Chapter 4

Participatory Approach

In Laos, "Sustainable Operation" is an important concept for rural electrification. In order to achieve this, the three most relevant keywords are; "People's Participation", "Capacity Building", and "Cost Recovery".

4-1 Three Key Words

4-1-1 People's Participation

What does the word "electrification" mean to the local people? The participatory planning process is based on the input of the people, making it a project not just by the outside donor but by the local people. People tend to see the outside donors as a "Santa Claus" as well as an unfamiliar authority. The study employs a participatory planning approach to formulate a pilot project closely working together with local villagers. The interests of different stakeholders such as the villagers, the JICA study team and MIH, have been openly discussed at community meetings, which helps promote mutual understanding among stakeholders and formulates a common platform to work with.

4-1-2 Capacity Building

How could the local people, who have not seen a PV device before, utilize SHS or BCS? What would be an appropriate level of skill and/or knowledge for a user or a VEC technician who is to support general PV users? The items to be incorporated in the training should be extracted from many cases before and after PV installation.

4-1-3 Cost Recovery

Due to the high initial investment costs, PV was, in general, thought to be unaffordable to "poor" villagers. How can we design and introduce an appropriate tariff system to cover both capital and running costs? This JICA pilot project has demonstrated that it is possible to create "affordable PV" for poor rural settings.

4-2 Opportunity to Make a Decision - Participatory Approach

The concept of "participatory approach" requires us to inform potential solar system users of the functions and restraints of SHS and BCS and to provide them with an opportunity to make a decision at every step of the pilot project: planning, implementation, monitoring and evaluation. In order to do this, a good communication technique such as the "PCM/ZOPP workshop" becomes important. This study employed the following steps for the participatory approach.

4-2-1 Preliminary reconnaissance survey

The counterpart visited proposed candidate villages for the pilot project to look into villagers' lives. By having small meetings with some villagers, the idea of introducing solar systems was discussed.

4-2-2 Village meeting

At the pilot villages, villagers, as many as possible, were asked to join a half-day village meeting, in which the objectives of the pilot project were presented and the JICA team asked the participation of villagers. An outline of the village meeting is as follows.

(1) Knowledge on electricity

Some villagers, who are already using batteries or even 'pico-hydro generators', have gained considerable knowledge of electricity. However solar systems are completely new to them. We showed some illustrations of SHS/BCS, a real PV module and a miniature model of PV to demonstrate how to use solar systems.

(2) Electricity demand

We asked the participants questions about their battery use, method and frequency of charging, and number of TV/audio equipment to estimate their potential demand for electricity. Individual bias can be minimized by this way of questioning. Since there are several options for rural electrification, such as mini-hydro, diesel, and grid extension, discussions take place to compare costs and advantages and disadvantages of those options to provide the participants with an insight to make a decision for their future electrification.

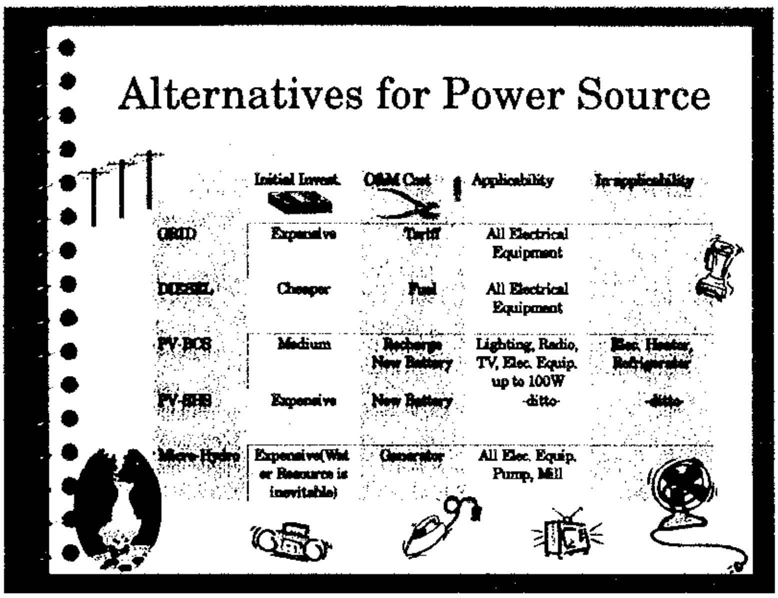

Figure 4-2-1 Alternative power sources for rural electrification

(3) Time frame of pilot project

If they express their interest in participating in the pilot project, a brief explanation is given regarding the flow of the events such as PCM/ZOPP planning workshop, application, installation, etc. Then, the project schedule is discussed considering the rainy season, road conditions or the busiest season for agricultural work.

4-2-3 PCM/ZOPP planning workshop (PCM-WS)

Inviting all the households that want to participate in the pilot project, a four-day long PCM workshop is held. The length of the workshop can be shorter if it is anticipated that good communication can be established and the time and process is sufficient to create trustful relations among related stakeholders of the project. It is also advisable to set an appropriate time for the workshop, not disturbing the busy season for agriculture or fishing since a large number of villagers are needed to participate. (See Figure 4-2-2)

(1) Self-introduction

Although villagers welcome us in general, they sometimes take a cautious attitude because of their inferiority complex or a sense of being victimized by outsiders. To establish an open discussion atmosphere at the beginning of the workshop, it is necessary to ask each participant to introduce him-/herself with simple information such as name, occupation or hobby. The self-introduction and reactions from the audience will give us a hint to understand the structure and characteristics of the village society. We can understand who is most trusted by others, who is in the less influential group, and get a feeling for maturity of the community and so on.

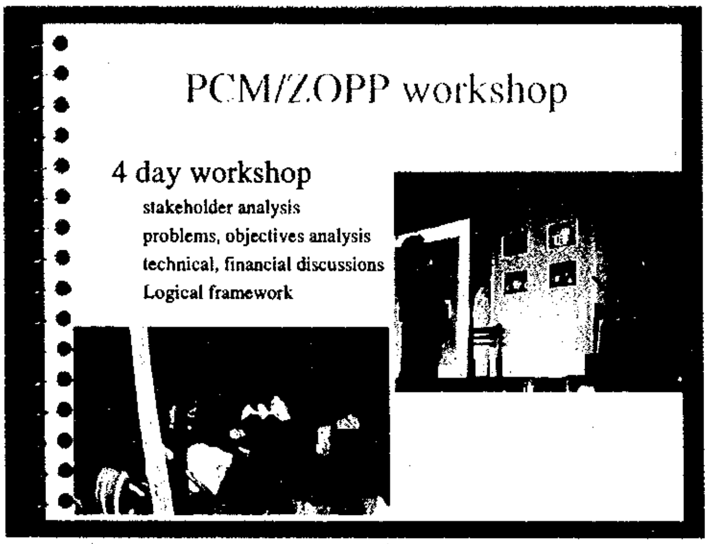

Figure 4-2-2 PCM/ZOPP planning workshop

(2) Stakeholder analysis

The participants are asked to list stakeholders of the pilot project: all groups, organizations or individuals that they think have something to do with rural electrification. Then, the participants are asked to identify 'interests' and 'powers/potentials' of the stakeholders. Normally, the stakeholders include village administration, elder group, youth group, women's union, district/provincial administration and military/police. In the case of a multi-ethnic and comparatively new village, an elder group may not be in existence. By analyzing those 'interests' and 'powers/potentials', the role and responsibility of each stakeholder, including outside organizations, for rural electrification can be clearly defined.

(3) Problem analysis

The participants are asked to identify 'problems' which they think hinder people's lives in the village regardless of their relation to electrification. (brain-storming) The problems identified here represent people's desires paradoxically. To better understand life in the village, it is important to gather a variety of opinions. It is not appropriate to focus upon a particular person or listen to a vocal group only.

Then, it is required to rearrange the problems into a form of a "problem-tree diagram" based on cause and effect relationships. It is important to lead the discussion to find out a practical starting point for problem solving.

(4) Objective analysis

The problems will be rephrased into desirable situations, or objectives. It is necessary to organize them into a form of an "objective tree". In this stage, it is recommended to formulate a common understanding among participants of a future vision and ways to achieve it. An open atmosphere for all the participants will have been created by this stage after going through the three-day meeting.

(5) Technical discussion

This session and the following 'financial discussion' are the most important sessions in terms of "marketing" of rural electrification. By showing and demonstrating a real PV module, controller and other system components, it is necessary to provide the participants with information on the functions, merits and demerits, limitations and maintenance requirements of solar systems. To convince the villagers of the benefits of solar systems, it is important to clearly answer the technical questions that the participants may ask in this session.

(6) Financial discussion

Typical issues to be discussed in this session are market price of PV systems, method of payment, method of fee collection, warranty period, cost burden of users, exchange rate adjustment, role and responsibility of newly established Village Electrification Committee, salary for the VEC staff, the price setting mechanism (for BCS). Preparation for those questions will be extremely important to gain villagers' trust.

(7) Logical framework

Based on the results of the above discussions, the workshop will be closed summarizing an action plan, which is agreed upon for rural electrification, into a "log-frame" format. The log-frame includes installation schedule, role and responsibilities of the villagers, establishment of the VEC, operation and maintenance of solar systems.

The workshop serves to make a consensus in two ways. One is to make a consensus within the village community, and the other is between the consumer (village) and the seller (PV provider). In order to achieve this, a 'visualization technique' would help. It is a technique to show every process/result of discussion to all the participants in an easily understandable way. Required tools/equipment for the visualization are: panels big enough for all the participants to see, plenty of small sheets of paper on which the participants can write down their opinions, felt pens, clips, etc. It also requires a neutral moderator who has good communication and facilitation skills to guide the workshop. At the end of the PCM workshop, we solicit applications for PV installation from the villagers and make them sign a contract. The installation starts soon after signing the contract.

4-2-4 Second workshop (Monitoring workshop)

After a certain period of using solar systems, it is recommended to have another workshop mainly for the purpose of monitoring the management of solar systems. Comments, troubles and findings from (one-year) experience of using solar systems will be discussed in the second workshop. In this study, we had to discuss the issue of monthly fee adjustment in the second workshop because the Lao currency, kip, plunged in 1999. A brief history of our workshops at the pilot villages, including workshops at the added three pilot villages, is shown below.

Table 4-2-1 History of workshops

Province	*Village*	*Pre-survey**	*Village meeting*	*PCM-WS*	*Installation of PV*	*Second WS*
Vientiane	Donsayoudom	7/1998	10/1998	1/1999	6/1999	6/2000
	Houaypong	7/1998	10/1998	2/1999	6/1999	6/2000
	Mai	7/1998	10/1998	6/1999	10/1999	6/2000
	Nongpen	7/1998	10/1998	2/1999	6/1999	6/2000
	Tangkam**	6/2000	7/2000	9/2000	10/2000	***10/2000
	Nakhoum**	6/2000	7/2000	9/2000	10/2000	***10/2000
	Nasath**	6/2000	7/2000	9/2000	10/2000	***10/2000
Borikhamxay	Namai	7/1998	10/1998	2/1999	10/1999	
	Paksoun	6/1999	6/1999	6/1999	11/1999	

*preliminary survey **added in 2000 ***Not PCM workshop

4-3 Results of PCM Workshops

4-3-1 Donsayoudom

The financial discussion in the PCM workshop turned into price negotiation between the seller (JICA study team) and the users. Since the study team had a stereotype understanding that "PV is too expensive for them to pay", the users were likely to win by asking a huge discount. However, to the surprise of the study team, the village people asked reduction of the monthly payment, and instead asked increase of the down payment. The tariff agreed upon has been collected smoothly so far. During the workshop, the participants were divided into two groups naturally. More than several men took their seats in front, surrounded by the rest of villagers including other men, women, elderly people and children. Usually only the men in front responded and expressed their opinions during the discussion. However, it was not quite likely that they dominated the village, because they turned back frequently to get consent from the silent majority behind them. The number of active presenters was limited throughout the workshop. The villagers chose the vocal group as the VEC members.

4-3-2 Houaypong

Villagers seriously asked about benefits of PV introduction. They wanted to have advice from experts about their ideas for increasing the benefits. One of the serious questions raised at the workshop was whether or not a 6V battery could be charged by a solar system. They were using those 6V batteries often so that charging those small batteries was a hassle. There were a number of related questions: how big the charging current is, what happens if the charging current exceeds the maximum standard charging current of a 6V battery, how to keep the current within a certain range, etc. Those issues are what they really wanted to know.

Figure 4-3-1 A view of Houaypoung village

It is obvious that the success of PV expansion depends on cost reduction and increased benefits.

There found some 'heavy users' in this village. Before the pilot project started, there were some households that had a color TV and an audio system. They were using small generators or batteries with inverters to supply 220V AC. After the PV installation many families bought Karaoke machines, color TV (19 inches), video CD, CD players and so on. Those appliances are driven by a DC-AC inverter (from 12V to 220V) that is directly connected to batteries. This cannot be recommended, because over-discharge often happens and the battery life becomes extremely short. Although the study team and the VEC have repeatedly warned them to stop the practice, they do not care about it. The village is located in the area where TV signal is weak, so that some people prefer VCD to TV programs broadcasted from Vientiane or Thailand.

4-3-3 Mai

At the PCM workshop, an elderly man, who was respected by the villagers, spoke most and the rest of participants listened to him seriously. Our objective is to see whether or not PV is useful for rural electrification in Laos. To provide solar systems for free is not likely to be replicable elsewhere, because the government budget is very limited. If it is feasible to collect certain fees from users, there is a big opportunity to expand rural electrification. For that particular purpose, we are searching for the way to electrify this village by soliciting contributions (paying tariff) from the villagers.

Figure 4-3-2 A view of Mai village (with children)

Another reason is that one will not take care of things that were given as free gifts. We explained this point, and stressed that this idea had been extracted through our past experience as a donor. Therefore, it is important that ' you' decide to own those things.

4-3-4 Nongpen

We had 44 participants in the PCM workshop. Though the village was recognized as having the lowest cash paying capacity among the pilot villages based on the socio-economical survey results, they didn't seem much concerned about money at least during the workshop. As for the question of hobbies, women responded 'weaving' at very high rate as we expected. There were some answers of 'appreciation of music' that could be considered as true spare time enjoyment.

4-3-5 Namai

In the PCM workshop, there were 68 participants from a total of 75 households[3]. When soliciting applications for PV at the later part of the workshop, it was found that their preferences were not in BCS. While they said SHS was too expensive, no one chose BCS. There were three reasons for that, according to them.

- In case of BCS, they need not to carry heavy batteries
- BCS operation needs someone for fee collection and management
- SHS, which includes a long-life battery and lighting equipment, looks high cost performance

In the past, they had bitter experience with difficult cooperative management on the operation of a gravity-fed water supply system. The fee collection, 100 kip per month, for the water supply system did not go well. Although the village leaders showed their reluctance to operate a BCS[4], one individual expressed his intension to operate a BCS. His proposal was to operate one unit of BCS (165W), which would be almost enough to serve six households. He was a man of entrepreneurship.

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[3] A government official mission visited in January 1999, holding a 24-day long workshop, and made the village merge with the neighboring village, Boki. The fact had never been informed to the study team until our second visit. The name as well as the chief of the new village remained the same.

[4] The study team changed its offer and decided to provide only a BCS at the third field survey, against the results of the PCM workshop. It was a big discouragement to the villagers.

4-3-6 Paksoun

For this village, the study team offered only a BCS from the beginning. The utilization rate of the BCS now is high and the VEC's income is better than expected. This is a successful case of BCS operation. More details of this case are described in Chapter 6.

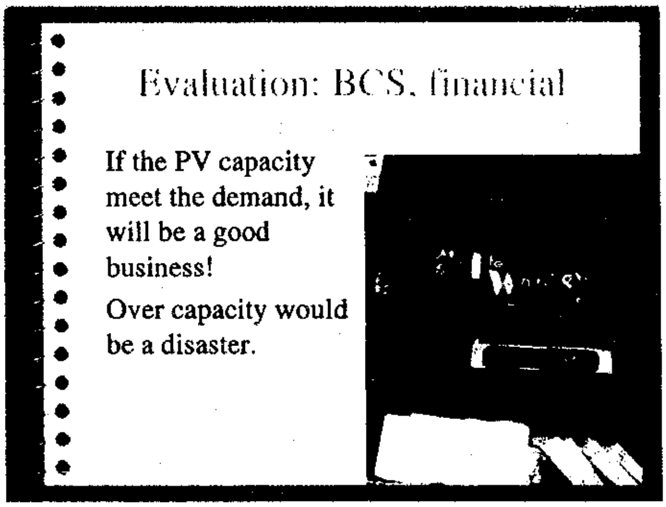


Figure 4-3-3 Successful BCS operation at Paksoun

4-4 Training Program for PV Users

4-4-1 VEC strengthening

To realize sustainable PV use in the villages, organization and function of VECs are important. Appropriate training programs should be designed for the VEC members, who are responsible for instructing general users and for doing regular maintenance and trouble-shooting, as well as for the end users.

(1) Training venue and materials

On-site mass training in a house with a basic 55W SHS is recommended because it will be practical and realistic for the villagers. It will be necessary to bring tools, equipment and training materials. Since AC power supply is not available in the villages, tools and equipment should be portable and DC driven. If the power from a PV module is necessary, it will require daylight and a place to set up. In those cases, nighttime training is impossible. An alternative power source, such as a small generator or battery might be needed when sunshine is uncertain.

(2) Assessing knowledge of trainees

Baseline knowledge for electricity varies by village as well as by individual. Some are familiar with battery use, while some aren't. Some have lights and B/W TV, and some have Karaoke and color TV with an inverter. It is important to understand how electricity is used in the villages and assess the knowledge of the trainees in order to design appropriate training programs.

