Chapter 7

Evaluation of Pilot Project

7-1 Overview of Pilot Project

7-1-1 Process of Pilot Project

As stated earlier, the major objectives in this study were to empirically analyze and evaluate the acceptability and sustainability of solar systems for rural electrification, and to propose a viable rural electrification strategy for Laos based on their social structure, life style, income and needs of the rural farming region. As a result of the pilot project, which was implemented in six villages of two provinces, it was confirmed that PV would be a realistic option for rural electrification. Based on this, a supplementary project, which covered three new villages, was planned for the capacity building of the counterpart (C/P) to facilitate the implementation of future projects. In this stage, C/P took initiative in implementing PV installation to strengthen their capability. The workflow of the whole pilot project is summarized as follows.

First survey in Laos : Baseline survey

(Sep. ~ Oct.1998) A field survey—baseline survey—was conducted in the villages which were first proposed for the pilot project, to understand geographic conditions and the current situation of energy use in order to come up with a basic system design. Based on this survey, the basic designs of SHS and BCS were drafted.

Second survey in Laos : PCM Workshop / Detailed survey of pilot villages

(Jan. ~ Feb. 1999) Through discussions between the study team and village people during PCM workshops at four pilot villages, the village people gained better understanding of the pilot project. Both parties reached an agreement on a tariff system and establishment of a village electrification committee. After the workshop, every PV applicant signed a contract.

Third survey in Laos : PCM Workshop / first stage PV installation

(May ~ Jun.1999) PV systems were installed in three villages (first group) out of the four villages where the PCM workshops were completed. At the same time, technical training sessions about VEC management were held targeting the VEC members. At the two remaining villages, PCM workshops were conducted and PV applicants singed contracts.

Fourth survey in Laos : Second stage PV installation / PV monitoring 1

(Sep. ~Oct. 1999) PV installation and guidance for the VEC were conducted at the second group of three villages. At the first group of villages, a PV monitoring survey was conducted to understand how villagers use and operate PV systems. Based on the result of the monitoring survey, problem-solving ideas and points to be improved were submitted to the VEC from the study team and C/P.

Fifth survey in Laos : PV monitoring 2 / PV promotion seminar

(Feb.~ Mar. 2000) The PV monitoring survey was continued at all of the six pilot villages and necessary consultation was given to the VEC members. To improve awareness on PV, a seminar was held inviting officers of concerned ministries and 11 provincial governments of northern Laos.

Sixth survey in Laos : Impact survey / Evaluation of pilot project

(May ~ Jun. 2000) Residents' meetings were held at all the pilot villages to get an evaluation of the pilot project from the villagers, and a PV impact survey was conducted at the same time.

Seventh survey in Laos : Capacity building—PV installation project by C/P

(Sep. ~Oct. 2000) The C/P gained experience to strengthen their capability of managing PV-based electrification projects through conducting a series of projects from preliminary meetings to installation and monitoring, and furthermore, establishment of a management organization at three new villages under the supervision of the JICA team.

7-1-2 Results of pilot project

55W PV modules were used in the pilot project, and Solar Home Systems and Battery Charging Stations were installed for demonstration in six pilot villages. We offered 55W-type and 110W-type PV systems for SHS applicants. A typical system of BCS (990W), which we offered, was composed of six basic units, and each basic unit had three modules (165W). The number of installed systems is shown below (See table 7-1-1~2).

Table 7-1-1 Installation of SHS

Village	Number of houses	As of Nov. 2000		
		55W	110W	Total
Donsayoudom	129	44	59	103
Houaypong	43	41	1	42
Nongpen	50	40	8	48
Mai	73	55	18	73
Total	295	180	86	266

Note: During the study, there were additional systems installed.

Table 7-1-2 Installation of BCS

	Donsayoudom		Houaypong	Namai	Paksoun
	Site 1	Site 2			
Number of systems	2	1	*	2	3
Capacity of PV array [W]	1,980	990	(165)	1,980	2,970

Note: The BCS at Houaypong was removed in November 2000.

