications of Charge Controller

The function of the charge controller is to protect the batteries against overcharge and over discharge. Appropriate selection of charge controller is required to maximize the lifetime of battery, which leads to the high reliability of the system. The characteristics of the charge controllers shall be the following:

a) Nominal Voltage: 12V

b) Module current: 8A minimum, 10A maximum

c) Operation current: 8A minimum, 10A maximum

A 55 Wp of PV module typically produces 3A to 3.2A at its peak power. Charge controllers will be rated to have extra capacity that can be 1.25 to 1.5 fold in current. This specification aims to allow adding another 55Wp PV module. Hence, the size mentioned above was required.

$$3 \times 1.25 \times 2 = 7.5 \Rightarrow 8A$$
$$3.2 \times 1.5 \times 2 = 9.6 \Rightarrow 10A$$

d) The charge controller must have Pulse Width Modulation

There are two types of function for charge controllers, namely simple switching interruption of charge and discharge (regulator) and Pulse Width Modulation (PWM). It seems that there is not enough experience to conclude which type of scheme is good or not. However, electronic switching is preferable to mechanical switching because mechanical parts are vulnerable.

e) The disconnection and reconnection voltages of the PV module and the loads of the charge controller must be fixed depending on the actual environment conditions and type of battery. The reference values for 20°C and 1.24 kg/L electrolyte density are the following:

- high voltage of disconnection =13.8v
- low voltage of disconnection =11.4v
- reconnection voltage = 12.6v

Each Lead-acid battery has its own suitable threshold voltage for protection of overcharging and over discharging. In addition, the relationship between battery voltage and battery state of charge varies according to each battery's characteristics. The supplier of SHS is required to choose the charge controller carefully to adjust the recommendation of proposed battery's manufacturer. The supplier is also required to submit detail technical sheet of both battery and charge controller for reasonable evaluation of proposition.

f) The charge controller must be fitted with a temperature compensation of high voltage of disconnection; the correcting factor to be applied is –4 or –5 mV/°C per battery cell (that is –24 or –30 mV/°C for a one piece 12V battery).

Appropriate end of charge voltage for a lead-acid battery varies according to the temperature. The specification represents a typical varying range as temperature changes.

g) Self-consumption of the charge controller must not exceed 10mA whatever the operation condition.

Since SHS provides only limited energy to the load, energy losses have to be minimized as much as possible. Recent charge controllers have capable of sophisticated control system with low energy consumption.

h) The charge controller must be protected against the following accidents:

- inversion of the polarities when connecting battery or module to the charge controller
- short-circuits during operation: for this type of protection a fuse or equivalent must be used, which the user can easily replace without opening the case of the charge controller
- over voltage in the module input or in the load output (thunderbolt)
- any use without battery, PV modules being connected to the charge controller.

Protections above will be required for the minimum protection of charge controllers.

i) The charge controller must be protected against current input 25% higher than the short-circuit current of the PV module and a load output current 25% higher than the maximal nominal current of the PV system (all appliances operating). For a period specified by the supplier. The charge controller must protect the module against nighttime discharge of the battery.

These protections have to be prepared for the protection of electronic devices in SHS.

j) The charge controller must not create interferences with the radio waves whatever the operation conditions

Interferes against appliances are standardized on many standards for electronic devices.

k) The case of a charge controller must have the following characteristics:

- minimum IP54 protection
- fitted with a wall fixation system

This protection degree should be required in sandy area like in Senegal. Charge controllers should not be hooked or laid on the ground but fixed on the wall so as to avoid being damaged by accident.

l) The printed circuit of the charge controller shall be attached mechanically to the case immovably with clips or screws.

Because printed circuit is the heart of charge controllers, it must be protected beyond the users' reach.

m) The charge controller must have a led lamp showing the battery state of or an equivalent indication system providing users the following minimum information:

- ready for use, charge level is sufficient
- disconnected, very low battery charge

n) The charge controller shall be fitted with a warning system indicating that battery discharged completely, if possible

It is difficult for users to always be conscious of using hours of appliances. Status indicators as LED lamps of charge controller can help users to recognize the system status. Users can understand the restriction of the system through those LED indicators.

o) Each charge controller must have a plate indicating at least following information:

- name, monogram or symbol of maker
- number or reference of the model
- nominal voltage (V)
- nominal module input and usage output current (A)

p) The charge controller must be marked a permanent indication of polarity on each electric connection terminal.