(3) Activities of VEC

The VEC is gaining experience in PV technical training, fee collection, minor trouble-shooting, and trouble-recording activities. The members of the VEC indicated their opinions as follows:

- Would like to fix a date for monthly fee collection.
- Would like to collect fees when visiting and checking the system.
- Would like to ask DOE/MIH to come and pick up collected fees at the village, because it will provide a regular chance for technical Q and A session with the VEC members.
- The VEC should visit PV users regularly for periodical checking.

Those comments reflect the eagerness of VEC members toward their responsibilities. Also they are expecting support from outside technicians.

4-4-2 Frequently Asked Questions

⇒ **Q1. Does a PV module attract lightning?**

A lightning generally strikes tall objects such as a tall tree or TV antenna. It may strike a PV module also, but is not attracted by the module.

⇒ **Q. Can a fan be used by SHS?**

The electricity supplied by SHS is 12V DC. Therefore a fan designed for 12V DC, such as used in automobile, can be used. A big fan and long operation could be a heavy burden for a battery.

⇒ **Q. Can a SHS charge a 6V battery?**

The SHS controller is designed for 12V batteries. However, two 6V batteries connected in series are equivalent to a 12V battery, and can be charged.

⇒ **Q. How to know the life of a battery?**

When a battery becomes old, its discharging capacity becomes smaller. A battery's life is coming to an end when hours of its power supply become very short. The SHS controller is designed to maximize battery life.

⇒ **Q. When a battery is low and the controller shuts down the electricity output, is it possible to use a light for emergency at night?**

It is possible by bypassing the controller, which means to connect cables from battery terminals directly to a light. But it may shorten battery life.

4-5 Recommendations for the Master Plan

4-5-1 Necessity of sector strategy

In case of rural water supply, the responsible authority in Laos, NamSaat, has 'the

Sector Strategy' which clearly states priority issues, roles and responsibilities of local people, the government and outside donors, and cost-sharing mechanism by each agency. It indicates the fundamental government's view for rural water supply, and roles of the government to people's life. Owing to this document, outside donors or NGOs, which have an interest to cooperate with the Lao people, can take necessary measures with confidence. It took three years for NamSaat to complete the Sector Strategy. Now it is playing a key role for both the Lao government and donors. A similar document in the field of rural electrification is strongly recommended.

4-5-2 Low cost and useful PV system

Basic strategy to expand solar systems, which are characterized as having high initial cost and low operation cost, would be as follows.

- To reduce the system costs as low as possible
- To create an environment for longer use and more benefits

The later is a strategy for increased benefits. It can be conceptualized in a formula $\{\Phi Y\}$, where Φ is a benefit factor which indicates how much a PV can satisfy people's needs and Y is a time factor to show the system's life. The conditional formula for PV expansion would be as follows:

$\{\Phi Y \geq X\}$ Where X indicates total system costs.

The information necessary for the potential buyers to make up their mind is detailed and reliable information on PV's benefits and costs. Particularly in case of BCS, a decision-making process to make a consensus among villagers is crucial. This study found out several possibilities for further cost reduction. It is important to incorporate those findings into the future system design.

4-5-3 Demand creation

In this study the JICA team conducted a four-day PCM workshop at each pilot village inviting potential users. This workshop provided opportunities for good communication and mutual understanding between the team and the villagers. It was not only contributing to our better understanding of the reality of people's lives, but also to stimulating people's interests for the absolutely new PV technology. We could learn a lot about their potential demand for electricity. In other words, the workshops created demand for solar system, which, otherwise, would have been latent. The comment made by one village chief, "After real ones (solar systems) came to the village, everybody now has recognized the true values (of solar systems). ", clearly indicates the possibility that the pilot project would work as an effective "Showcase" for the further expansion of solar systems.

Chapter 5

Photovoltaic System and Installation

5-1 Site Survey

5-1-1 Characteristics of Pilot Villages

The pilot villages in Vientiane province--Nongpen Donsayoudom, Houaypong and Mai--are located about 60km north of Vientiane. Except for Nongpen, the access to the three villages, which are located on the Nam Ngum Lake, is easy because large boats are available. The road reaching Nongpen is rough and it is difficult to drive a car in the rainy season. The pilot villages in Borikhamxay province--Namai and Paksoun--are located about 120km east of Vientiane near Pakxan. The road reaching Namai was improved. To go to Paksoun, it is necessary to take a small boat for 10 minutes. A typical rural house has a living room, a sleeping room, and a kitchen with a floor above ground (1to 2 meters). Woven bamboo is often used as wall. The roof of traditional house is made of bamboo or straw. Sometimes galvanized corrugated steel sheet is used for roofing.

Table 5-1-1 Outline of the pilot villages

	Name of village	No. of surveyed houses	Distance from the nearest grid line	Features of each village	Accessibility of each village
Vientiane Province	Donsayoudom	126	14.5km from Nam Ngum dam	*Village is divided into two areas by a creek *Houses located in orderly way *Good road	*Easy (1hr by boat) *Material transportation by boat
	Houaypong	42	14.2km from Nam Ngum dam	*Undulating land *Houses are dispersed	*Easy (1hr by boat) *Material transportation by boat
	Mai	58	14.3km from Nam Ngum dam	*Village is divided by a stream. *Houses are dispersed comparatively	*Easy (50min by boat) *Material transportation by boat
	Nongpen	49	6km from branch of KM 13	*Village is divided into four blocks *Houses are concentrated in every block	*Difficult (30min by car from branch of KM 13) *Bumpy road *Hard access even in dry season
Borikhamxay Province	Namai	-	4km from Khambon village	*Divided into three areas *There is a space beside the main road	*Easy (40min from Pakxan by car) *New road was constructed
	Paksoun	-	20km from the suburbs of Pakxan	*Village is beside a river *Houses are concentrated *There is a space in the center of the village	*Easy (40min by car plus 10 min by boat from Pakxan) *Material transportation by small boat

5-2 Basic Design of PV System

5-2-1 Solar Home System (SHS)

(1) Components

The specifications of major components, PV modules, batteries and controllers, which were all procured in Japan, are shown in Table 5-2-1.

Table 5-2-1 Specifications of major components

Name	PV module	Battery
Type	GT-136N	SL12-110
Capacity	55(W)	110(Ah)(100hr rate)
Performance	V_{oc}(Open) :21.6(V) I_{sc}(Short) :3.47(A) V_{op}(Optimum):17.3(V) I_{op}(Optimum) :3.16(A)	Voltage : 12(V) Solution: 4(litters/battery)
Dimension(mm)	W:330-L:1,298-D:35	H254- W171-L407
Weight(kg)	6.7	35
Quantity	For SHS:600ea For BCS:150ea	For SHS:300ea

Name	Controller	
Type	SCCRE-15	SCCRE-40
Capacity	15A	40A
Performance	Over charge:15.2V Over discharge:11.4V Temp. factor:-20mV/degC Protection from reverse connection	Over charge:15.2V Temp. factor:-20mV/degC Protection from reverse connection
Dimension(mm)	W217 - H68 - D112	W217 - H72.2 – D212
Weight(kg)	1.28	2.37
Quantity	For SHS:300ea	For BCS:45ea

(2) Battery usage in pilot villages

Battery usage and electric appliances in each pilot village were studied before conducting the design of solar systems. (See Table 5-2-2, 5-2-3) Average hours of usage are also shown in Table 5-2-4.

Table 5-2-2 Battery usage in each pilot village

Name of village	No. of houses surveyed	No. of battery householders (Battery capacity)				Total
		120Ah	70Ah	50Ah	others	(Rate(%))
Donsayoudom	84	10	21	18	5	54 (64.3)
Houaypong	44	7	10	6	0	23 (52.3)
Nongpen	50	1	10	18	4	33 (66.0)
Mai	57	3	2	11	4	20 (35.1)
Namai	42	1	1	13	3	18 (42.9)
Somsanouk	34	1	4	10	4	19 (55.9)
Natong	38	1	3	4	1	9 (23.7)
Total	265	14	30	62	16	122 (46.0)

Table 5-2-3 Electric appliances in each pilot village

Unit:[ea.]

Name of village	TV				Lighting				Radio			
Capacity of battery	120	70	50	Total	120	70	50	Total	120	70	50	Total
Donsayoudom	10	21	17	48	9	13	16	38	8	9	4	21
Houaypong	5	5	0	10	7	9	6	22	7	7	4	18
Nongpen	0	8	10	18	1	7	12	20	1	10	17	28
Mai	2	1	11	14	3	2	6	11	1	2	9	12
Namai	0	0	10	10	0	1	5	6	1	1	6	8
Somsanouk	1	2	9	12	1	3	8	12	1	1	8	10
Natong	1	3	4	8	1	3	3	7	0	1	3	4
Total	19	40	61	120	22	38	56	116	19	31	51	101

Table 5-2-4 Average hours of electric appliance usage

Unit:[hr]

Name of village	TV				Lighting			
	120Ah	70Ah	50Ah	Average	120Ah	70Ah	50Ah	Average
Donsayoudom	4.8	4.0	4.5	4.3	3.4	3.1	1.7	2.6
Houaypong	4.8	5.3	-	5.1	4.1	4.8	3.8	4.3
Nongpen	-	3.0	3.2	3.1	2.0	3.7	2.6	3.0
Mai	4.5	2.0	4.8	4.6	2.0	4.0	4.2	3.6
Namai	-	-	2.4	2.4	4.0	2.0	2.1	2.1
Somsanouk	7.0	4.0	3.8	4.1	7.0	3.3	3.4	3.7
Natong	4.0	3.0	4.3	3.8	4.0	2.7	3.5	3.2
Average	4.8	3.8	3.9	4.0	3.6	3.6	2.8	3.2

(3) Calculation base

1) Insolation data

Insolation in Laos was calculated from the data on sunshine hours. The value of minimum insolation was used for the system design.

Table 5-2-5 Calculated Insolation in Vientiane

[kWh/m²/day]

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Insolation	4.8	4.7	5.4	5.6	5.5	4.9	4.9	4.6	4.6	5.0	4.7	4.7	5.0

2) Estimated power consumption

From Table 5-2-4, power consumption was estimated and is shown in Table 5-2-6.

Table 5-2-6 Estimated power consumption

Appliance	Peak Watt	No. of units	Hours of usage	Power consumption
Fluorescent lamp	8 W	1	3.2 h	25.6 Wh
TV	24 W	1	4.0 h	96.0 Wh
Total	32 W	-	-	121.6 Wh

3) Loss factor

The assumed loss factor for the design is shown in Table 5-2-7.

Table 5-2-7 Factor of system loss

Item	Charging					Discharging	
	Dirt	Temp.	Wire	Diode	Charging	Controller	Wire
Factor	0.98	0.9	0.97	0.97	0.8	0.95	0.97

4) Other conditions

Depth of discharge: 50[%]   Number of days of autonomy: 2 Days

(4) System capacity

1) System capacity

*Calculated system capacity

PV capacity: 43.2[W]   Battery capacity: 791[Wh]

*Specification of materials available

Output of PV module: 55[W]   Capacity of battery: 1,320[Wh]

Hence, one 55W-PV module is good enough for a SHS.

2) Days of autonomy

*Capacity of battery available : 1,320[Wh]

*Daily power consumption: 121.6[Wh/day] → Daily depth of discharge: 10[%]

*Threshold of over-discharge protection: 50[%] of depth of discharge

Hence, the maximum length of system autonomy is four days.

(5) Performance of SHS

The conditions for system operation were simulated based on the estimated insolation from the sunshine hour data at the Vientiane meteorological station.

1) Stability of power supply

Table 5-2-8 shows the estimated number of days which may cause the restriction of power use.

*110W SHS : Supply is available throughout a year.

*55W SHS : Some restricted days in the rainy season

Table 5-2-8 Potential of power use restriction

Unit: [day]

Capacity	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
110W	0	0	0	0	0	0	1	0	0	0	0	0	1
55W	0	0	0	0	0	0	8	14	2	0	0	0	24

2) Excess power

System capacity was designed for the minimum amount of insolation, which occurs in August. During the dry season, generated electricity is more than actual consumption. There is a significant amount of untapped electric energy every month. (See Table 5-2-9)

Table 5-2-9 Estimated excess power

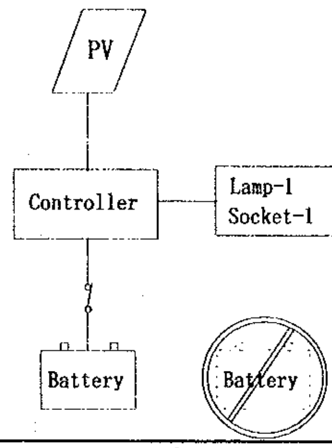
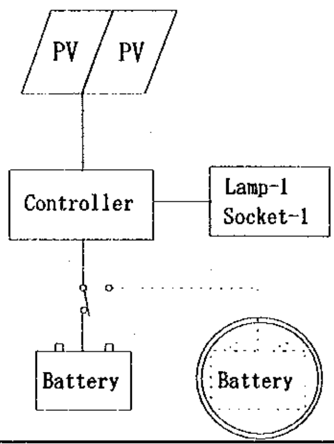
Unit : [Wh]

Capacity	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
110W	8,510	6,853	5,623	9,281	7,017	6,149	2,935	2,432	4,874	6,477	4,666	6,264	71,081
55W	2,370	1,724	1,255	2,488	1,760	1,467	202	0	622	1369	522	1,227	15,006

3) Comparison of 110W and 55W systems

A comparison of 110W SHS and 55W SHS is shown in Table 5-2-10.

Table 5-2-10 System comparison

PV Capacity	55W	110W
Skeleton diagram		
No. of PV module	1	2
Charging an extra battery	No	Possible

5-2-2 Battery Charging Station (BCS)

(1) Battery usage of pilot villages

Type of battery : 12(V) - 120(Ah), 12(V) - 70(Ah), 12(V) - 50(Ah),

Frequency of charging : 2 to 4 times per month

Table 5-2-11 Battery capacity and frequency of battery charge

Unit : [houses]

Name of village	120Ah					70Ah					50Ah				
Times of charge in a month	1	2	3	4	5<	1	2	3	4	5<	1	2	3	4	5<
Donsayoudom		2	2	6	2		1	6	9	2		1	6	8	3
Houaypong		7				2	5	1	1	1	1	3	2		
Nongpen				1		1	1	1	6	1		4	2	10	
Mai		3					2				2	6	1	2	
Namai		2					1				1	6	1	1	2
Somsanouk	1						2		2			1	8	2	
Natong				1			2	1				2	1	2	
Total	1	14	2	8	2	3	14	9	18	4	4	23	21	25	5

(2) System simulation

Based on the sunshine hour data from the Vientiane meteorological station, the optimum PV array capacity was calculated for battery capacities of 120(Ah), 70(Ah) and 50(Ah), and for depth of discharges of 50%, 60%, and 70%. Figure 5-2-1 shows the number of days that charging full in one day is possible in a year. For example, in the case of 50 (Ah), 70 % discharge, 165W of PV array will be able to charge the battery about 250 days in a year.

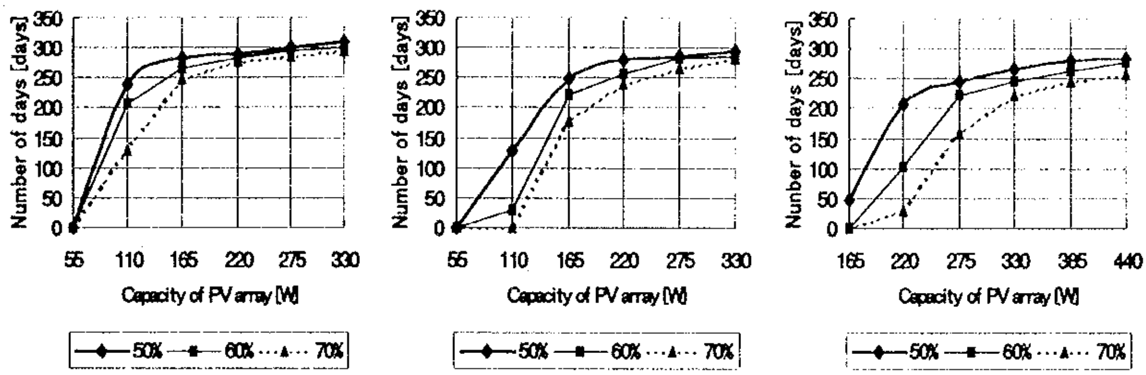


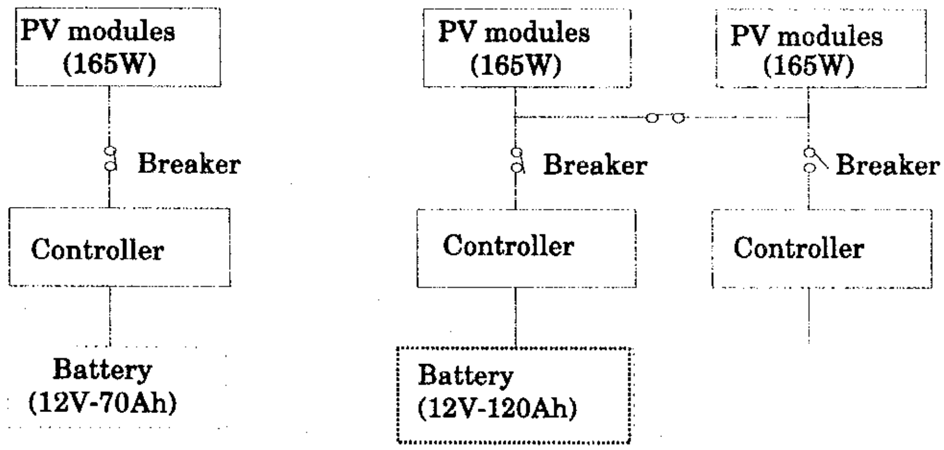
Figure 5-2-1 Number of days possible to charge full

(3) System capacity

System capacity of BCS was decided as follows.