In particular, creating a sustainable and replicable model of PV-based rural electrification was the main objective of the study. The following three points were focused on in the pilot project.

- **Appropriate capacity and configuration of PV system**
- **Appropriate cost sharing by villagers (users)**
- **Management and maintenance by villagers**

In the past, there were cases that people did not accept PV electrification because the generation capacity was too small against their expectations. However, as a result of this pilot project, we found that people of rural Laos would accept PV electrification from the viewpoint of their electricity demand and their ability to share costs and maintenance. Accordingly, it can be concluded that there is a high possibility of PV introduction in rural area of Laos.

7-2 Capacity Building: To strengthen management capability of C/P

Originally this study was scheduled to be finished in September 2000. However the duration of the study was extended to strengthen C/P's capability to implement PV-based rural electrification projects in the future, because we viewed there is a strong need for PV among rural people. The C/P took the initiative in the added pilot project and carried out necessary tasks following the "Flow Chart of Rural Electrification by Solar System" (See Attachment). The JICA study team gave advice if it was deemed necessary.

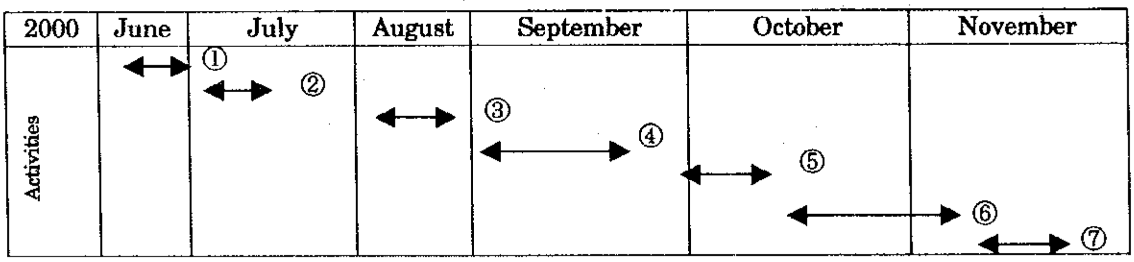
7-2-1 Reason for extension

Although the C/P had experience in the first-stage PV installation projects, they didn't have an opportunity to take the initiative in doing a series of planning and administrative work regarding PV electrification, such as site survey, procurement of equipment, negotiation of contract, organizational development and so on. This point posed a concern for their management capability for future projects. The C/P requested during the sixth site survey that they wanted to try PV installation by themselves at new villages under the supervision of the study team. Candidate villages for this venture were Tankham, Nakhoum and Nasath in the Hinheup district of Vientiane province.

Considering their request and situation, the study team reached the conclusion that the request was reasonable and the C/P would benefit a lot from this undertaking. This issue was reported to JICA and was soon approved. JICA made a decision to extend the duration of study by several months to conduct additional PV installations at new villages.

7-2-2 C/P project at new villages

The actual workflow of the C/P project and the number of installed systems are as follows.



Note :

① Selection of villages for installation/Preliminary survey
② Baseline survey /Residents' meeting/Application and contract
③ Material procurement/ Arrangement of transporting materials
④ Planning of installation schedule/Consideration of system design
⑤ Support to the VEC in new villages/Confirmation of work process
⑥ Installation work/Technical training for villagers
⑦ Collection of initial payment/Monitoring

Figure 7-2-1 Schedule of C/P's work

Table 7-2-1 Number of installed PV systems in the new villages

Village	Tangkham	Nakhoum	Nasath	Total
# of houses	26	38	46	110
# of systems	22	32	36	90

Note: Installed systems are all 55W SHS

7-2-3 Evaluation of the C/P project

The C/P performed independently a series of work for the new PV project, and successfully completed the introduction of PV systems into the three new villages. Although there is room for improvement in their performance on material management and the VEC development, they recognized those points after wrap-up meetings with the study team and would pay attention to those points in future projects. In conclusion, it can be said that the C/P have reached a sufficient level of managing PV-based rural electrification projects. Thus, this additional undertaking largely contributed to the capacity building of the C/P. In the future, it is very likely that many rural electrification projects will be implemented nationwide. In that case, it is not efficient that a limited number of central government engineers are always involved in system installation or technical training. Rather, they, as pioneers, need to transfer their know-how to local engineers, who will play a major role in the later stage, by working together in first-round model projects.