These notifications are helpful not only for making suppliers feel responsibility but also for avoiding misconnection of devices.

q) The terminals must be out of the reach of users.

Terminals of battery and charge controller can be the access point to allow users tampering. Tampering system is liable to lead inappropriate use of system. Every terminal must be masked appropriately to prevent tampering.

(5) Technical Specifications of Lamps

1) F/L lamps, Ballasts and fixtures

To make lamps work as long as possible, the quality of ballast inverter of fluorescent lamp is the most important factor. From this point of view, the technical specifications are defined concerning voltage, nominal power, luminous efficiency, the ballast wave shape, frequency of ballast, ballast efficiency and exposure resistance.

Lamps are specified as the set including the bulb, the inverter and the case holding both components. Two types of lamp have been proposed:

- Fluorescent lamps with electronic ballast and straight tube
- LED lamp

a) nominal voltage: 12V

b) nominal power: 8W

Normally the brightness of a lamp is in proportion with the energy consumption of fluorescent lamps. Moreover, the requirement of people for the brightness varies according to their cultural background. Some may consider 8W lamp is comparatively dark and some may consider it is too bright. When planning SHS, the energy consumption of loads is a restriction of system utilization period. The selection of lamp size eventually depends on the planned size of PV system, the planned utilization period and the variation of devices available on the market. In Senegal, the suppliers have the capability of procuring any kind of requirement for lamps.

c) frequency of the ballast: minimum 16kHz

The wave frequency of the ballast interferes radio waves if it is too small. 16kHz is minimum requirement of frequency for ballasts of good quality.

d) The ballast must ensure normal operation of the lamp at voltage between -15% and +25% of the normal voltage.

Operation voltage of components with SHS varies according to the voltage of a battery that varies according to its state of charge. Therefore, appliances should be assured of stable operation under voltage range described here.

e) The luminous efficiency of the ballast-lamp set must be minimum 40 lumens per watt.

f) The efficiency of the ballast must be minimum 80%.

g) The characteristics of the ballast current must satisfy the following conditions:

h) The shape of the wave must be symmetrical.

i) The peak factor must not exceed 1.7 times of the nominal operation current of the lamp at voltage between 11V to 12.5V.

j) The ballast must be properly isolated

Lamp products of good quality declare at least this level of technical specifications to avoid reducing lamp life. Especially, maximum crest factor (ratio of maximum peak current to average lamp operating current of the fluorescent tube) and efficiency of ballast are important.

k) The ballast must be protected against destruction in the case of;

- removal of the tube from its support while the lamp is under work or if the switch is turn on while there is no tube
- the ignition of the lamp doesn't work
- the polarities of the supplying voltage is inversed
- the terminals of the ballast are short-circuited

These protections should be provided to ensure for safety and reliability of fluorescent lamp system.

l) The ballast must not create interferences on radio waves whatever the conditions of usage

Any interference on radio wave must be avoided because noises on radio caused by electrodes lead to users' dissatisfaction against the PV system.

m) The lamp must be fitted with a wall fixation system

n) The electric connection point of the ballast;

- must allow a strong connection of the supply cable without causing any damage
- must have a size sufficient enough to allow connection of cable
- must have a permanent marking indicating of polarity of each input cable, which will be up to 2.5 mm^2

Any appliances provided for SHS should have easy installation system and robustness against external forces by installation.

o) Since each system will provide one entrance lamp, the lamp should have a protection system against water infiltration.

This requirement for protection can be defined with IP degrees, though, here specially mentioned to emphasize this requirement for outdoor lamps. In Senegal, it must be noted that many families in villages need gate lamps to light up yard where they spend night hours in summer season.

p) If the lamp is fitted with a protection cover, this cover must be;

- insect proof
- easy to remove when the users need to change the bulb

q) The external lamps must follow IP 54 protection standard. An alternative solution to use the type of internal lamps with a protection system satisfying to the same tightness requirements is possible.

r) For each lamp, it must be possible to change separately the tube and the converter using spare parts without replacing the whole lamp set.