*50 (Ah) and 70 (Ah) : 165W PV modules (three 55W modules in parallel connection)

*120(Ah) : Two 165W PV modules connected in parallel



1)50Ah and 70Ah 2)120Ah

Figure 5-2-2 Block diagram of BCS

5-3 Installation of PV System

5-3-1 SHS

(1) Basic system specifications

A system image with the basic specifications of SHS is shown as follows.

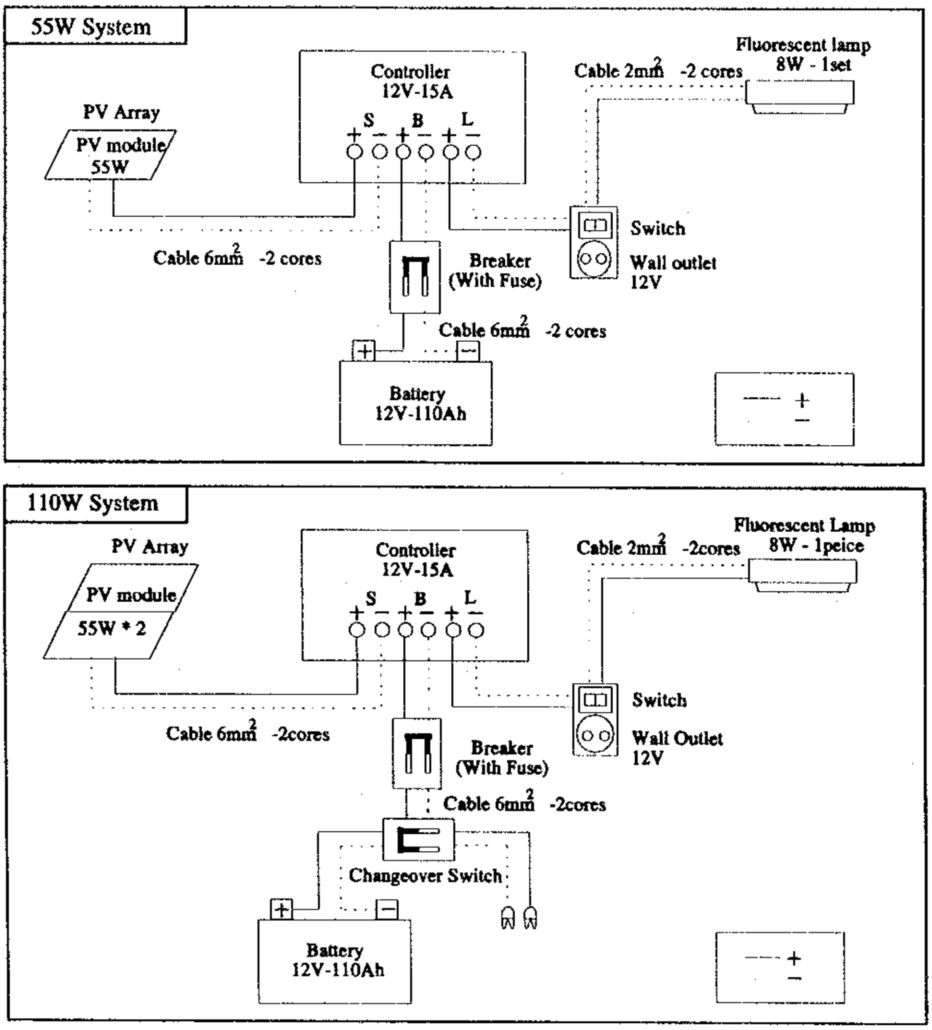


Figure 5-3-1 System diagrams of SHS

Table 5-3-1 Basic specifications of SHS

Equipment	55(W) SHS	110(W) SHS
PV module	1 module of 55(W)	2 modules of 55(W)
Type of mounting	Roof top or Pole mount	
Controller / Fuse	1 (15A) / 1 (10A)	
Battery	1 (110(Ah))	
Fluorescent lamp	1(8(W))	
On –off switch / wall socket	1 for fluorescent lamp / 1 for DC 12(V)	
Cables	$6mm^2$(multi core)-2c*15m, $2mm^2$(single core)-2c*15m	
Changeover switch	No	1 (For charging an extra battery)

(2) Items for installation

Major items for SHS installation are shown in Table 5-3-2.

Table 5-3-2 Major Items for SHS Installation

Item	Points
PV array (Pole mount)	*Direction: South *Tilted angle: 20 degrees *Pole: Galvanized steel pole (Corrosion-resistant)
PV array (Roof top)	*Roof facing to south: direct fixing to roof, same inclination of roof (10 cm space is needed between roof and PV array) *Roof not facing to south: Prefabricated mount, angle 20 degrees
Controller	*Install at high place where children can't reach but user can check the indicators *Install on wall or column Wood plate is used if necessary.
Battery	*Connection: After circuit connection check before filling solution *1 to 2 days of initial charge is necessary after filling solution before use
Cables	*PV array – Controller – Battery: 6mm² sq * 2C (multi core) *Controller – Lamp, Socket: 2mm² sq * 2C (single core)

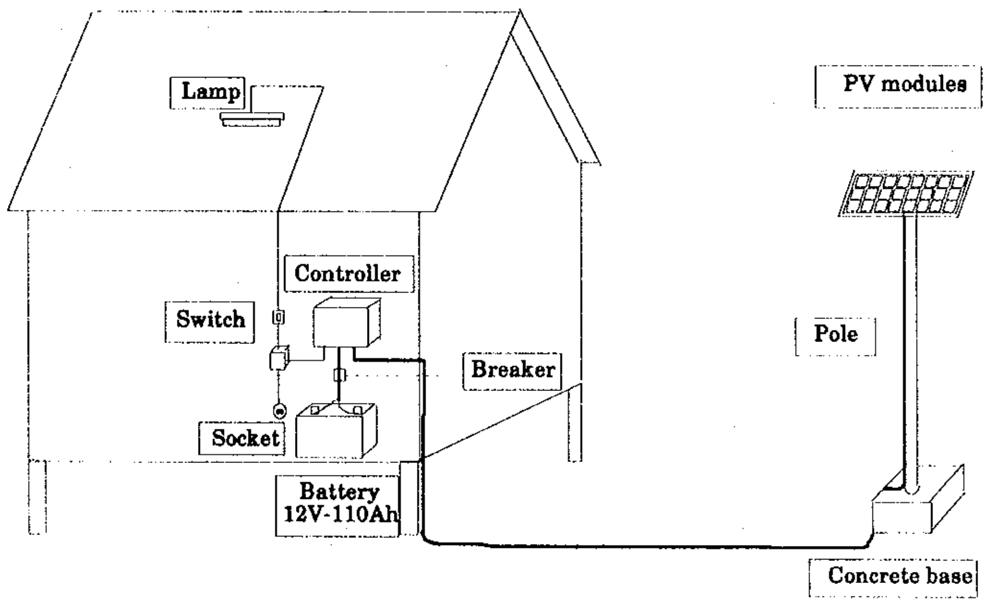


Figure 5-3-2 An Image of 55W SHS System

5-3-2 BCS

(1) Basic system configuration

The basic unit capacity of BCS is 165W consisting of three PV modules. A standard 1kW BCS system which has six basic units is proposed. The standard system can be expanded to a larger size to meet the estimated demand of target village.

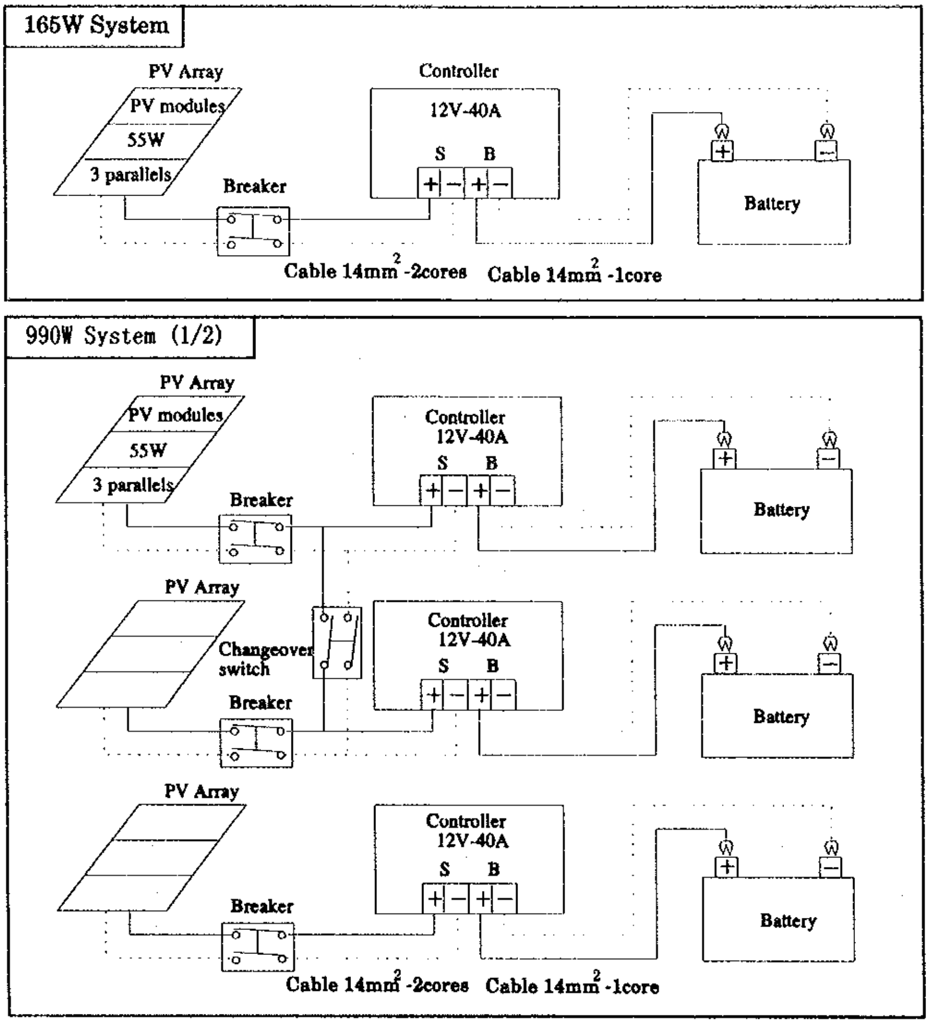


Figure 5-3-3 System diagram of BCS

Table 5-3-3 Basic configurations of BCS

Equipment	A standard 1kW BCS
No. of PV modules	6 units of 165W
Mounting	Structure on ground
No. of Controllers	6
Cable	PV: $14mm^2$-2c*10m*6 Battery: $14mm^2$-1c*2m*12
Breakers	6
Charging room	Roof : Corrugated fiber board Column : Concrete pole Wall : Prefabricated concrete block

(2) Items for installation

Major items for BCS installation are shown in Table 5-3-4.

Table 5-3-4 Major items for BCS installation

Item	Points
PV array For 6 units	*Direction: South Tilted angle: 20 degrees *Structure: Steel pole and L shaped steel angle *6 column*6 row structure on the ground
Controller Switch	*Install a waterproof box on the wall. *Install a controller and a switch inside of the box.
Wiring	*3 modules are connected in parallel. *PV array – SW – Controller: $6mm^2$ sq * 2C (multi core) *Controller – Battery: $6mm^2$ sq * 1C with special connector
Charging room	*Inflammable materials and good ventilation

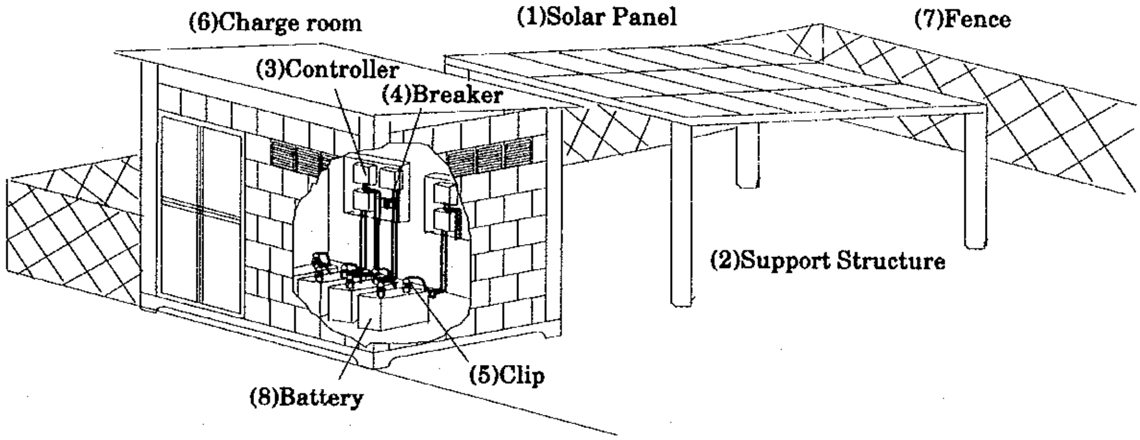


Figure 5-3-4 Image drawing of BCS

5-4 Installation Work

In the pilot project, the entire installation (construction) work of PV systems was divided into two periods; before and after the rainy season to avoid bad conditions for installation.

Table 5-4-1 Schedule of installation work

Installation stage	Province	Village	System type
First round (1/Jun.~25/Jun.99)	Vientiane	Donsayoudom, Houaypong	SHS, BCS
		Nongpen	SHS
Second round (8/Oct.~22/Oct.99)	Vientiane	Donsayoudom, Houaypong, Mai, Nongpen	SHS
	Borikhamxay	Paksoun, Namai	BCS

5-4-1 Work flow

Installation work was subcontracted to SVT, which had experience of installing PV systems in Laos, under the supervision of the JICA study team and MIH/DOE.

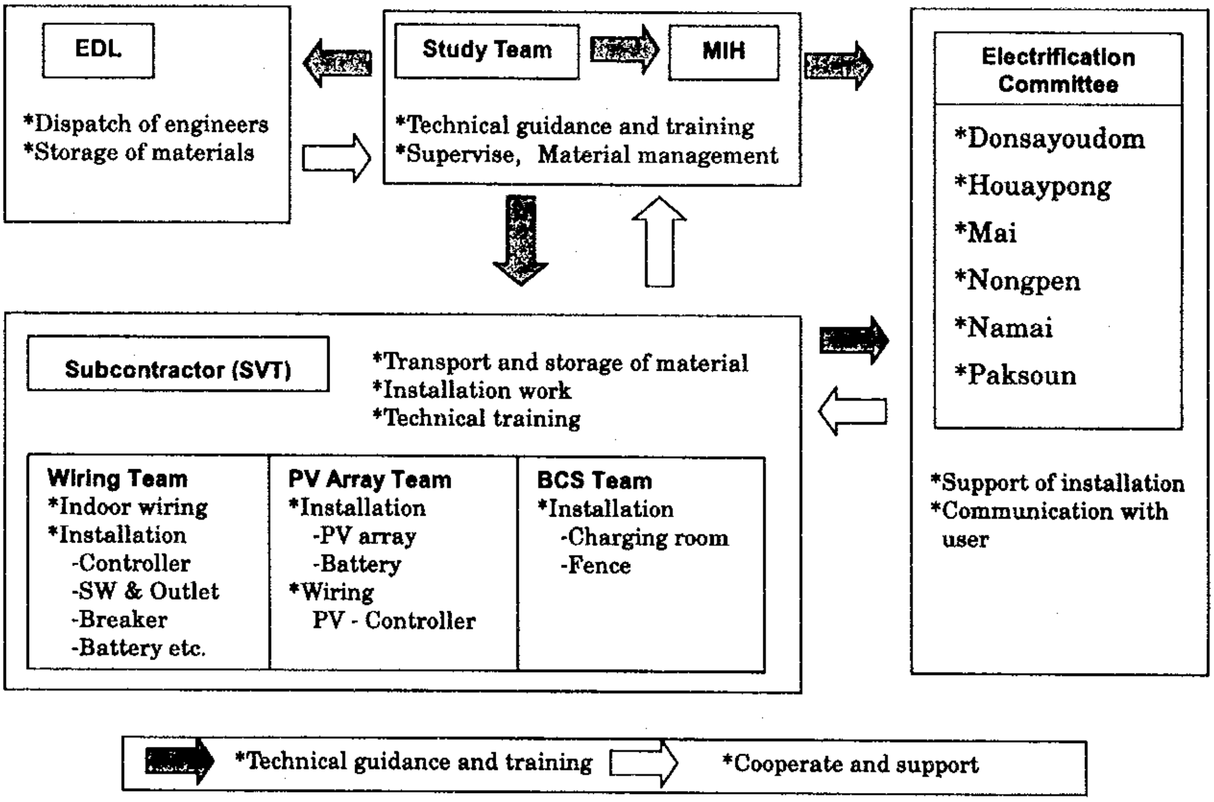


Figure 5-4-1 Installation work flow

5-4-2 Number of PV systems installed

1) SHS

152 systems were installed in the first round and 102 systems were installed in the second round. Therefore, a total of 254 systems were installed. In addition, one SHS was installed for demonstration purpose at each EDL local office in Vientiane province and Borikhamxay province.