7-3 Evaluation of pilot project

7-3-1 Technical Evaluation

On the basis of the operating status and the results of the monitoring survey of each system, we evaluated the pilot systems from a technology standpoint. The results of the technical evaluation were reflected in the discussion of the standard PV system suited for Laos.

(1) SHS (Solar Home System)

1) System configuration and PV array capacity are good.

Two types of PV systems — 55W and 110W —were tested in the pilot project. These systems have been used effectively, making the best use of their characteristics until now, and these systems have been operated non-stop. The possession rate of each electrical appliance is ranked in the following order from high to low: lamp, TV, and radio-cassette recorder. Basically, lamps and TVs tend to be used at night. It is thought that a PV array, which has a capacity of less than 55W, is quite enough when only a lamp is used. However, when a TV and/or a radio cassette recorder are used, it is thought that a 55W system is suitable. The 110W system is capable of charging another battery, and this function is being used well. In Nongpen, a new battery-charging business using the PV system has appeared.

2) Voltage drop between controller and battery is large

There was a case in which some batteries could not be charged fully because a voltage drop occurred due to the looseness of terminal parts between the controller and the battery. The pilot system has a function to easily cut the circuit with a breaker at the battery side in consideration of safety. Also, a line fuse that can be procured at the local market is used, and the voltage drop is caused when this part comes loose. Therefore, to decrease the voltage drop, the number of connection parts and the factors which cause the voltage drop need to be reduced.

(2) BCS (Battery Charging System)

1) System configuration and PV array capacity are good.

BCS has few factors that would cause the voltage to drop, etc., because it consists of fewer parts compared with SHS. In Paksoun they are charging their batteries periodically, and those batteries are being charged fully. From the above results, it is judged that the capacity of BCS is proper. But the capacity of the PV array should be increased at places where radiation is small.

2) Capacity of controller is too large.

A controller with a capacity of 40A was used in the pilot project because use of a 400W PV system had been designed to charge a 120Ah battery. But in this project a 150W PV system is adopted as the basic system for charging a battery which is less than 80Ah, and two basic systems are connected in parallel when charging a 120Ah battery. Therefore, it is thought that 20A is sufficient as the capacity of the controller. There are some controllers which can operate in parallel, and in this case it is possible to decrease the capacity of the controller further.

7-3-2 Social and economic evaluation

(1) PV electricity demand in non-electrified villages

The explicit and potential demand for PV electricity turned out to be fairly high. As PV systems in the pilot project require villagers to share the system and maintenance cost, they had to pay for the initial charge and the monthly tariff. Accordingly, we could estimate their demand from their willingness to make for those payments. The explicit demand can be assessed by the fact that many houses already have batteries in unelectrified areas. This means that people who already have batteries are willing to pay for this mode of electricity despite the higher cost and inconvenience as compared with grid electricity. In addition, it turned out that the potential demand for PV electrification is high because of the high application rate for pilot systems. Fast spread-out of batteries and appliances in the past also implies that there is high potential demand for electricity. Thus there is explicit and potential demand for electricity, and it is possible to introduce PV systems into rural areas as long as the amount of payment falls in the affordable range. However, the scale of demand and the speed of propagation depend on following points.