Some lamps that are equipped both tube and ballast together (so called "compact lamp") is available in the market. However, those lamps are not common for public. Considering convenience of users to replace lamps when they died, conventional type of fluorescent lamp was requested in the tender document. Nevertheless, compact lamps should not be excluded for the future plan because they have high efficiency and long life. The selection of lamp type should be considered according to the style of project and general market situation.

s) For incomprehensible things of these prescriptions, refer to IEC458, IEC921, IEC924 and IEC925 standards relative to the characteristics and performances of transistorized ballasts.

These standards are requirement for general tubular fluorescent lamps that is utilized in various DC product market besides PV systems.

2) LED Lamp

LED lamp was adopted as new attempt for rural lighting because quite a few users expressed the demand to a night-light for security. LED lamp consumes only small amount of energy (for example, 7Wh/day will be for 10 hour/day utilization, what about only 4% of estimated daily generation of 55Wp PV module). The tender document described specs provided by the manufacturer of LED lamp because it is a new device in the market.

a) Type	:	LED lamp
b) Nominal voltage	:	12V
c) Nominal power	:	0.7W
d) Nominal current	:	60mA
e) Luminous efficiency	:	22 lumen/W
f) Working temperture	:	+10 degC to +50 degC
g) Outlet	:	E27

(6) Outlets

Outlets specialized for DC system is not popular in the market. AC outlets are compatible for adapting to DC system. However, whenever AC outlets are used, those outlets must bear a practical way of prevention for connection in reverse. For example, an earth pole can be a mark of protection against reverse connecting. The tender specification was as follows:

a) DC/DC Converter The TV outlets are designed for 12V appliances (radio, television, etc).

b) The television outlets shall be fitted with one indicator making the difference with standard 220V outlets. There must be an IP 32 protection standard at minimum and a permanent marking indicating + and – polarity.

(7) DC/DC Converter

It is necessary to reduce the system voltage to use radio of 9V or 6V. DC/DC converter is a device that converts from DC 12V to significant voltage. The specification defined in the tender document were:

a) The radio outlet shall be connected to a DC/DC converter to adapt 6 and 9v voltage.

b) The DC/DC converter must meet the following technical standards:

- Nominal input voltage : 12V
- Nominal output voltage : 6V or 9V
- Nominal current : 2A

c) The supplied voltage must correspond to the output voltage of the charge controller.

d) The converter must be a type of electronic conversion.

Some ineffective converter uses resistance to reduce the voltage. In order to be proposed such ineffective converter, the specification requested converters with electronic chopper circuit.

e) The case of the converter must have a IP 32 minimum protection standard

f) The case of the converter must be fitted with a wall fixation or hanging system

g) The switch of the converter must be clearly indicated to avoid confusion

In developing countries, because the house building may not sealed as tight as expected, IP32 should be requested as minimum requirement of protection degree for interior components.

(8) Cables

1) Wiring between PV Module and Battery through Charge Controller

a) The cable used between module to charge controller and between charge controller to battery connection must be adapted to external usage, following to the IEC60811 international standards.

b) *H07 R-NF type or equivalent standards*

c) The section of the cable shall be 4 mm^2.

d) Maximum length: 10 m/system

The cable between a PV module and a charge controller as well as between a charge controller and a battery should prevent energy losses due to the wiring as much as possible. For this purpose, the installer should locate those components as close as possible with cable of significant section. Since the cable between PV module and the charge controller is exposed to the air, the cover of cable should resist water, direct sun and other corrosives.

2) Internal Wiring of Buildings

- Cables

  The cables to be used for internal wiring should be available in the Senegalese market:

  a) A03 VVF 2.5 types of wires or equivalent

  b) 2.5 mm^2 section

  c) Total inclusive lengths: 80 m/system

  Cable section described here is the minimum requirement. Whenever possible, the installer should use thicker cable and make the wiring distance short to prevent voltage drop due to the cable.

- Switches

  a) Switches shall be available in the Senegalese domestic market.

  b) The following characteristics shall be respected:

     - The level of protection shall be IP 43 for interior switches, and IP 55 for outside the buildings.