Table 5-4-2 Number of SHS installed

Village	Number of houses	Initial applications			First round			Second round			Total		
		55W	110W	Total	55W	110W	Total	55W	110W	Total	55W	110W	Total
Donsayoudom	129	34	34	68	35	50	85	9	9	18	44	59	103
Houaypong	43	21	1	22	28	1	29	10	0	10	38	1	39
Nongpen	50	39	5	44	32	6	38	4	2	6	36	8	44
Mai	68	28	28	56				34	34	68	34	34	68
Total	288	122	68	190	95	57	152	57	45	102	152	102	254

According to Table 5-4-2, the number of SHS installed increased by more than 30% from the applications collected at the PCM workshop. There were many late applicants before and during the installation. In Donsayoudom and Houaypong, the number of applicants reached from 50% to 80% of the total households. Villagers in Mai obtained information about SHS from Houaypong people and they were eager to have a SHS. All the households applied for SHS eventually.

2) BCS

Different sizes of BCS, from 1kW to 3kW, were installed in Donsayoudom, Paksoun and Namai. In addition, a small 165W system was installed for experiment in Houaypong.

Table 5-4-3 Installation of BCS

	Donsayoudom		Houaypong	Namai	Paksoun
	Site 1	Site 2			
Number of basic units (165W)	12	6	1	12	18
Capacity of PV array [W]	1,980	990	165	1,980	2,970
Number of controllers [unit]	12	6	1	12	18

5-4-3 Installation work

Before the installation work, the study team, the MIH engineers, and the subcontractor discussed installation methods suitable for Laos and applied the output in the actual installation work. From the experience of installation work of SHS and BCS, points deserving special attention are described in the following.

(1) SHS

1) Marking installation position of major equipment

(PV array position)

*Sunshine condition should be best throughout a year.

* When the position is selected, an agreement should be obtained from the user.

(Fluorescent lamp and switch)

*User's opinion should be considered as priority.

*If the position is unsuitable, select from several options proposed by technician.

2) Indoor wiring

*Equipment is basically installed on wall or column.

*In case that strength of the wall or the column is insufficient, equipment is installed on a wood board which is specially prepared.

*Indoor wiring should be executed carefully to ensure correct connection.

*For a 110W system, a changeover switch is installed between the breaker and the battery.

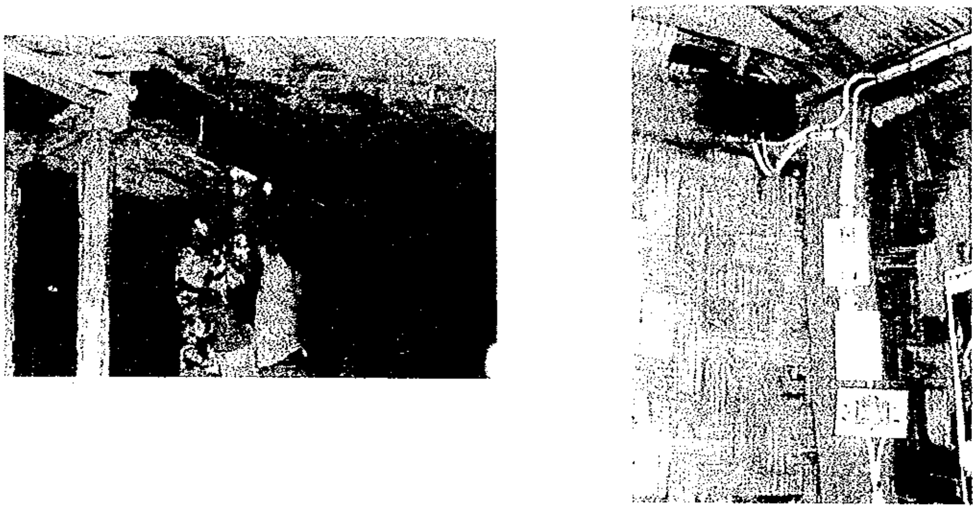


Figure 5-4-2 Indoor wiring

3) Installation of PV array

(Pole mount type)

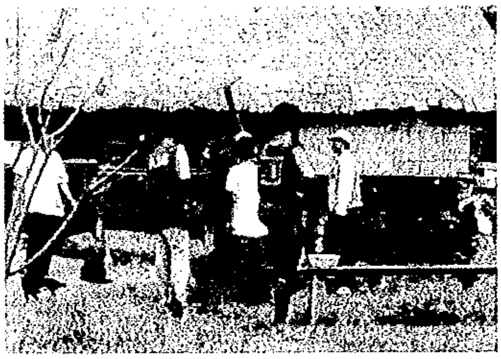
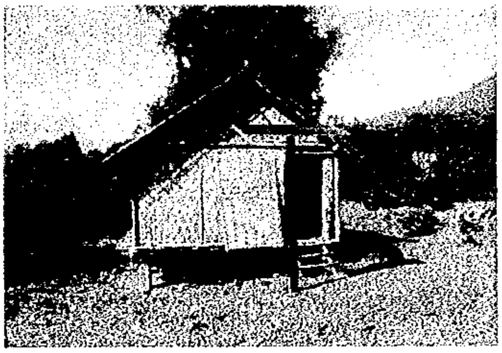
* For improving efficiency, using rivets is recommended to fix a PV module onto a support structure.

*PV array should be installed facing south using a compass.

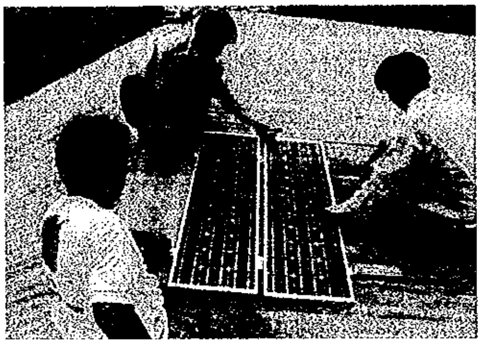
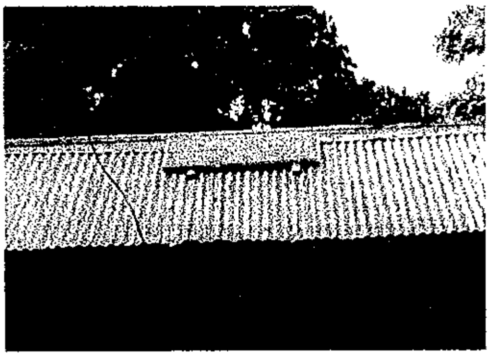
(Roof mount type)

*PV module is fixed onto timbers already fixed on the roof.

*Waterproofing should be conducted.

(1) Installation of PV array (pole mount type)

(2) Installation of PV array (roof top type)

Figure 5-4-3 Installation work of PV array

4) Installation of battery

*Electrolyte was filled into batteries before installation, because the batteries used in this project were transported without electrolyte (dry condition) from Japan.

*Batteries should be charged for around two days after filled with electrolyte.

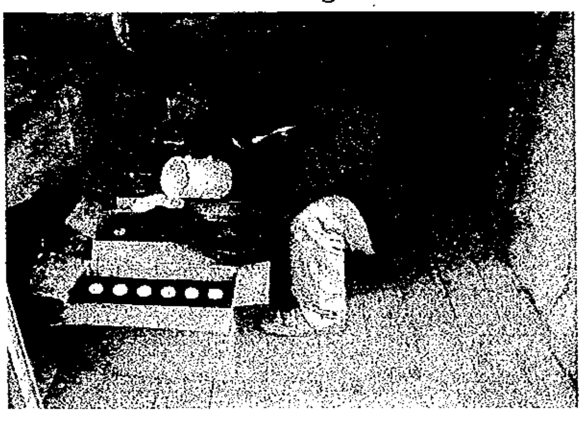


Figure 5-4-4 Filling electrolyte

Figure 5-4-5 Visual Inspection

(2) BCS

1) Survey of installation site

*Distance from user's houses should be short.

*Shape and area of the site should be suitable.

*Sunshine conditions should be good.

*Effect of shades should be checked.

2) Construction of battery charge room and fence

*Battery charge room should be built with noninflammable materials with good ventilation because hydrogen is discharged from batteries.

*Fence should be built around PV arrays and the charge room to prevent animals from entering.

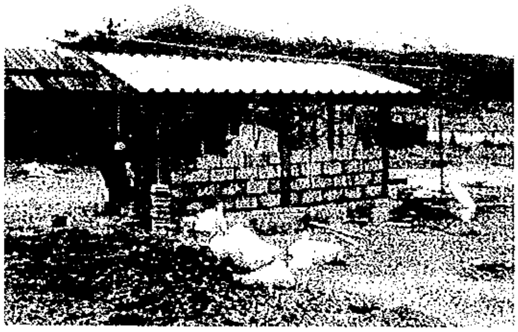
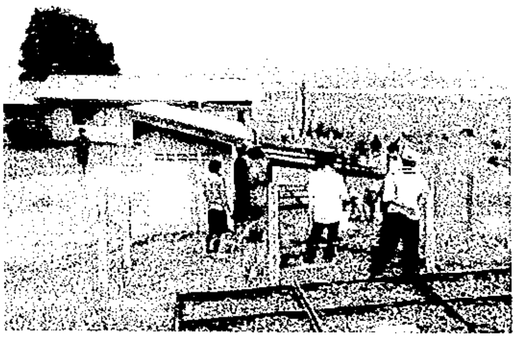


Figure 5-4-6 Battery charge room

3) Installation of PV array

*One steel support structure can accommodate 18 PV modules.

*The support structure can be removed from the foundation easily.



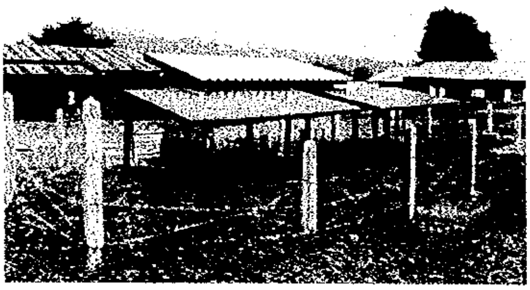


Figure 5-4-7 PV arrays and support structure

4) Installation of equipment and wiring

*Controllers and breakers are installed in a steel box.

*The box is installed on the wall of the battery charge room.

*Cables from the PV arrays are laid into the charge room and connected to breakers.

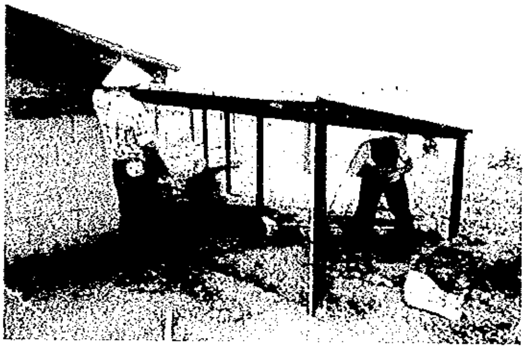


Figure 5-4-8 Installation of equipment

(3) Check and inspection

The study team and the MIH engineers oversaw the installation work to check the progress of installation and find problems early. Also, the study team, the MIH engineers, and the subcontractor inspected all the PV systems after installation.

Table 5-4-4 Check and inspection points (SHS)

Item	Check	Inspection
PV array	*Installation position *Direction and tilted angle *Capacity	*Visual inspection (Dirt, broken etc.) *Characteristic measurement (Voltage and Current)
Controller	*Installation position *State of connection *State of installation	*Confirmation of operation and display
Fluorescent lamp		*Confirmation of lighting
Switch		*Confirmation of function
Wall outlet		*Confirmation of voltage
Breaker		*Confirmation of switch on and off
Battery	*State of installation *Level of battery liquid	*Confirmation of connection
Wiring	*Route of wiring	*Visual inspection

Table 5-4-5 Check and inspection points (BCS)

Item	Construction check	Inspection
PV array	*Installation position *Direction and tilted angle *State of installation	*Visual inspection (Dirt, broken etc.)
Controller	*Installation position *State of connection *State of installation	*Confirmation of operation and display
Breaker		* Confirmation of switch on and off
Box	*Installation position *State of installation	* Visual inspection
Charging room and Fence	*State of installation *Level of battery liquid	* Visual inspection
Wiring	*Route of wiring	*Visual inspection

(4) Monitoring of installation work

1) Installation work

*Each worker is assigned a standardized job to speed up the learning process.

*In the first round of installation, the installation work was slow because of "the wrong direction of PV array," "insufficient battery liquid," and "loose installation of indoor equipment".

*In the second round, speed and quality of installation was improved owing to the previous experience and advice from the JICA team.

2) Transportation

*In the first round, it was difficult to transport materials in a timely manner, and installation was sometimes suspended due to lack of materials.

*In the transportation to Donsayoudom and Houaypong by boat, prior arrangements were not good and caused shortage and surplus of materials.

*The situation was improved in the second round.

(5) Record of installation work

The study team recorded the installation work in the first round and handed the record over to the counterpart during the fourth survey in Laos. We also prepared a list of major equipment installed in each village.

5-5 Technical Training and Education

5-5-1 Workshop

Workshops on installation of PV system were held as shown in Table 5-5-1. The first half of these workshops was a lecture and the second half was a practical training. In the practical training, participants tried installation of equipment and wiring.

Table 5-5-1 Workshops on PV system

Target	Date	Place	Participants	Contents
Central Engineer	May 24	Vientiane (HPO)	HPO 5 EDL 3 STENO 3	*Various PV systems *Outline of SHS and BCS *Management of installation and maintenance
Local Engineer (Vientiane Province)	May 26	Nam Ngum (Hotel)	EDL Local office 2 Donsayoudom 5 Nongpen 5 Houaypong 5 Mai 5	*Outline of SHS and BCS *Management of installation and maintenance *Training on installation

Figure 5-5-1 Workshop (Nam Ngum)

5-5-2 On-site training

The study team gave training on maintenance management methods for SHS and BCS to local engineers on site, and we distributed a maintenance management manual to users to educate them for proper operation method of SHS. At the four pilot villages in Vientiane province, on the basis of results of the monitoring survey, the study team trained the VEC again in October 1999.

5-5-3 Maintenance and management manual

We made a maintenance and management manual covering the following items for SHS and BCS, and these manuals were distributed after translated into Lao.

*Start and stop method

*Meaning of indication lamps of controller

*Simple maintenance and inspection method

5-6 Data Monitoring System

5-6-1 Insolation monitoring system

The study team installed an insolation monitoring system on the top of MIH building in June 1999.

Table 5-6-1 Insolation data

Month		Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
No. of days		23	31	31	30	31	30	31
Daily	**Ave.**	**4.47**	**4.58**	**3.82**	**3.87**	**4.44**	**4.08**	**3.75**
Insolation	Max.	6.76	6.05	6.20	6.32	6.29	5.04	4.78
[kWh/m²/day]	Min.	2.73	1.68	2.15	1.52	1.78	2.50	1.24

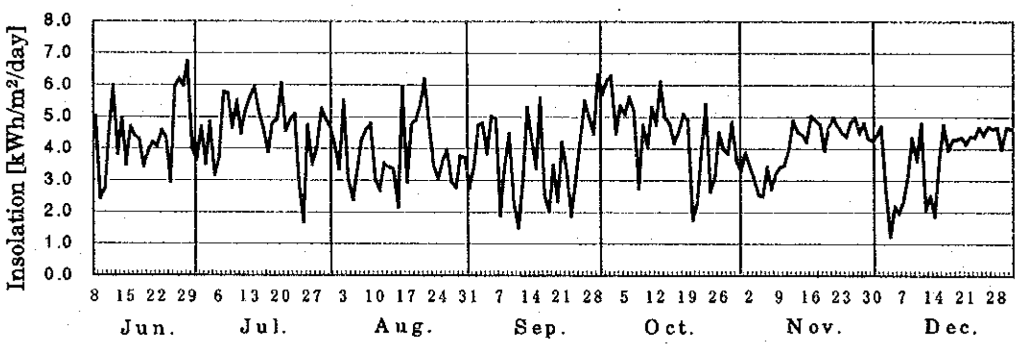


Figure 5-6-1 Fluctuation of daily insolation (June~December 1999)

The insolation in August, September and December 1999 was below 4.0[kWh/m²/day], because the rainfall in 1999 was more than average. But days with no sunshine were not detected during this measuring period, and low insolation days did not last more than several days. The estimated insolation from the sunshine hour data was used to design the pilot system. However, the measured insolation was smaller than the estimated insolation, because sunshine hours in 1999 were shorter than average.

5-6-2 Operation monitoring system

Regarding the operating conditions at one household that is monitored in Mai, it was found that one 8W fluorescent lamp was used from 6PM to 7AM everyday. (See Figure 5-6-2, Table 5-6-2) There was little insolation on the first day of monitoring because it rained, and the battery voltage decreased to 11.6V by using an electrical appliance at night. But on the second day the weather was getting better and charging battery was going well. Then in the afternoon of the third day a battery became full charge, and "trickle charging" started.

(Utilization Factor)
The utilization factor was fluctuating between 50% and 80%. These values include the losses caused by the PV array and the controller. The utilization factor showed 78.9% on the seventh day, when no charge control was performed. Hence, about 20% loss is caused by the PV array.

(Charge and Discharge Power)
This battery was judged to be full charge according to the battery voltage on the third day, but the charge power exceeded the discharge power after that. This suggests that another battery was charged by this solar system.