①Cash income levels and ease of obtaining cash income
②Comparison with alternative energy sources such as battery charging in town and kerosene
③Scale of benefits of PV electrification as compared with expectations and costs to people

(2) Affordability to villagers

In this pilot project, people easily paid the following fees and major troubles were not found in fee collection. Villagers in rural Laos are living a subsistence level of life. However, when they need money, they can get cash income by selling livestock, etc. They can afford to pay the initial and monthly payment (shown below) which was set by JICA consultants. The initial payment is almost equal to $ 15~ $ 20, and the monthly payment is about $ 0.75~ $ 1.5. (Exchange rate: $ 1=7,700Kip as of June 2000)

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

* According to the PV lease contract, the monthly payment may change due to inflation. People have agreed to the new tariff of 7,000kip (SHS-55W) and 12,000kip (SHS-110W) set in June 2000.

(3) Benefit of PV electrification

At the beginning, there was concern that PV electrification was not acceptable for village people who were familiar with grid electrification, because PV systems had a small capacity. The study team selected pilot villages paying attention to avoid PV projects for villages that were covered by a grid electrification plan. Besides, the team took time to explain the generation capacity and their share of the cost of PV in advance. And finally, the decision to use PV systems was the villagers' choice. As a result, only the villagers who really wanted PV despite some restrictions in its use applied for PV.

In the pilot project, people used electricity mainly for lighting, which is useful for a better life, productive work, entertainment and security as shown below. It has given a benefit to all family members.

Productive use: Torch light --- fishing and hunting at night (for men)
: Fluorescent light--- cooking and weaving at night (for women),
: Fluorescent light --- studying at night (for children)
Entertainment: Radio/TV/ Fluorescent light for dinner time and chatting with family and friends
Security : Torch light for night walking
: Radio and TV for information gathering (news, etc.)

According to the questionnaire survey and interviews, the direct benefits are as follows:

Economic benefit: Increase of income due to longer working time at night
: Decrease of energy expenses in some households which relied on battery charging in town before
Benefits for daily life : Ease of housework with light
: Saving time and labor to charge batteries in town
Cultural benefits: Better social life at night
: Information and entertainment from TV and radio,
: Ease of study at night

It is especially important to note that many cases of income increase were reported. It was also a significant factor in reducing the financial burden of users and led to the expansion of PV electrification. Additionally, the domestic work (cooking at night) of women was made easier because of better light, which is an indirect benefit of the system. And we heard that some villagers were getting better at managing money because of the mandatory monthly payment.

(4) Capability of villagers in maintenance

Whether or not PV electrification is accepted by villagers depends on maintenance of systems as well as demand, affordability, and benefits. In this point, it was also confirmed in the pilot project that villagers could easily handle their PV systems and the VEC was able to help to maintain their PV systems.

1) Familiarity with battery handling

The villagers are used to using batteries. As there are various batteries used in village life, the villagers are familiar with small and large sized batteries and do not have special resistance against using PV system batteries. In particular, 6V batteries are widely used for night fishing, walking at night and listening to the radio.

2) VEC support and maintenance : Background for cooperative work

In the pilot project, the Village Electrification Committee (VEC) was established and was monitored to find out whether it would function to support people in case of problems that could not be dealt with by an individual. It was demonstrated that the VEC had provided basic services to users such as a periodical check, minor repair, fee collection, etc. Then it turned out that VEC is effective in doing daily maintenance and management of PV systems. The reasons why the VEC works well are that capable members are selected and people in the pilot villages are good at collaborative work. Usually there are some organizations, or cooperatives, in a remote village to undertake development activities. The VEC is viewed as one of them and the villagers are cooperative, which is attributed to the strong communal mechanism in rural Laos.

There are some villages where people's backgrounds are different. At such villages, solidarity of villagers is relatively weak compared with villages with uniformity. For example in Nongpen village, which is small and made of one ethnic group, villagers have a strong cooperative spirit and the VEC is also active to work. On the other hand, in Donsayoudom village, which is composed of people with different backgrounds who settled from all over the country, people's behavior is more individualistic and their ties to the community look weak. At such villages, maintenance of PV systems depends more on each user and the VEC's involvement will be limited in the early stage. It would take some time to achieve sustainable management of PV systems. However, even in such a case, villagers expect the VEC to help them make best use of PV systems. Table 7-3-1 shows an example of responsibilities and jobs of the VEC members.