     - Bipolar switches.

  c) ON/OFF position of the switch shall be identified clearly and shall correspond to the following directions:

     - + ON: turning on, the switch moving from up to down

     - + OFF: turning off, the switch moving from down to up.

Switches have movement on their surface. Therefore, severer protection will be required than other interior components require. Here described IP43 for interior switches to prevent smaller foreign bodies.

- Connection boxes
  a) The protection shall be IP 55.
  This protection degree is for boxes of outdoor use, though, it is preferable to apply this protection degree to internal boxes because the house hold in rural villages of Senegal may not resist water infiltration.
  b) Sufficient number of clips shall be prepared for wiring, that allows carrying out the installation following to the installation specifications of this book.

  All the necessary installation materials (screws, connectors, fittings, etc.) must be always included into the SHS supply.

4.3 Technical Specifications of Installation (SHS)

General description of requirement for the SHS installation is:

The complete installation of the systems shall be made carefully. The visual aesthetic of all installations must be respected:

a) Verticality of wires and of components fixed on the walls (outlets, switches, charge controller, clips, etc.).

b) Balance and arrangement of clips (every 25 cm)

c) Recovery of walls after making holes

(1) PV Module

- Installation of PV module
  a) The supports of the PV modules shall be static.

  Some system allows using flexible support structure for PV module so called "tracking system". However, *tracking system requires users to adjust* the direction of PV module frequently, which leads to complicated system operation. Tracking system does not seem to get used to general users in Senegal. It is preferable to adopt conventional support structure.

b) The inclination of the modules in comparison with the horizontal position must be 15° with a margin of + or – 5°

To maximize the irradiance on the PV surface, the tilt angle of PV module should be kept at the same degree as the latitude of the site. However, tilt angle must not smaller than 10 degree to allow automatic cleaning by the rainwater. Some say the minimum tilt angle for automatic cleaning is 15 degree. The latitude of the site for the pilot project is around 14 degree. The requested tilt angle is the angle to optimize energy collection at the site of the pilot project.

c) The modules must be oriented towards the true South with a margin of + or – 10°

To optimize energy collection, the fixed PV module should be installed to always face to the equator. Since the site is in the northern hemisphere, the PV module was requested to face to the true south.

d) At each site, the place where the modules are installed must be chosen so that there shall not be any shade on them between 90 minutes after sunrise and 90 minutes before sunset.

In any situation, shading must be avoided because even small part of shaded on a PV module cause a significant power loss.

- Fixation of PV modules

The method to fix a PV module should be consulted for each house because the condition to optimize the installation varies with the houses. The installer must investigate the site to see the best method for fixation of PV module before the tender or the installation. There are 3 ways to mount a PV module, that is, rooftop, wall fixation and ground. The PV module was mounted to the wall of the building for the pilot project. Here describes the minimum requirement of each mounting method.

Rooftop Mounting

a) In case of installation on a roof, a minimal distance of 0.1m must be left between the back of the modules and the roof. The module support must be fixed to the body of the frame or of the building, but not to the roof itself. A mounting system can be planned if necessary.

A minimum distance of 0.1 m is a requirement to keep a cooling system for the PV module.

Wall Mounting

b) In case of wall mounting, the module support must be fixed at minimum 2 points. This system must pierce the wall (bolts and tightening plate).

Ground Mounting

c) In case of ground mounting, the module support must be installed in a space out of the passages. The modules and wires must be set out of the children's reach. The buried wires must set into a conduit(PVC or PE pipe).

d) The feet of the module support must be bolted or embedded in concrete on the ground. The minimal dimension of these reinforced concrete shall be 300mm x 300mm x 300mm.

e) A unique reinforced concrete stone slab with a section of 250mm x 250mm chained in the length is another acceptable option.

f) Whatever the case, the concrete shall be weighed at minimum 350kg. The lowest level of the module from the ground shall be at least 1m.

Whatever the mounting method, the material for mounting components should satisfy the requirement below:

g) The components used for the module fixation to the support (nuts, washers, bolts) must be stainless materials.

h) The combination of the various materials (including bolts) on one same system is accepted provided that the technical arrangements preventing the forming of an electrochemical pile among these materials are clearly specified.