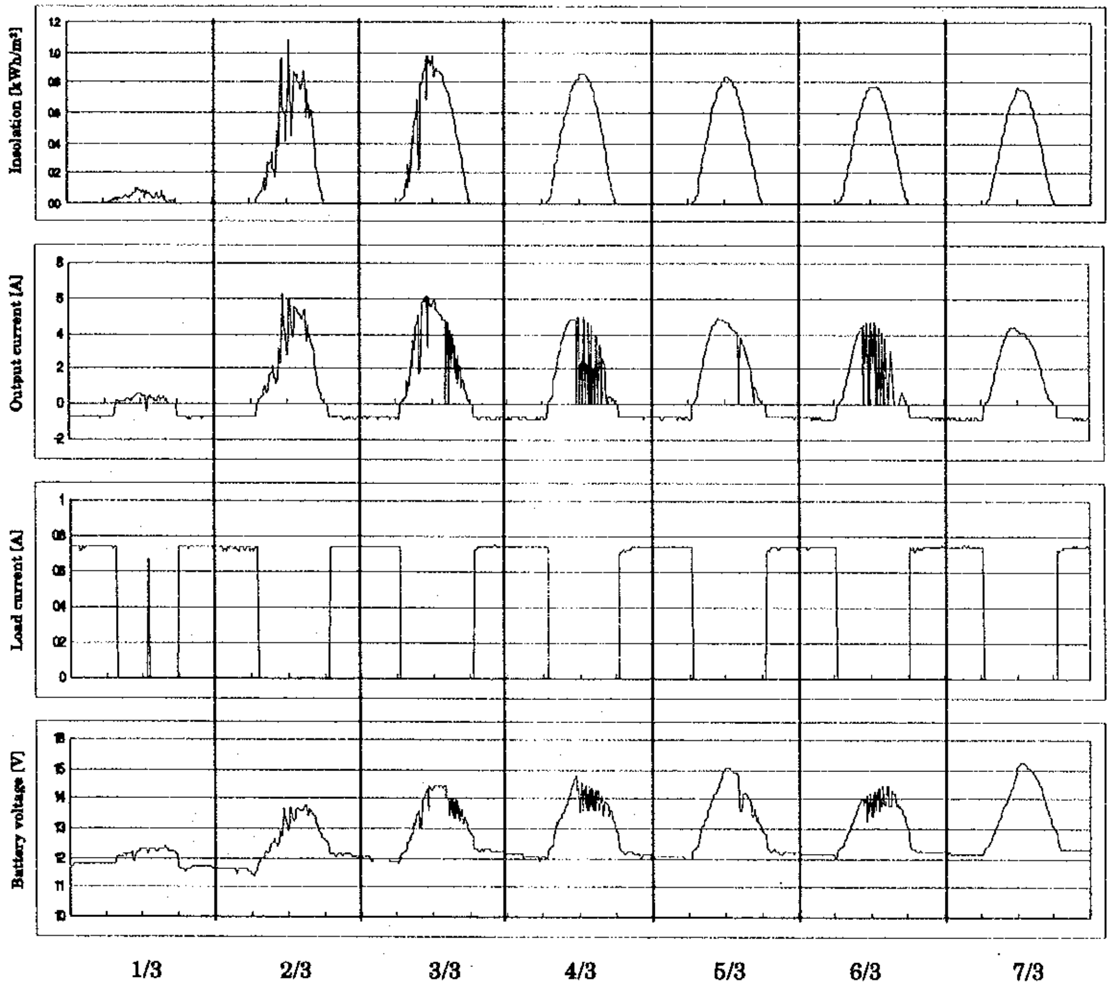


Figure 5-6-2 Operation of 110W SHS at a household in Mai (1/Mar.~7/Mar./00)

Table 5-6-2 Charge and discharge power

Item		Day 1	2	3	4	5	6	7	Notes
Insolation	[kWh/m²]	0.51	4.97	6.09	5.78	5.60	5.21	4.99	A
Charge power	[Wh]	33.2	417.7	497.2	334.6	469.5	284.4	432.9	B
Discharge power	[Wh]	121.8	110.0	110.1	113.1	108.5	111.0	108.7	C
Generated power (estimation)	[Wh]	56.1	546.7	669.9	635.8	616.0	573.1	548.9	D=A*110
Utilization factor	[%]	59.2	76.4	74.2	52.6	76.2	49.6	78.9	E=B/D*100

5-7 Monitoring Survey

The study team and the MIH engineers performed a monitoring survey on the operation and maintenance of PV systems two times. Also we held a meeting at each SHS pilot village one year after the installation to collected opinions regarding PV systems. Based on the survey results, the study team improved PV systems and trained the VEC again.

5-7-1 Items for monitoring survey

The monitoring surveys were executed interviewing the VEC and PV system users , and inspecting the installed solar systems at each village.

Table 5-7-1 Items for monitoring survey

System	SHS			BCS
Objector	Committee	User of SHS		Manager
Method	Interview	Interview	Inspection	Interview
Item	1.State of maintenance 1)Items 2)Frequency 2.Corresponse to problems 3.Storage of spare parts 4.Weather conditions 1)Rain 2)Lightning 3)Wind	1.State of operation 1)Faults and problems 2)System stoppage 2.Load condition 1)Type and capacity 2)Usage pattern 3.State of battery water 4.Questions about SHS	1.PV array 1)Open circuit voltage 2)Current 3)Temperature of PV module 2.Battery 1)State voltage 2)Temperature of Battery liquid 3)Specific gravity 4)Level of battery liquid 3.Visual inspection 1)Installation state 2)Damage and trouble 3)Connection state	1.Managemant system 1)Manager 2)Management method 3)Maintenance 4)Charging fee 5)Record of charging 6)Money collection 7)Management 2.State of operation 1)Using state 2)User 3)Type of battery 4) Fault and problems

5-7-2 Results of monitoring survey on SHS

(1) Electrification committee

1) Houaypong, Mai, and Nongpen

*The committee had carried out maintenance frequently and kept records of problems and when water was replenished.

*The committee had taken appropriate measures if a fault or problem occurred such as replacing fluorescent tubes and fuses.

2) Donsayoudom

*The records for problems and replenishing water were inadequate.

*Fluorescent tubes and fuses were not replaced in some systems.

*Maintenance seemed not to be executed sufficiently. So we required the committee to keep maintenance records and respond to problems.

Table 5-7-2 Results of interview survey with electrification committee

Survey item	Donsayoudom	Houaypong	Mai	Nongpen
Maintenance - Frequency	Once a month	Once a week	Once a month	Twice a week
- Items	Visual inspection Check of battery liquid Check of lamp and SW	Visual inspection Check of battery liquid Check of lamp and SW	Visual inspection Check of battery liquid Check of lamp and SW	Visual inspection Cleaning of PV module Check of battery liquid Check of lamp and SW
Response to problems	User responds	Committee responds	Committee responds	Committee responds
Storage of spare parts	Committee stores spare parts	Committee stores spare parts	Lamp is stored in each house	Committee stores spare parts
Weather conditions - Rain	More than average year	Too much It continued for 4 days.	-	More than average year
- Lightning	No damage	It struck a tall tree once	-	No damage
- Wind	Not strong	Not strong	-	Not strong

(2) Households with SHS

The interview survey was executed for almost all of the households with SHS, covering operation and maintenance of system and usage of electrical appliances. The study team checked each solar system and maintenance with the counterpart.

Table 5-7-3 Results of monitoring survey

Number of households	Village	Donsayoudom		Houaypong		Mai	Nongpen	
	Survey	1st	2nd	1st	2nd	2nd	1st	2nd
-installed SHS		85	103	29	39	68	38	44
-monitored		84	100	28	38	65	38	43
-faults or troubles occurred		17	58	2	11	4	6	7
-system was stopped		0	2	1	0	0	1	0
-lamp became black		19	31	8	15	23	11	18
-have electric appliances other than 8w lamp		70	82	23	25	31	27	33
-filled water into battery		4	37	12	19	15	26	13

1) Operating of SHS

After seven months of SHS operation, some faults and problems were reported.

Table 5-7-4 Faults and problems

Contents of faults and problems	Donsayoudom		Houaypong		Nongpen		Mai
	1st	2nd	1st	2nd	1st	2nd	2nd
Ballast was broken	5	3	1		1		
Output cable of ballast was cut			1				
Lamp made noise				1			
Lamp did not work	7	29	4	15	2	9	4
Fuse in breaker blew	4	4	1	2		2	
Display of controller was wrong	1						
A part of switch case was melted			1				

During the first monitoring survey, there were many faults and problems related to fluorescent lamps. It was thought that there was a relationship between the fluorescent lamps not working and the blacked lamp edge. The study teamed found that some switches had faults, loose contact for example, and caused the blackening of lamps. Therefore, we requested the subcontractor to change faulty switches.

During the second monitoring survey, it was found that some light ballasts (circuit board) were manufactured in low quality and caused this problem. So we collected faulty ballasts and sent back to the manufacturer to study them.

Except for the fluorescent lamps, no major faults were found. Only five systems experienced system stoppage, and 55W SHS was functioning very well as expected.

2) Usage of electrical appliances

We studied the number and usage pattern of electrical appliances.

Table 5-7-5 Electrical appliances

	Village name	Surveyed System	TV B/W	TV Color	Midget 5W	Lamp 10W	Lamp 20W	Radio Cassette	Speaker	Fan	Video
1st	Donsayoudom	84	51	0	0	15	11	38	11	1	0
1st	Houaypong	28	9	1	1	2	18	18	7	0	1
1st	Nongpen	38	16	0	0	1	15	13	1	0	0
1st	Total	150	76	1	1	18	44	69	19	1	1
2nd	Donsayoudom	100	67	0	0	13	12	43	11	1	0
2nd	Houaypong	38	11	1	1	1	17	20	8	0	1
2nd	Nongpen	43	19	0	0	1	17	16	1	0	0
2nd	Mai	65	29	0	0	0	0	5	0	0	0
2nd	Total	246	60	1	1	15	46	84	20	1	1

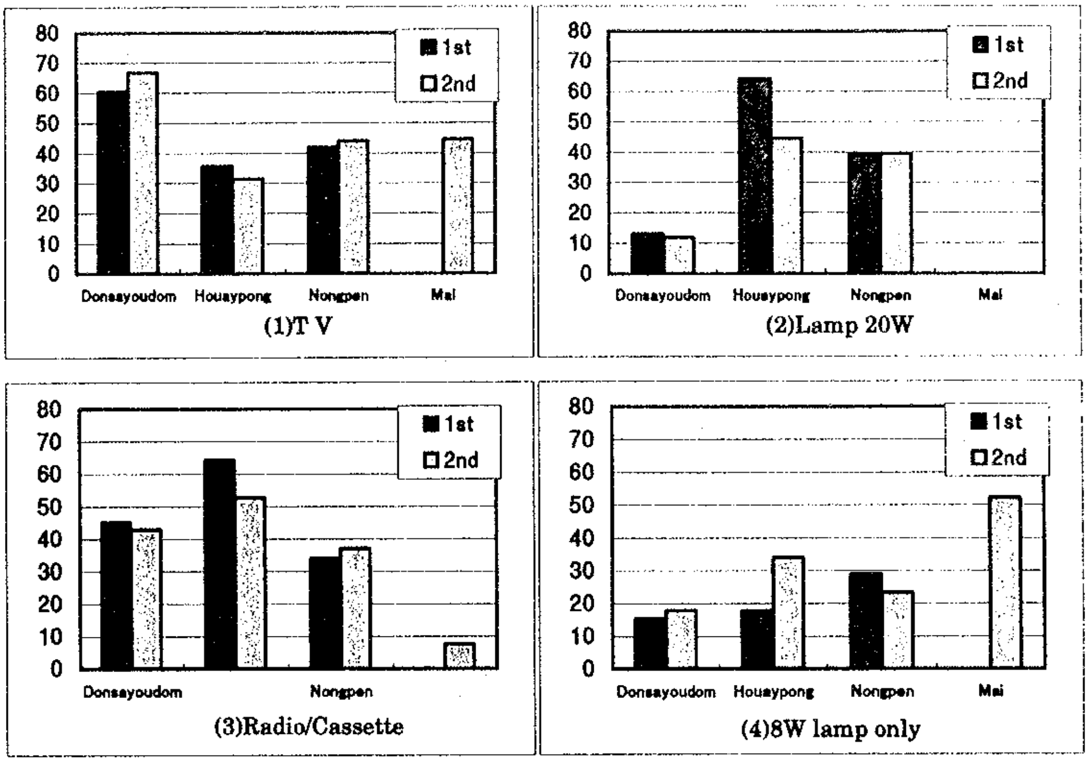
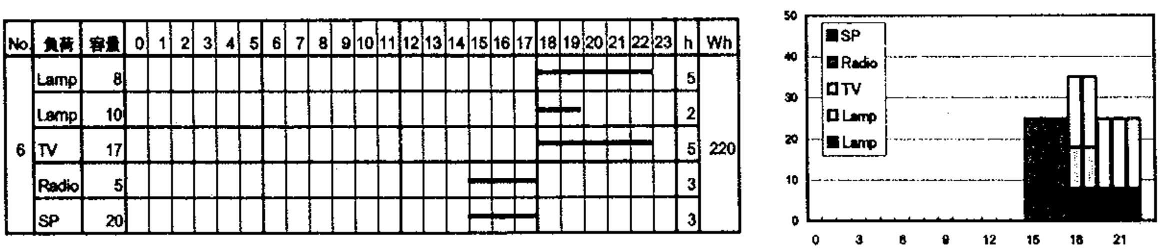


Figure 5-7-1 Number of electrical appliances

The major appliances used with SHS are TV, 20W fluorescent lamp, radio and cassette player. The ownership rate of them is over 30%. The usage pattern of appliances of each house was studied based on a research sheet shown in Figure 5-7-2(1), and an example is shown in Figure 5-7-2(2). Radios were mainly used in the daytime, and lamps and TV were used at night. There were many households that turn off lights before sleeping, but some households kept lights on until morning.



(1)Research sheet (2)Example of usage pattern

Figure 5-7-2 Usage pattern of appliances

The distribution of daily electricity consumption in each village is shown in Figure 5-7-3. The original estimation of power consumption was at 121.6Wh per day. In the second survey, the proportion of 55W SHS users increased, which led to the smaller average power consumption.

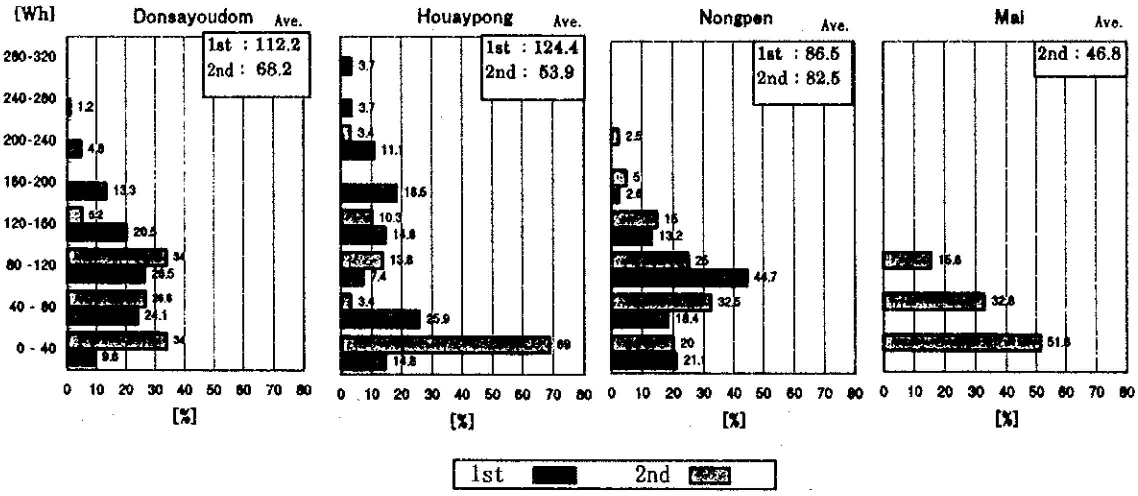


Figure 5-7-3 Distribution of electricity consumption

3) Battery water

A liquid type battery should be filled with distilled water periodically, because the water in battery evaporates during charging and overcharging. If a battery is left without replenishing water, it would be damaged and its life would become shorter. It is estimated that the appropriate interval of replenishing water is six to 12 months, but there may be a case in which the interval was shorter if charge control is not functioning well. At present, the VEC recommend the users to fill water when the water level goes down from the standard level. The users seem to follow this instruction. (See Table 5-7-6) They can buy a bottle of distilled water in the market for 1,500 kip.

Table 5-7-6 Record of filling water

Village name	1st survey						2nd survey					
	Surveyed households	Jun	Jul	Aug	Sep	At survey	Surveyed households	Oct	Nov	Dec	Jan	Feb
Donsayoudom	84	2	0	0	0	2	100	0	1	9	15	13
Houaypong	28	4	0	3	3	4	34	1	5	6	8	6
Nongpen	38	0	23	1	6	3	44	15 1)				
Mai							67		1		5	9

1)Date of replenishing water was not clear.

4) Precautions for system usage

The study team required users to improve system usage at the first survey. They connected electrical loads to battery directly in many cases, which was common before the installation of solar systems. In some cases of changing a fuse, the VEC gave wrong instructions. Based on these cases, we explained why those measures were unsuitable and requested improvement.

Table 5-7-7 Examples of incorrect system usage

Examples of incorrect system usage	Donsayoudom	Houaypong	Nongpen
Electrical appliance was connected with battery directly.	16	3	0
Battery was connected with another battery directly.	1	2	0
When replenishing water, electrolyte was used instead of distilled water.	1	1	0
After a fuse blew, copper wire was used instead of fuse.	3	0	0
Another battery was charged using a 55W system.	0	1	0

5) Conclusion

We proposed two types of SHS: 55W and 110W. At present, it can be said that both systems are used well. There are few examples of system stoppages. With a 55W SHS, a TV, a radio, and a 20W lamp or 8W lamp can be used. A 110W SHS has a function to charge another battery and this function is being used well. For example, battery-charging shops appeared in Nongpen.