Table 7-3-1 Activities of the VEC in Nongpen

	Leader	Cashier	Technician
Responsibility	Overall management	Fee collection and keeping record	Periodical check and maintenance of PV systems
Jobs	• Recording troubles • Fee collection • Trouble shooting / Minor repair (Report difficult cases to MIH) • Periodical check of PV system • Participation in technical training • Instruction to users (how to use properly and how to maintain) • Keeping spare parts		

The success of the monthly fee collection and maintenance by the VEC is attributed to the following points:

① **Densely located houses in village**: It is easy to collect money from all the users in a day due to high housing density. If houses are scattered, 50 households in a 20km radius for example, it would take several days to finish the fee collection.

② **Communal mechanism**: There is a strong communal mechanism in the pilot villages, which facilitates the VEC to work smoothly.

These are applicable to most rural villages in Laos. However, it can be said that commercial-based PV introduction targeting individuals is better for large-scale, individual-oriented villages such as Donsayoudom.

Figure 7-3-1 Central area of Nongpen village

Table 7-3-2 shows structure and functions of the VECs in the pilot villages.

Table 7-3-2 Structure and functions of the VECs in pilot villages

		Donsayoudom	Houaypong	Nongpen	Mai	Namai	Paksoun
1.Member Selection		After PCM W/S, Village meeting (Recommendation)	After PCM W/S, Village meeting (by draw after meeting)	Village meeting (Recommendation during W/S period)	After PCM W/S, Village meeting (Recommendation)	After PCM W/S, Village meeting (Recommendation)	After PCM W/S, Village meeting (Recommendation)
2.Position/Responsibility		Leader 1 Cashier 1 Technician 2	Leader 1 Others 2	Leader 1 Cashier 1 Technician 1 Assistant 2	Leader 1 Cashier 1 Technician 2	Technician 3	Leader 1 Cashier 1 Key manager 1 Technician 1 Assistant 2
3.Educational Level		Secondary 1 High 1	Secondary 1 High 2	Secondary 3	Primary 2 Secondary 1	Primary 3	Primary 6
4.Work Experience		Teacher experience 1 Carpenter experience1	Carpenter experience1	Nothing special	Teacher experience 1 Electric wiring experience 1	Nothing special	Nothing special
5.Technical/Electrical Experience		Boat engine maintenance and repair 4	Boat engine maintenance and repair 3	Machine maintenance school experience 1	Electrical work 1	Nothing special	Boat engine maintenance and repair 6
6.Social Group		Village executive 1 Youth Union 3	Village executive 1 Youth Union 1 Security group 1	Village executive 1	Village executive 1 Security group 1	Village executive 1 Youth Union 1 Security group 1	Village executive 3 Security group 2 Village advisor 1
7.Tariff collection	Frequency	Once a month	Once a month	Once a month	Once a month	Every time after charging	Once a month
	Method	Visit each Household	Visit each Household	Visit each Household	Visit each Household	At pick-up	Membership ＊(Collection by Each group leader)
8.Maintenance	Frequency	Once a month	Once a week	Twice a week	Once a month	Every two days	Every day
	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 PV modules 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 array Cleaning of clips	Visual inspection Cleaning of PV array Cleaning of clips
9.Problem solving		User	Committee	Committee	Committee	— (BCS)	— (BCS)
10.Storage of spare parts		Committee stores spare parts	Committee stores spare parts	Committee stores spare parts	Lamptube is stored in each house	— (BCS)	— (BCS)

＊Although registered members have a priority to charge their batteries, non-members can also use BCS. However they have to pay every time, after charging.