- Wiring of the module
  - a) All connection wires for the module shall be H07RNF flexible type.
  - b) The wires between the modules shall be systematically collected in the protection pipes set up under the modules, which are resistant to bad weather.
  - c) The wire between the module and the building shall be mechanically protected by pipe or a tube made for that purpose and buried (if the module is fixed on the ground).
  - d) The acceptable voltage drops shall be;
    - module-charge controller connection : maximum 2%
    - charge controller- battery connection : maximum 1%
    - charge controller- lamp connection (the farthest lamp), under all lamps lit :5%.

  The minimum requirement of cable section should be 2.5 mm2 for internal (between a charge controller and loads) and 4 mm2 for external (between a PV module and a battery through a charge controller) to keep the acceptable voltage drop described above. However, installer must choose the cable to control the voltage drop according to the equation below.

$$\ell = \frac{1}{2} \cdot \frac{VS}{\rho I}$$

where,

ℓ: length of cable
V: system voltage
S: section of cable
ρ : resistance factor (=1/χ, cupper;0.018)
I: current

(2) Charge Controller

The charge controller shall be set under shelter at 1.5 m from the ground, on a place as close as possible to the battery.

As mentioned above, the terminal of charge controller can be an access of users for tampering. Therefore, shelter type of charge controller is preferable to an open aired terminal. The LED indicator on the charge controller is only a way of monitoring the system condition. The charge controller should be fixed on the wall as high as users can easily see the LED indicator.

(3) Battery

a) The battery shall be set in a well- ventilated room where people do not spend the day (office, bedrooms, etc.) and shall be out of children's reach.

Due to a chemical reaction of a lead-acid battery, hydrogen gas that has wide range of explosion is emitted when gassing. Batteries should be located in a well ventilated room.

b) The wires for battery connections shall be:

- either terminal covered with appropriate material
- or covered in appropriate battery lead connections.

c) Soldering shall be strictly forbidden.

d) The battery lead connections shall be protected by stoppers filled with silicone, which shall protect them against tampering by users.

The wiring connection at the battery terminal should be tight but be reasonable for replacement. Simply winding the bare wire around the terminal should be avoided. Soldering is not also appropriate for replacement of the battery.

Silicone or greasing on the terminal will prevent a corrosion of the battery terminal. Corrosion of the battery terminal should be prevented because substances by corrosion will increase electric resistance, which leads to an ineffective charge of the system.

e) Preliminary charge shall be done following to the procedure as shown in attached sheet.

Preliminary charge (Initial charge) of a battery should be accomplished without connecting a charge controller in order to avoid regulating the charge before being fully charged. The procedure of preliminary charge should be carried out in accordance with an instruction manual of the manufacturer.

(4) Interior Wiring of Buildings

Cables should be fixed tightly so as to prevent damages due to involuntary hooking or stumbling by users. Therefore:

a) The wires shall be installed on surface of the walls or the structures of the frames of the roof.

b) The wires clips shall be put every 25 cm. Cables shall be set perfectly horizontally or vertically. At the points where the directions have to change, the curve shall exceed 6 times its exterior diameter.

c) The distance between components like switches, outlets, connection boxes, a charge controller and the closest clips leading cables to those components shall be equal to 5cm.

d) All connections shall be made with connection barrettes inside the appliances. Every terminal shall be hided.

   A bare terminal can be an access for tampering by users. Every possibility of tampering should be removed carefully by this kind of specifications.

e) The connections or shunts by splices are forbidden. All connections shall be set in connection boxes or in electric appliances.

f) The end of cable in an appliance shall be done through a pressing terminal whose size shall be adapted to the sections of the cables.

   When connecting cable, splicing without any appliances causes energy loss. For this reason, every connections or shunts should be done through a metallic terminal.

g) The cable goes to components located outside building like switches, outlets and lamps, shall be made in water drop. The entrance of the cable shall be made from lower horizontal level.

   It is necessary to protect water infiltration through a hole that is pierced on the wall for wiring. Looping of cable will prevent the water infiltration.

h) In order to make repairing easier, the cable color shall be standardized for all installations, with a standard color code for the positive and the negative poles.

   This is useful not only for easy repair but also for prevention of reverse polarity.