5-7-3 Results of monitoring survey on BCS

The results of an interview survey on the BCS management are shown in Table 5-7-8.

Table 5-7-8 Results of interview survey on BCS management

Interview item	Donsayoudom	Namai	Paksoun
Member	Head 1, Cashier 1, Engineer 2 (Total 4)	Engineer 3 (Total 3)	Cashier 1, Engineer 4, Key 1 (Total 6)
Management method	One person manages one BCS for one month.	One engineer manages BCS.	Two engineers manage BCS. (in two shifts)
Maintenance	One time a week *Cleaning of PV array *Cleaning of clips	One time two days *Cleaning of PV array *Cleaning of clips	Every day *Cleaning of PV array *Cleaning of clips
Charging record	Cashier keeps record.	Engineer keeps record.	Cashier keeps record.
Charging state	3 to 4 batteries are charged on average.	8 to 10 batteries are charged on average.	15 to 18 batteries are charged on average.
User	Mainly in the village Coming from five neighboring villages. (Phak etc.)	Mainly in the village	70 members in the village Coming from neighboring villages.
Battery	6V 12V-50Ah, 70Ah, 120Ah	6V 12V-50Ah, 70Ah, 120Ah	6V 12V-50Ah, 70Ah, 120Ah
Fault and problem	None	None	None

(Paksoun)

*This BCS has some 70 members who can charge a battery once every four or five days.

*Faults and problems of the system have not been reported.

*Batteries are charged and discharged at correct intervals.

(Donsayoudom and Namai)

*These BCS have no membership and charge batteries on a first-come first-served basis.

*The number of users fluctuates and the utilization factor of BCS is relatively low.

* Faults and problems of the system have not been reported.

(Reference; Samll BCS in Houaypong village)

The small (165W) BCS installed in Houaypong operated well at first, the number of customers,however, gradually decreased because it could not charge batteries full several weeks later. There found no problem with the system when we inspected. One reason for the inadequate charging was that a clip to connect a battery was rusted. Also the batteries brought to the BCS were mostly old, so they were needed to charge at higher voltage than a new one. So we gave instructions to the owner regarding the method of maintenance and operation, and also we reset voltage values of the controller for charging old batteries. As a result, batteries have been charged well since then.

Chapter 6

Economic Analysis/Financial Management

6-1 Cost Analysis

6-1-1 Forecast of Module Production Cost

Global PV module shipments increased from 46.5MW in 1990 to 201.5MW in 1999. (See Table 6-1-1) The average production cost of PV modules decreased from $5.5/Wp in 1990 to $4.25/Wp in 1993. After that, average production costs in 1996 and 1997 remained almost flat: $4.15/Wp and $4.25/Wp respectively. However, the minimum production cost has shown a steady decline every year: $4.0/Wp in 1990, $3.5/Wp in 1993, $3.0/Wp in 1996, and $2.75/Wp in 1997. The gap between the average costs and the minimum costs is attributed to the difference in order quantity or module specifications.

Table 6-1-1 Trend of global PV module production

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production (MW)	46.5	55.3	57.9	60.1	69.4	77.6	88.6	125.8	153.2	201.5
Growth rate (%)	15.7	18.9	4.7	3.8	15.5	11.8	14.2	42.0	21.8	31.5

On the other hand, demand for PV modules in the future will expand due to lower production costs and growing concern over global environmental issues (reduction of CO_2 emissions). According to a forecast report in the United States, global demand for PV modules is expected to expand to 640MW in 2005 and 1,920MW in 2010 with an annual growth rate of 23%. Actual shipments of PV modules after 1997 have shown a remarkable growth rate of 31.5% per year.

Global PV module production in 1999 reached 201.5MW, out of which 163.8MW (80% of total) was produced by eight big companies (See Table 6-1-2). The growth of future demand will encourage new manufacturers to enter the market and accelerate competition and cost reduction.

Some study reports and research laboratories forecasted the future production cost of PV modules. According to a World Bank report -- Renewable Energy Technologies, A Review of the Status and Costs of Selected Technologies -- the production cost of PV modules will fall from $2.3/Wp in 2000 to $1.7/Wp in 2010. An ADB (Asian

Development Bank) report -- Solar Photovoltaic Power Generation using PV Technology -- states that module cost will decrease from $3.2/Wp in 2000 to $2.7/Wp in 2005. Photovoltaic Energy Systems, Inc.(USA) is forecasting that the cost will go down from $2.5/Wp in 2000 to $2.0/Wp in 2005, and $1.75/Wp in 2010. Moreover, the module cost target set by the Department of Energy (DOE) of the United States is $1.7/Wp in 2004. DOE's ambitious production cost forecast is at $0.5/Wp in 2010. Figure 6-1-1 shows a summary of these forecasts.

Table 6-1-2 Eight leading companies of module manufacturing

No	Company	Country	Production (MW)			
			1996	1997	1998	1999
1	BP Solarex	GER, US, AUS	19.3	26.1	29.3	32.5
2	Kyocera	JPN	9.1	15.4	24.5	30.3
3	Sharp	JPN	5.0	10.6	14.0	30.0
4	Siemens Solar	US	17.0	24.0	20.0	26.0
5	Sanyo	JPN	4.6	4.7	6.5	13.0
6	Astropower	US	2.9	4.3	7.2	12.0
7	Photowatt	FRN	2.6	5.7	12.0	10.0
8	ASE	US, GER	3.0	6.0	7.0	10.0
Total			63.5	96.8	120.5	163.8

(Note) GER: Germany, US: United States, AUS: Australia, JPN: Japan, FRN: France
(Source) Solar System, No.80

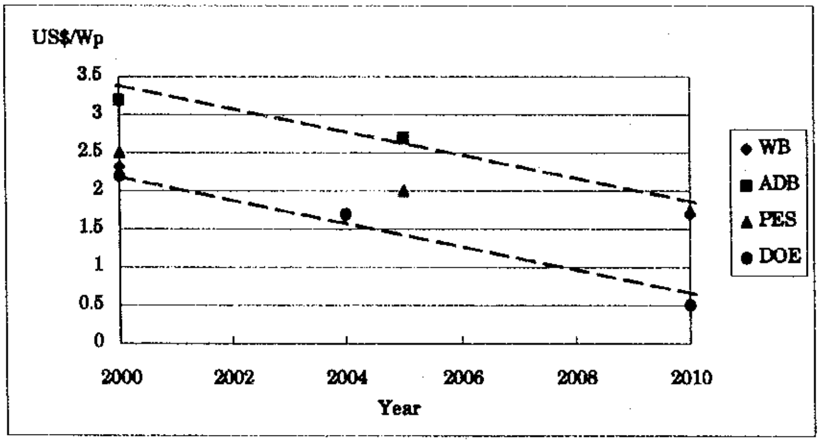


Figure 6-1-1 Forecast of PV module production cost

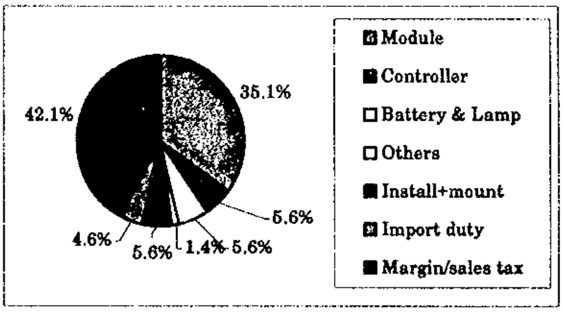
Figure 6-1-1 suggests that the difference between the high and low estimates for PV module production cost is around $1.0. In this study, we assumed that the module production cost would reach $2.0/Wp in 2005, which lies between the high and low cases. Considering marketing and distribution costs, we assumed that the real market price of a PV module in 2005 would be $3.0/Wp. The declining PV module price significantly contributes to the reduction of total system costs because the module accounts for about half of total system cost.

6-1-2 Cost Structure of PV System

Solar Home System (SHS) has already been sold in Laos. The market price of a typical 50W-class SHS is about $700. Table 6-1-3 shows an estimated cost breakdown of 50W-SHS. The import duty on solar equipment in Laos is 10%.

Table 6-1-3 Cost structure of 50W-SHS

Components	Cost $	
Module	250	35.1%
Controller	40	5.6%
Battery & Lamp	40	5.6%
Others	10	1.4%
Install+mount	40	5.6%
Import duty	33	4.6%
Margin/sales tax	300	42.1%
Total	713	



Major components are: PV module(s), a standard automotive battery, an electronic controller and fluorescent lamp(s). An automotive battery rather than a special PV battery is used because of its affordable price and availability. Fluorescent lamps with high efficiency are specially designed for solar systems.

In Table 6-1-3, as already mentioned, the SHS price includes import duties, sales tax, and profit margin. Nevertheless, when the Lao government procures the system components, sales tax and profit margin can be ignored. Moreover, according to the Customs Department of Laos, the import duties can be exempted for PV system components as long as they are imported by the government.

In conclusion, the prices of typical SHS (50W) and BCS (1.8kW) in the future (year 2005) will decrease to $270 and $6,500, respectively, owing to lowered costs and import duty exemption (See Table 6-1-4~5). In this study, we used $300 for 50W-SHS and $7,000 for 1.8kW-BCS, considering contingent expenses.

System Cost in the Future

Table 6-1-4 Cost structure forecast of 50W-SHS in 2005

Components	Cost $	
Module	150	55.6%
Controller	35	13.0%
Battery & Lamp	35	13.0%
Others	10	3.7%
Install+mount	40	14.8%
Import duty	0	0.0%
Margin/sales tax	0	0.0%
Total	270	

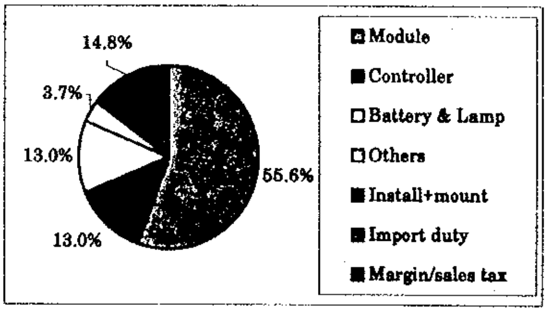
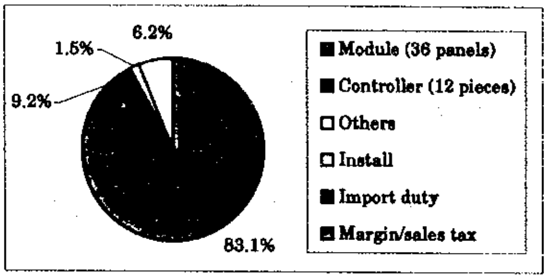


Table 6-1-5 Cost structure forecast of 1.8kW-BCS in 2005

Components	Cost $	
Module (36 panels)	5,400	83.1%
Controller (12 pieces)	600	9.2%
Others	100	1.5%
Install	400	6.2%
Import duty	0	0.0%
Margin/sales tax	0	0.0%
Total	6,500	



Assumptions of System Costs in the Future (2005)
- 50W-SHS : $300
- 1.8kW-BCS : $7,000

6-1-3 Tariff of PV System

We calculated the monthly fee for SHS and BCS assuming 50 units of 50W-SHS and one 1.8kW-BCS are installed in a typical village.

(1) Solar Home System (SHS)

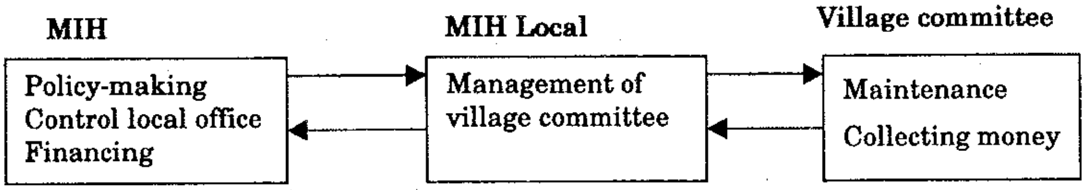
Assumption of 50W-SHS

Calculation period	20 years
Discount rate	0.75%
Capacity of SHS	50W
Electric appliances	One fluorescent lamp & B/W TV
System cost (future price)	$300
Life of PV module	20 years
Life of controller	10 years

To install one SHS, an initial investment of $300 is necessary. In addition, some overhead expenses for system management and maintenance are also required.

Overhead expenses

To manage Solar Home Systems in a village, it is necessary to organize a management unit. Expenses for the management unit in the future are assumed to be as follows.



Salary of village committee

The village electrification committee consists of three persons and their salary is $1.33(10,000kip)/ month-person.

$1.33/month-person $\times$ 3 persons $\times$ 12 months/year = $48/year

Expenses for MIH local office

MIH local office needs a budget for administration. Considering transportation cost (motor bike fuel) and other administrative costs, the following expenses are estimated.

Fuel expense	5 liters/trip $\times$ $0.40/liter $\times$ 6 times/year = $12/year
Administrative expenses	$2.67/month $\times$ 12 months/year = $32/year

Spare Parts Expense

In only the first year, one module and two sets of system components except batteries are prepared as spare parts ($270).

Annual Maintenance Expense

Generally, it is said that a solar system is maintenance free. Problems to be considered in the future are corrosion of the cable connection and other small troubles. So, we assumed the annual maintenance expense would gradually go up as follows.

1 – 5 years	0
6 – 10 years	$0.4/system-year $\times$ 50 systems = $20/year
11 – 15 years	$0.8/system-year $\times$ 50 systems = $40/year
16 – 20 years	$1.2/system-year $\times$ 50 systems = $60/year

Replacement of Charge Controller

The life of the charge controller is assumed to be 10 years. The price of the charge controller is $35.

$35/unit×50 units = $1,750

The initial charge is set to be $20. Based on the above assumptions, the monthly charge was calculated so that the net present value (NPV) of 20 year cash-flow becomes zero with a discount rate of 0.75%(See Table 6-1-6). In these calculations, 0.75% soft loans, such as from Japan Bank for International Cooperation (JBIC), World Bank, and Asian Development Bank are assumed.

Table 6-1-6 Cash flow of 50W-SHS for 20 years (50households)

(Unit: US$)

Item \ Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial Investment Cost	15,000																			
Spare Parts	270																			
Salaries for VEC	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Expenses for Local Office	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Maintenance Cost	0	0	0	0	0	20	20	20	20	20	40	40	40	40	40	60	60	60	60	60
Controller Replacement											1,750									
Total Cash Out	**15,362**	**92**	**92**	**92**	**92**	**112**	**112**	**112**	**112**	**112**	**1,882**	**132**	**132**	**132**	**132**	**152**	**152**	**152**	**152**	**152**
Down-payment	1,000																			
Yearly fee	973	973	973	973	973	973	973	973	973	973	973	973	973	973	973	973	973	973	973	973
Total Cash In	**1,973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**	**973**
Net Cash Flow	-13,389	**881**	**881**	**881**	**881**	**861**	**861**	**861**	**861**	**861**	-909	**841**	**841**	**841**	**841**	**821**	**821**	**821**	**821**	821

Down-payment :	US$20.00
Monthly Charge :	US$1.62

Discount rate	0.75%
NPV at 0.75% of DR	-0

Table 6-1-7 Cash flow of 50W-SHS for 10 years (50housuholds)

(Unit: US$)

Item \ Year	1	2	3	4	5	6	7	8	9	10
Initial Investment Cost	15,000									
Spare Parts	270									
Salaries for VEC	48	48	48	48	48	48	48	48	48	48
Expenses for Local Office	44	44	44	44	44	44	44	44	44	44
Maintenance Cost	0	0	0	0	0	20	20	20	20	20
Total Cash Out	**15,362**	**92**	**92**	**92**	**92**	**112**	**112**	**112**	**112**	**112**
Down-payment	1,000									
Yearly fee	1,577	1,577	1,577	1,577	1,577	1,577	1,577	1,577	1,577	1,577
Total Cash In	**2,577**	**1,577**	**1,577**	**1,577**	**1,577**	**1,577**	**1,577**	**1,577**	**1,577**	**1,577**
Net Cash Flow	-12,785	**1,485**	**1,485**	**1,485**	**1,485**	**1,465**	**1,465**	**1,465**	**1,465**	**1,465**

Down-payment :	US$20.00
Monthly Charge :	US$2.63

Discount rate	0.75%
NPV at 0.75% of DR	-0

Table 6-1-8 Cash flow of 50W-SHS for 5 years (50households)

(Unit: US$)

Item \ Year	1	2	3	4	5
Initial Investment Cost	15,000				
Spare Parts	270				
Salaries for VEC	48	48	48	48	48
Expenses for Local Office	44	44	44	44	44
Total Cash Out	**15,362**	**92**	**92**	**92**	**92**
Down-payment	1,000				
Yearly fee	2,989	2,989	2,989	2,989	2,989
Total Cash In	**3,989**	**2,989**	**2,989**	**2,989**	**2,989**
Net Cash Flow	-11,373	**2,897**	**2,897**	**2,897**	**2,897**

Down-payment :	US$20.00
Monthly Charge :	US$4.98

Discount rate	0.75%
NPV at 0.75% of DR	-0

Table 6-1-6 shows the result of cash-flow analysis over 20 years. In this case, the monthly charge is calculated to be $1.62. Tables 6-1-7 and 6-1-8 show cash-flow for 10 and 5 years, and the monthly fees go up to $2.63 and $4.98 respectively.

Table 6-1-9 Recommended tariff of 50W-SHS

		Exchange rate 6,000kip/$	Exchange rate 7,500kip/$	Exchange rate 9,000kip/$
Down-payment	$20	120,000kip	150,000kip	180,000kip
Monthly fee (20 years leasing)	$1.62	9,720kip	12,150kip	14,580kip
Monthly fee (10 years leasing)	$2.63	15,780kip	19,725kip	23,670kip
Monthly fee (5 years leasing)	$4.98	29,880kip	37,350kip	44,820kip

The reason why the down-payment is set at $20 is that the price of a battery in the market is $20-25. If a person who cannot pay the down-payment of $20 had a system, he would not replace the battery and could not sustain the system. In case of high income households, a shorter leasing period might be offered.

(2) Battery Charge Station (BCS)

In the case of BCS, we calculated an internal rate of return (IRR) for a 1.8kW-BCS assuming a commercial battery charging station.

Given a commercial setting, the battery charge fee is set at $0.27(2,000kip) /charge. People in a remote area far from the grid charge batteries using diesel generators. Generally, the charging price is around 2,000 to 2,500kip/charge. We think that 2,000kip is a reasonable price for rural areas. A 1.8kW-BCS has 12 charge controllers and can charge 360 batteries every month. However, we assumed that the utilization ratio of the BCS will be 80% (288 batteries every month) in consideration of cloudy or rainy days. Assumptions for 1.8kW-BCS are as follows.

Assumptions for 1.8kW-BCS

Calculation period	20 years	
Discount rate	0.75%	
Capacity of BCS	1.8 kW	
System cost (future price)	$7,000	
Life of PV module	20 years	
Life of charge controller	10 years,	$50 per unit

Overhead Expenses

Salary for Operator

The BCS needs an operator who connects batteries in the morning and charges fees at disconnecting in the afternoon. This is not a full-time job. Therefore, we assumed that his salary is $6.67(50,000kip)/month.

$6.67/month × 12 months/year = $80/year

Spare Parts Expense

One module and one controller are prepared as spare parts. ($200)

Annual Maintenance Expense

Like SHS, we assumed that annual maintenance expenses would go up as follows.

1 – 5 years	0
6 – 10 years	$10/year
11 – 15 years	$15/year
16 – 20 years	$20/year

Table 6-1-10 shows that the IRR for a 1.8kW-BCS with a charging fee of $0.27 (2,000kip)/charge becomes 11.2%, which indicates that a good possibility of becoming a commercial venture if its owner can secure a low interest loan.

Next we calculated the monthly leasing charge when the government leases a BCS to the village committee. We did not consider collecting a down payment because the committee would not have any seed money before start-up. In the case of a leasing service, the administrative expenses ($44 per year) of the local government office need to be covered by the monthly charge.

Table 6-1-11 shows the cash flow of a 1.8kW-BCS for 20 years. The monthly leasing charge was calculated so that the net present value (NPV) for 20 years becomes zero with a low interest rate of 0.75%. In this case, the monthly leasing charge becomes $45.91. Tables 6-1-12 and 6-1-13 show cash flow for 10- and 5-year calculation periods. For the 10- and 5-year periods, the monthly leasing charges jump up to $72.78 and $132.13 respectively.

Table 6-1-10 Cash flow and IRR for 1.8kW-BCS(Charge fee=$0.27)

(Unit: US$)

Item / Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial Investment Cost	7,000																			
Spare Parts	200																			
Operator Salary	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Maintenance Cost	0	0	0	0	0	10	10	10	10	10	15	15	15	15	15	20	20	20	20	20
Controller Replacement											600									
Total Cash Out	7,280	80	80	80	80	90	90	90	90	90	695	95	95	95	95	100	100	100	100	100
Annual income	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933
Total Cash In	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933	933
Net Cash Flow	-6,347	853	853	853	853	843	843	843	843	843	238	838	838	838	838	833	833	833	833	833
Battery Charge Fee/charge	US$0.27 (2,000kip/charge)																			
Internal Rate of Return	11.2%																			

Table 6-1-11 Cash flow for 1.8kW-BCS for 20 years

(Unit: US$)

Item / Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial Investment Cost	7,000																			
Spare Parts	200																			
Operator Salary	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Expenses for Local Office	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Maintenance Cost	0	0	0	0	0	10	10	10	10	10	15	15	15	15	15	20	20	20	20	20
Controller Replacement											600									
Total Cash Out	7,324	124	124	124	124	134	134	134	134	134	739	139	139	139	139	144	144	144	144	144
Annual income	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551
Total Cash In	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551	551
Net Cash Flow	-6,773	427	427	427	427	417	417	417	417	417	-188	412	412	412	412	407	407	407	407	407
Monthly Charge:	US$45.91																			

Discount rate	0.75%
NPV at 0.75% of DR	0

Table 6-1-12 Cash flow for 1.8kW-BCS for 10 years

Item / Year	1	2	3	4	5	6	7	8	9	10
Initial Investment Cost	7,000									
Spare Parts	200									
Operator Salary	80	80	80	80	80	80	80	80	80	80
Expenses for Local Office	44	44	44	44	44	44	44	44	44	44
Maintenance Cost	0	0	0	0	0	10	10	10	10	10
Total Cash Out	7,324	124	124	124	124	134	134	134	134	134
Annual income	873	873	873	873	873	873	873	873	873	873
Total Cash In	873	873	873	873	873	873	873	873	873	873
Net Cash Flow	-6,451	749	749	749	749	739	739	739	739	739
Monthly Charge:	US$72.78									

Discount rate	0.75%
NPV at 0.75% of DR	-0

Table 6-1-13 Cash flow for 1.8kW-BCS for 5 years

Item / Year	1	2	3	4	5
Initial Investment Cost	7,000				
Spare Parts	200				
Operator Salary	80	80	80	80	80
Expenses for Local Office	44	44	44	44	44
Total Cash Out	7,324	124	124	124	124
Annual income	1,586	1,586	1,586	1,586	1,586
Total Cash In	1,586	1,586	1,586	1,586	1,586
Net Cash Flow	-5,738	1,462	1,462	1,462	1,462
Monthly Charge:	US$132.13				

Discount rate	0.75%
NPV at 0.75% of DR	-0

Table 6-1-14 Recommended leasing charge of 1.8kW-BCS

		Exchange rate 6,000kip/$	Exchange rate 7,500kip/$	Exchange rate 9,000kip/$
Monthly fee (20 year leasing)	$45.91	275,460kip	344,325kip	413,190kip
Monthly fee (10 year leasing)	$72.78	436,680kip	545,850kip	655,020kip
Monthly fee (5 year leasing)	$132.13	792,780kip	990,975kip	1,189,170kip

Given the current exchange rate (7,500kip/$ as of June 2000), the monthly leasing charge of the BCS becomes 344,325kip. A 1.8kW-BCS can charge 288 batteries per month if the utilization ratio is 80%. In that case, the leasing cost per charge is about 1,200kip, which is regarded as being quite reasonable. A BCS is better than a SHS if a user charges his battery only once a week, because he will only have to pay around 8,000 to 10,000 kip per month. However, if he wants to charge more often, then his monthly battery charging fee goes up, and he would be better off using an SHS.

6-2 Comparison between PV Systems and Alternative Systems

6-2-1 Life cycle cost comparison

There are some options for village electrification. In this section, we calculated present value of life cycle cost for 20 years of SHS, small hydro, and diesel generator power to electrify a village of 50 households (See Table 6-2-3~5). The discount rate is generic 4%. Table 6-2-1 shows a comparison of life-cycle costs of these systems. The load of one household is assumed to be 80W. The capacity of the diesel generator is assumed to be 5kW although 3.5kW seems good enough, because it is difficult to find a diesel generator under 5kW in the market.

Table 6-2-1 Present Value of electrification costs for 20 years (50HH/village)

Electrification method	50W-SHS	5 kW diesel	3.5kW hydro
Cost per HH ($)	396	617	512

This table shows the costs per household for 20 years at the present value. The figure for a diesel generator becomes $617, and $512 for small hydro. Among the three options, SHS is the cheapest at $396. This indicates that SHS is the most economical in case of small scale electrification. In the long run, diesel generation is expensive despite its low initial investment because fuel costs and maintenance costs are quite high. When village scale increases, from 50 to 100 households for instance, the present cost of the diesel generator and small hydro will decrease. The difference between SHS and small hydro would become negligible. (See Table 6-2-2)

Table 6-2-2 Present Value of electrification costs for 20 years (100HH/village)

Electrification method	50W-SHS	7 kW diesel	7kW hydro
Cost per HH ($)	396	485	416

On the other hand, in the case of a 5 km long grid extension for 50 households, the present cost for 20 years is $1,006. (See Table 6-2-6) In the case of 100 households, however, the cost is $518. Thus, grid extension is not economically feasible unless aggregate demand for electricity of the target village is big enough. A sensitivity analysis was carried out by changing the scale of the village from 30 to 100 households. (See Figure 6-2-1,6-2-2)

Cost Analysis

(1) SHS (Future price)

Assumptions

Calculation period	20 years
Discount rate	4%
Capacity of SHS	50W
System cost	$300
Life of PV module	20 years
Life of battery	3 years
Life of controller	10 years
Annual maintenance cost	1 – 5 years : 0
	6 – 10 years : $0.4
	11 – 15 years : $0.8
	16 – 20 years : $1.2

Table 6-2-3 50W Solar Home System : Life-cycle cost

(Unit : $)

Year	Capital cost	Battery & controller replace	O/M cost	Cost / household
1	300		0.0	300
2			0.0	0
3			0.0	0
4		20.0	0.0	20.0
5			0.0	0
6			0.4	0.4
7		20.0	0.4	20.4
8			0.4	0.4
9			0.4	0.4
10		20.0	0.4	20.4
11		35.0	0.8	35.8
12			0.8	0.8
13		20.0	0.8	20.8
14			0.8	0.8
15			0.8	0.8
16		20.0	1.2	21.2
17			1.2	1.2
18			1.2	1.2
19		20.0	1.2	21.2
20			1.2	1.2
			Total	467
		Net Present Value		396

(2) Diesel Generator

Assumptions

Calculation period	20 years
Discount rate	4%
Load per household	80W
Number of households	50 households
Diversity factor	0.8
Daily operating hours	3 hours (18:00 – 21:00)
Annual load	3,504 kWh/year
Annual output	3,809 kWh/year
Generator Capacity	5 kW (minimum size)
Generator unit cost	$600/kW
Generator efficiency	20%
Generator life	10 years
Installation cost for generator	20% of generator cost
Annual O/M cost	20% of generator cost
Length of distribution line	1 km
Distribution line cost	$5,000/km
Distribution loss	8%
Distribution line life	20 years
Total initial investment	$8,600
Diesel oil price	$0.5/l (including transport & storage costs)
Calorific value of diesel oil	9,200kcal
	0.467l/kWh

Table 6-2-4 5kW Diesel Generator : Life-cycle cost

(Unit : $)

Year	Capital cost	Fuel cost	O/M cost	Total cost	Cost / household
1	8,600	890	600	10,090	201.8
2		890	600	1,490	29.8
3		890	600	1,490	29.8
4		890	600	1,490	29.8
5		890	600	1,490	29.8
6		890	600	1,490	29.8
7		890	600	1,490	29.8
8		890	600	1,490	29.8
9		890	600	1,490	29.8
10		890	600	1,490	29.8
11	3,600	890	600	5,090	101.8
12		890	600	1,490	29.8
13		890	600	1,490	29.8
14		890	600	1,490	29.8
15		890	600	1,490	29.8
16		890	600	1,490	29.8
17		890	600	1,490	29.8
18		890	600	1,490	29.8
19		890	600	1,490	29.8
20		890	600	1,490	29.8
				Total	840
			Present Value		617

(3) Small Hydro (Micro Hydro)

Assumptions

Calculation period	20 years
Discount rate	4%
Load per household	80W
Number of households	50 households
Diversity factor	0.8
Daily usage hours	3 hours (18:00 – 21:00)
Annual load	3,504 kWh/year
Annual output	3,809 kWh/year
Micro hydro capacity	3.5kW
Micro hydro unit cost	$3,700/kW (including civil work)
Turbine & generator life	20 years
Annual O/M cost	2% of plant cost
Length of distribution line	2 km
Distribution line cost	$5,000/km
Distribution loss	8%
Line life	20 years
Total initial investment cost	$22,950

Table 6-2-5 3.5 kW Small (Micro) Hydro : Life-cycle cost

(Unit : $)

Year	Capital cost	O/M cost	Total cost	Cost per household
1	22,950	259	23,209	464.2
2		259	259	5.2
3		259	259	5.2
4		259	259	5.2
5		259	259	5.2
6		259	259	5.2
7		259	259	5.2
8		259	259	5.2
9		259	259	5.2
10		259	259	5.2
11		259	259	5.2
12		259	259	5.2
13		259	259	5.2
14		259	259	5.2
15		259	259	5.2
16		259	259	5.2
17		259	259	5.2
18		259	259	5.2
19		259	259	5.2
20		259	259	5.2
			Total	563
		Present Value		512

(4) Grid Extension

Assumptions

Calculation period	20 years
Discount rate	4%
Load per household	80W
Number of households	50 households
Diversity factor	0.8
Daily usage hours	3 hours (18:00 – 21:00)
Annual load	3,504 kWh/year
Length of transmission line (22kV)	5 km
Transmission line cost	$9,000/km
Length of distribution line	1 km
Distribution line cost	$5,000/km
Line life	20 years
Transformer cost (22kV to 380V)	$850/unit
Total initial investment	$50,850
Electricity cost	$0.03/kWh

Table 6-2-6 5 km Grid Extension : Life-cycle cost

(Unit : $)

Year	Capital cost	Electricity cost	Total cost	Cost per household
1	50,850	105	50,955	1,019.1
2		105	105	2.1
3		105	105	2.1
4		105	105	2.1
5		105	105	2.1
6		105	105	2.1
7		105	105	2.1
8		105	105	2.1
9		105	105	2.1
10		105	105	2.1
11		105	105	2.1
12		105	105	2.1
13		105	105	2.1
14		105	105	2.1
15		105	105	2.1
16		105	105	2.1
17		105	105	2.1
18		105	105	2.1
19		105	105	2.1
20		105	105	2.1
			Total	1,059
		Present Value		1,006

6-2-2 Sensitivity Analysis

Table 6-2-7 shows the profile of unelectrified villages in Vientiane province and Borikhamxay province in terms of number of households per village. About 80% of unelectrified villages have less than 100 households. In Borikhamxay province, there are many small villages that have less than 50 households.

Table 6-2-7 Distribution of households

No. of households	0 – 50	51 – 100	>100
Vientiane	38.3%	40.8%	20.9%
Borikhamxay	62.8%	25.1%	12.1%

A sensitivity analysis was carried out by changing the scale of a village from 30 to 100 households. Assumptions are the same as those in the previous section. However, the capacity of diesel and small hydro generators was changed to meet the electricity demand of the village. Figure 6-2-1 shows the results of the sensitivity analysis.

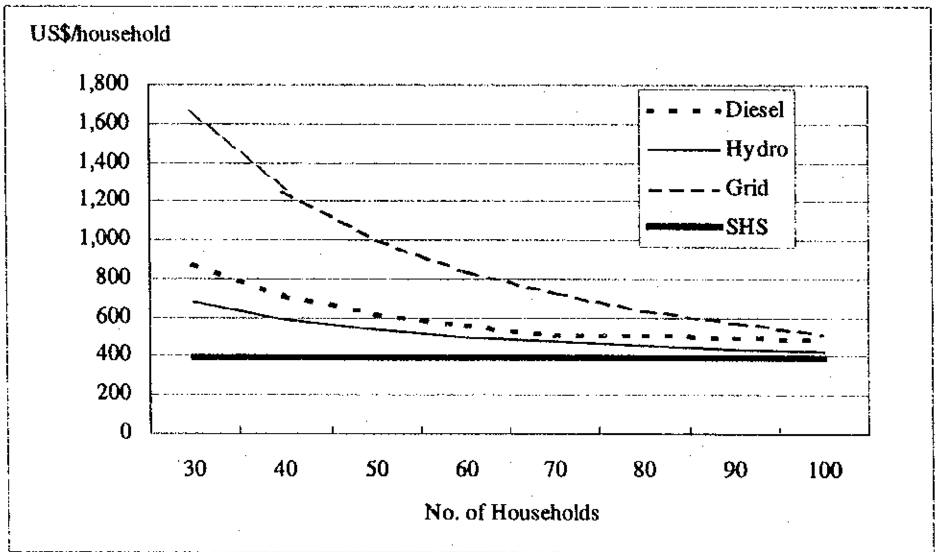


Figure 6-2-1 Sensitivity analysis of each system (Load : 80W/household)

According to Figure 6-2-1, when the electricity load per household is as small as 80W and the village scale is 100 households, SHS is economical compared to alternative systems. However, SHS also has a weak point because SHS cannot accommodate AC electric appliances without an inverter. Diesel generation has a higher cost structure than hydro. In remote areas, fuel cost including its transportation is inevitably high. A small hydro generator can supply AC power and has social benefits of saving fuel and foreign currency, which is much more favorable for Laos.

A grid extension of 5km is not economical for such small demand. However, grid extension becomes economical when electricity demand per household increases, for instance from 80W to 160W as shown in Figure 6-2-2. It is obvious that the grid extension cost per household decreases when the village scale increases. When electricity demand increases, a household will have many electric appliances such as fan, color TV, and audio system. In this case, using SHS is not recommendable because it requires an inverter and extra solar panels to use AC electric appliances, which leads to higher costs. Therefore, SHS will not be practical in case of large electricity demand.