(5) Switches

Switches shall be installed for each lamp. For double doors, the switch shall be set at the left of the entrance, at 20 cm from the door when the door is flapped against the wall.
Switches should be located on a place where people can easily access even under the darkness. For example, even if users want to operate the switch at the head of their bed, it is less useful for users' access because every user has to enter the room first before lying on the bed.

(6) Lamps

Lamp bodies shall be set on the walls and their position must be at 1.80 m in comparison with the vertical from the ground except for case of contrary specifications. Therefore, all fluorescent lamp bodies installed in the same building shall be set at the same height generally except for case of contrary specifications.

1.80 m represents the height that enables users to replace lamp bulbs easily as well as the height that won't prevent users' routine activities.

(7) Connection boxes

Connection boxes shall be solidly fixed to the walls. They shall be high enough to be out-of- reach of users.

Connection box is a component that gathers cable connections and shunts inside. As mentioned above, connections and shunts of cable can be an access for tampering by users. Therefore, the connection box should be fixed tightly on the height of out of users' reach.

(8) Outlets

Outlets shall be installed at 25 cm from the ground and shall be fitted with a "disabuser" which allows making the difference from 220V standard outlets.

Especially when AC outlet socket is applied to the system, the protection against reverse connection should be prepared.

(9) Documentation to be Handed Over at the Submission of Tender

The tender document requested bidders to submit documents below with the propositions. Those document listed here will be the minimum requirement for any tender.

1) PV Module

A technical sheet of the modules giving the I-V characteristics and showing the life duration as well as the guarantee period of the modules should be submitted. The conditions will be defined according to the following standards:

* The irradiance: 1,000 W/m^2; air-mass 1.5
* Temperature for junction of the cells of: 25°c; 40°c; 60°c
* A copy of the certificate for the ISPRA test of the modules or any other institute authorized to test the modules according to the standards cited.

2) Battery

a) The characteristics of batteries: number of cycles according to the depth of the discharging

b) The charging and discharging characteristics according to the different regimes of electricity and to the different temperatures

c) The discharging characteristics according to the time allocated: 10h; 20h; 100h .

d) The characteristics of the duration of the charging at several voltage of charge limits

e) The voltage characteristics at the end of charge according to the temperature.

3) Lamps

A technical sheet of lamps: Life duration and guarantee shall be indicated.

4) Charge controller

A technical sheet of regulators: Life duration and guarantee shall be indicated.

ATTACHED SHEET: Pre-Charging of Batteries

The pre-charging of batteries must be done according to the following procedure. If the manufacturer recommends specific charging procedure, that procedure should be superior to the procedure below.

(1) Preparation of Battery

a) Measure the electrolyte density

b) Fill the batteries up to the low level marking

c) At least two hours wait after filling up electrolyte

d) Adjust the electrolyte at its nominal level, if necessary

e) Measure battery voltage

f) Measure density of electrolyte

g) Measure temperature of electrolyte

h) If the temperature of the electrolyte is higher than 55°C or if its density drops down to 1.20 kg/l, pre-charging must be postponed until the following day.

(2) Charging

The charging source shall not be connected to charge control apparatus to avoid early stop of charging. The battery should be connected directly to the module or to a generator.

The battery shall be charged as follows:

a) Constant current should be used in the first stage until the gassing, if possible

b) After this stage, the value of the current will be reduced to nearly 2.5A

c) In case the above procedure cannot be respected, the battery will be charged during 24 hours

d) Measure voltage, and electrolyte density every 30 minutes after gassing starts

e) It is considered that the battery is full charged;

- During constant current charging, when voltage and electrolyte density do not show any variations higher than the accuracy of the measuring instrument for duration of two hours and considering the variations of temperature of the electrolyte;
- During constant voltage charging, when the recorded current and electrolyte density don't show any variations higher than the accuracy of the measuring instrument for duration of 2 hours, considering the electrolyte temperature variations, except for when maker provides a specifics.

f) The measured peaks shall be recorded in an appropriate form. The gap between the measured peaks should not exceed 0,005V for the voltage and 0,01kg/l for the density by each cell.

g) At the end of the charging process, the level of electrolyte must be adjusted at the maximum mark of each cell.