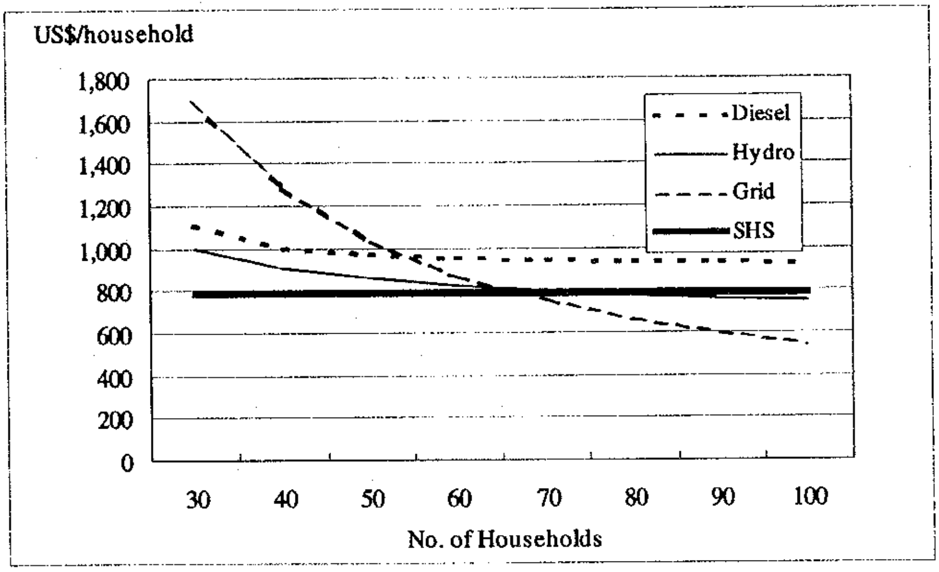


Figure 6-2-2 Sensitivity analysis of each system(Load : 160W/household)

6-3 Contract and Collecting Money

6-3-1 Contract System

Although the prices of solar system components, especially PV modules, are steadily going down, most rural villagers cannot afford an SHS yet. Average annual income in our survey villages was 1.2 million kip ($150) per household. On the other hand, the future system price of 50W-SHS will be more than 2 million kip. Considering this situation, it is very difficult for villagers to buy an SHS with cash or by short-term installment. Also, the very limited high-income people who can afford it will buy many electric appliances and their demand for electricity will constantly grow. In that case, a small 50W-SHS will not be to able supply enough electricity within a few years. Therefore, a small SHS is recommended for a household that will live with few electric appliances.

To disseminate SHS in rural areas, a long-term leasing system is very effective because the payment can be made small enough for villagers. In this study, we introduced a 20-year lease service contract scheme for SHS and set the monthly charge at $1.0 to $1.5. During the monitoring period of more than one year, no household has terminated the contract due to failure to pay the monthly charge. This indicates that a long-term lease system does work in remote areas of Laos. An advantage of the lease service system is to have a contract that includes maintenance services, which addresses the concerns of users. Furthermore, if a user moves to another place which is already electrified, he can cancel the contract by returning his solar system.

We propose a lease contract system to facilitate spreading SHS in rural areas. Explaining the contents of the lease contract before installation and making applicants sign the contract are very important to assure their commitment to payment and to achieve 100% charge collection, which will lead to sustainable operation of SHS.

Advantage of Lease System
- Users in rural areas can pay the monthly charge because it's small enough.
- Contract includes maintenance service.
- Users can decline to renew the contract if they don't need the system.

6-3-2 Contents of Lease Contract

(1) SHS

The provisions of sample contract are as follows.

1. Type of Solar Home System (SHS)
I, as Renter, apply for a

______55W system which includes one solar panel with mounting, one charge controller, one fluorescent lamp, one battery (70Ah), and standard cables and connections.

______110W system which includes two solar panels with mounting, one charge controller, one fluorescent lamp, one battery (120Ah), and standard cables and connections.

Income and electricity demand are different from household to household. Users can select from two system options considering their income and electricity demand.

2. Down payment

I agree to pay the following amount as a down payment. The down payment will be collected by a designated officer.

******* kip (55W system)---------((70Ah local battery price equivalent))*

******* kip (110W system)--------((120Ah local battery price equivalent))*

The down payment is recommended to be set at the same price as the battery. In this lease contract, the user is responsible for the replacement of batteries, fluorescent lights, switches, and so on. If these components become faulty, the user has to replace them. The battery, sold for about $20, is still the most expensive component. If a person who cannot pay the down payment had a system, he would not replace the battery and could not sustain the system. Moreover, the down payment is important to confirm his commitment to payment.

3. Monthly Charge

I agree to pay the following amount every month. The monthly charge will be collected by the Village Electrification Committee (VEC) every month.

******* kip (55W system)*

******* kip(110W system)*

The monthly charge may change due to inflation. Charges to the tariff will be announced two months in advance.

The village electrification committee (VEC) is designated to collect the monthly charge. If the lessor (government) were to collect the monthly charge from a remote area, it would require a lot of time and money. The VEC collects the monthly charge on behalf of the government, reducing overhead expenses. Such a fee collection system is not at all unique. EdL employs the same system in rural areas.

This monthly charge will be reviewed, and changed if necessary, every year due to inflation because expenses such as maintenance costs, and salaries increase every year. EdL has introduced a new electricity tariff which is also adjusted for inflation.

4. Warranty

Battery, fluorescent lamp, indoor wiring, switch, and wall outlet are covered by a one-year warranty.

Some of products break within half a year due to poor quality, even if the product life is said to be more than one year. In the pilot project, we sometimes experienced such problems. Under the warranty, we changed faulty components free of charge.

5. User's Liability

I agree to replace at my expense the battery, fluorescent lamp, indoor wiring, switch, and wall outlet by myself after the one-year warranty period has expired. In the event the SHS is malfunctioning, the user shall notify the VEC.

Here, the user's responsibility is confirmed. Each user has the responsibility for replacing batteries, fluorescent lamps, and so on after the warranty period expires. The user must report to the VEC when something goes wrong with the system.

6. Duration of Contract

The term of this Lease is 20 years. After 20 years, the ownership of SHS will be transferred to the user. The user can purchase the SHS by paying the residual value at any time. Until this lease is terminated, the SHS shall remain the property of the Government, and the user is not allowed to sell or modify the SHS. In case the user wishes to terminate the lease before expiration, the user shall notify the VEC one month in advance and the user shall return the SHS to the VEC.

Generally, the life of a PV module is 20 to 30 years. In this lease service, the monthly charge is set to recover investment costs, including maintenance costs, in 20 years. Therefore, the system is handed over to the user after 20 years. Moreover, if the user wishes, he can buy the system by paying the residual value at any time.

When released from the contract, the user must dismantle the system by himself and return it to the VEC. In the pilot project, some users canceled the contract because they moved. It needs to be made clear who is responsible for dismantling the system.

7. Failure of Payment

In case the user fails to pay the monthly charge for two consecutive months, this Lease may be terminated

In the pilot project, there has been no user failing to pay the monthly charge for two consecutive months. This provision is well accepted.

8. Relocation of the System

In case of relocating the SHS, the user is responsible for the cost incurred.

During the pilot project, some users built new houses. At an early stage, there was an argument about who will pay the re-installation cost. Therefore, it is necessary to make clear who is responsible for paying the moving cost.

9. Reduction of System Capacity
In case the user wishes to reduce the capacity from 110W to 55W, the user shall notify the VEC one month in advance and return the solar panel to the VEC.

A 110W-system user can make a request to reduce to a 55W-system. Later in the pilot project, some users actually reduced their system capacity.

10. Government's Liability
The Government is responsible for installation, ordinary maintenance, and replacement of the charge controller and solar panel if they are faulty.

The government is responsible for the above-mentioned services free of charge.

11. Transfer of Lease Contract
The user can transfer this lease contract to another user. The second user must notify the VEC immediately after transfer is completed. In this case, the Government is not responsible for system installation.

In the pilot project, some users transferred their system to their brothers without notice. If such an event often occurs, the government cannot keep track of the names of real users. So we allowed the transfer of the right-of-lease contract to another person, but required prior formal notification to the VEC. The second user does not need to pay a down payment. The relocation cost is to be borne by users.

All amounts charged under this Lease are nonrefundable.

Down payment and monthly charges paid under the contract are not refunded even in case of canceling or transferring the contract, or in case of reducing PV capacity.

The undersigned hereby applies to lease a Solar Home System. I HAVE READ THE ABOVE LEASE AS STATED AND AGREE TO BE BOUND BY THE TERMS AND CONDITIONS CONTAINED WITHIN. I ALSO CERTIFY THAT THE INFORMATION I HAVE PROVIDED IS COMPLETE AND ACCURATE.

Date:____________________
Signature:____________________________

For the second user (in case of transfer)
I agree to take over the system under the same lease conditions as the former user.

*Date:*________________________
*Name:*____________________________________
*Signature:*__________________________________

*Date:*________________________
*Name:*____________________________________
*Signature:*__________________________________

Even when the right under the leasing contract is transferred, a new contract is not prepared. The new user continues to use the same contract by signing his name and entering the date.

(2) BCS

In the BCS pilot project, we signed a leasing contract with the Village Electrification Committee, not with each household. The VEC is responsible for the management of BCS, including fee collection. They need to pay to the government only a fixed monthly charge. In this case, the balance is their profit.

The rationale for this scheme is as follows.

- It is very difficult to collect fees from users unless there is a full-time operator at the project site.
- VEC has an incentive to get more users in order to increase their profit.
- Create a workable business model for future commercial applications

The provisions of the sample contract are as follows.

The Village Electrification Committee (VEC) in "Name of Village" hereby applies for the battery charging service to be provided by the service agency (Government).

1. Capacity of BCS *The BCS consists of ** units. Capacity of one unit system is 165W.*

The Battery Charge Station (BCS) is composed of several 165W units. One unit can charge one battery in one day. If the village wants to install a BCS, the VEC estimates the demand for battery charging and applies for the necessary number of units.

2. Monthly leasing charge *The VEC agrees to pay ***** kip monthly fee to the Service Agency (Government).* *The monthly leasing charge is subject to change due to inflation every year.*

In the case of BCS, down payment is not set forth. The VEC collects money from users for battery charging and pays a monthly leasing charge to the government. Also, the monthly leasing charge will be reviewed every year for the same reason as SHS.

3. VEC's Liability
In case a part of the BCS such as a PV module or charge controller is stolen, the VEC agrees to pay for the replacement.

The VEC is responsible for the management of BCS. If a part of the system, such as a PV module or charge controller is stolen, the VEC has to pay for replacement.

4. Government's Liability
In case of BCS failure, the Government repairs or replaces the system without charge.

The government retains the ownership of BCS throughout the lease period. The government has to repair or replace faulty components free of charge.

5. Termination
The term of this Lease is 20 years. After 20 years, ownership of BCS will be transferred to the VEC. In case the VEC wishes to terminate this contract, VEC will notify the Government one month in advance. In case of failure to pay the monthly charge for two consecutive months, this contract may be terminated.

The monthly leasing charge is set to recover investment costs as well as maintenance costs in 20 years. Therefore, the system is handed over to the VEC after 20 years. Canceling the contract is possible in case of user request, or non-payment.

In the case of BCS, it is not common to transfer the system to another village. For this reason, this contract does not involve a provision for transferring the right of the lease contract to another village. Also, we did not allow for reducing the system capacity under this contract. Generally, people in the village wish to install a large system. If the actual demand is smaller than the capacity of the BCS, the VEC may not be able to pay the monthly leasing charge. To avoid such a problem, it is necessary to design the system capacity properly and to keep the load factor as high as possible. When demand grows, they can add more PV units.

(3) Responsibility of VEC

In the pilot project, the village electrification committee (VEC) was organized to maintain and manage the system. During the monitoring period, there were some issues between users and the VEC. So we clarified the responsibilities of the VEC as follows.

- *The VEC shall collect monthly charges from users every month and keep the money until the Government comes to the village to collect it every ** months.*

In the pilot project, the monthly charge was collected by the VEC. The JICA team and/or MIH officer went to the village every two or three months to receive the money and to pay salaries. In future projects, the government should set a timetable beforehand for collecting money from the VEC.

- *The VEC will try to fix any problem by following the maintenance manual when a user reports a problem to the VEC.*

In monitoring this project, there were problems such as voltage drop because of loose cable connections. In order to solve these problems, we made a maintenance manual including troubleshooting and explained to the VEC how to fix problems. But they are not experts on PV systems. Sometimes they could not fix a problem.

- *If the VEC cannot fix a problem, the VEC shall report the problem to the Government.*

The VEC has the responsibility to report problems that they cannot fix. They need to keep records on the details of problems in the technical book.

- *The VEC shall visit each household every month for a periodical inspection according to the maintenance manual.*

The solar home system (SHS) is a new technology in rural areas. If users cannot maintain the battery properly, its life becomes shorter. Therefore, regular checking by the VEC is important for the system.

- *The VEC shall keep the system until the Government comes to the village if user returns it, or hand over the lease contract to a new user who wishes to install it as a second user.*

Some SHS were removed when households moved. In that case, the VEC is expected to keep the system components temporarily in a safe place to prevent theft. It is sometimes necessary to charge and discharge the battery to keep it in good condition.

- *The members of VEC are paid monthly. The amount of monthly remuneration is suggested to be same as the system monthly charge for 110W.*

The VEC basically consists of three members -- Chief, Technician, and Financial officer-- and they get a salary every month. In the pilot project, the amount of salary was set to be the same as the monthly charge for 110-SHS. As a result, their salary automatically goes up when the monthly charge is raised due to inflation. The amount of the salary is almost equal to the remuneration that EDL pays to their designated village leader for checking watt-hour meters and collecting electricity charges.

6-3-3 Fee Collection Record

The fee collection ledger is managed by the VEC. When collecting monthly fees from each household, date and amount of payment are recorded together with signatures of payer and collector in this ledger. No receipt is issued. This ledger has enough space to keep records for 10 years.

6-4 Collecting Money in Pilot Project

6-4-1 Revenue and Expenses

In the pilot project, the SHS charges were set as follows:

①Initial charge 100,000kip (SHS-55W) 150,000kip (SHS-110W)
②Monthly charge 5,000kip (SHS-55W) 10,000kip (SHS-110W)

The monthly charge will be reviewed every year and may change due to inflation. On the other hand, the BCS monthly charge was set as 100,000kip/kW. However, during the start-up period, the utilization factor was low and the monthly charge was cut to help the VEC.

(1) Fee collection

All SHS users paid their down payments, and monthly charge collection has been also very smooth. Some users had technical problems with their lamps, and they were exempted from paying monthly charges until the problems were fixed. As for BCS, Paksoun showed a remarkable performance for having a high load factor and a perfect record of paying lease charges. At Donsayoudom and Namai, battery charge users are increasing but the VEC has some difficulty in checking users and collecting fees properly. We provided necessary guidance to help them learn the management method of BCS and to improve the situation.

(2) Expenses

There were some items that we approved as necessary expenses to maintain the pilot systems:

- Salary of VEC members
- Maintenance tools
- Transportation to training seminar
- Spare parts

Many fluorescent kits and tubes were found faulty after a few months. These parts were supposed to be replaced immediately under the warranty. But it took quite a long time to get replacement parts from the original supplier. To cope with this problem, we bought some spare kits and tubes from local venders.

6-4-2 Utilization Ratio of BCS

We installed BCS at three villages : Donsayoudom, Namai, and Paksoun. Among these villages, Paksoun's system is being managed very well. This management system should be viewed as a model case. Its utilization ratio in the past eight months was very high, at around 80%. They introduced a membership system. Frequent users register as members and can charge batteries on the day of the week which is assigned to each member. Other irregular users can use the BCS when it is not fully occupied. They do not need to charge batteries every week.

The charging fee for a member is set at 4,500kip/month. When a member wants to charge his battery without assignment, he has to pay an extra fee of 1,000kip/charge. Charging fees for a non-member are set 1,000kip for a 6V battery, 2,000kip for a 50-70Ah battery, and 3,000kip for a 120Ah battery respectively. Before the BCS, people used to charge their batteries at a charging shop in the village where the shop owner was using a diesel generator. And the charging fee was much higher.

Paksoun's successful operation is attributed to the following.

①Introduction of membership system to secure stable demand
②Having cost advantage over existing competitors
③Balancing demand and system capacity

Table 6-4-1 Utilization ratio of BCS in Paksoun (1999~2000)

	Battery Type	Nov	Dec	Jan	Feb	Mar	Apr	May
Member	6V Battery	36	39	36	48	36	12	39
	50Ah Battery	217	214	221	209	215	209	209
	70Ah Battery	140	144	150	132	144	126	128
	120Ah Battery	0	1	0	3	1	2	1
Non-member	6V Battery	111	63	40	62	65	70	54
	50Ah Battery	19	40	48	20	31	30	25
	70Ah Battery	7	24	12	9	20	16	12
	120Ah Battery	1	4	2	5	2	2	0
Member	Utilization ratio	69%	70%	72%	69%	70%	64%	66%
Non-member	Utilization ratio	15%	19%	16%	13%	16%	16%	12%
Total	Utilization ratio	85%	89%	88%	82%	86%	80%	78%

(Note) 3kW-BCS has 18 charge controllers and can charge 540 batteries per month at maximum.
One unit (165W) can charge two 6V batteries together.
Two units (330W) are needed to charge a 120Ah battery