7-3-3 Lessons learned from the pilot project

There were the past cases in which people did not accept PV electrification because the generation capacity was too small against their expectations. However as a result of the pilot project, we found that the people of rural Laos would accept PV electrification. Since this pilot project required the villagers to pay an initial charge and monthly fees, it was confirmed that electricity is the item that they are willing to pay a substantial amount of money for. Hence, it is possible to introduce PV into remote villages by balancing costs and benefits. Villagers can secure enough funds by selling livestock, although their life is at a subsistent level. They can manage PV systems without major problems. In summary, there is a great potential that PV can be introduced to rural areas in Laos. Key findings are as follows.

(1) Confirmation of electricity demand: PV systems were accepted by villagers

The explicit and potential demand for PV electricity would be fairly high, judging from the high application rate for pilot systems. This point can also be confirmed by the fact that there were many battery users before PV installation, and the use of batteries and appliances was spread quickly. Thus, there is strong demand and it is possible to introduce PV into remote villages as long as the amount of payment falls in the affordable range.

(2) Confirmation of affordability : Villagers can pay cost of PV systems

As this pilot system required the villagers to pay actual costs, there was an anxiety that they could not afford the systems due to insufficient cash income. However, payment and collection of fees were done without problem and their capability of payment was confirmed. Generally villagers' lives are at a subsistence level. However, when they need cash, they can get it by selling livestock, etc. There is a class of people who can afford to pay the $1.5～$2.0 monthly payment.

(3) Confirmation of electrification effects : Benefits of PV electrification

Although there was a doubt at the beginning about the benefits of PV due to its small capacity, there were direct and indirect benefits found in various aspects in the pilot project. Worrisome negative effects of electrification, such as negative effects from TV and income disparities among villagers were not seen more than one year after PV installation. However, the issue cannot be evaluated within a year or two. Possible negative effects of PV electrification must be monitored by the C/P in the future.

(4) Confirmation of capability of maintenance : Handling batteries and VEC

The most worrisome point is whether villagers can manage and maintain PV systems.

However it turned out that they are used to handling batteries and the VEC works well as a support system. The pilot project created a sense of ownership among users, and collaborative work through the VEC functioned effectively as expected owing to communal mechanisms and the physical proximity of villagers due to high housing density in the pilot villages.

7-3-4 Key issues for rural electrification by PV

(1) Sufficient explanation to people

Before introduction of PV systems, people have to know what is going to be introduced, and what it costs to them. This study held a series of workshops to explain to people the benefits of PV electrification, as well as the costs and duties that they have to bear, in order to avoid unnecessary troubles arising from overly high expectations.

(2) Affordability of payment

The pilot village people can afford to pay the SHS fee for the current pilot project because they have been paying the monthly fees on schedule. However, it is necessary to set reasonable prices in consideration of the market prices of alternative energy sources such as battery charging and kerosene, in order to promote the spread of PV.

Most people in the pilot villages preferred SHS because they were offered a bigger discount on SHS compared with BCS. Also, relatively richer villages were selected as pilot villages, so the system was affordable for them. In reality, the price of SHS is more expensive than BCS, taking actual costs into account. Therefore, BCS is thought to play a bigger role in the future expansion of PV. It is important to specify the roles of SHS and BCS and set reasonable prices for each to guarantee future expansion.

(3) Replacement of battery

Each household has to buy a new battery after the old one expires. Normally, PV batteries last for five years, but car batteries last only for two to three years. Villagers are responsible for the maintenance of their batteries, and the VEC is supposed to help the villagers get maximum use of their batteries by doing periodical checking. A car battery is affordable in even remote villages because we can find many examples of battery usage as a means of power supply.

(4) Maintenance and problem solving among villagers

It is desirable to achieve sustainable PV electrification so that the VEC gains and accumulates know-how for the operation and maintenance of solar systems, and so that it can resolve problems when they occur without any help from the outside. It is also important for the VEC to instruct the villagers to take care of their solar systems by giving sufficient training. In addition, it would be necessary to develop a mechanism which will enable the VEC to get technical and managerial advice from MIH or EdL.

(5) Income generation by PV

Many cases are reported that some PV users increased their income after PV introduction by weaving at night, extending shop hours, or starting battery charging services. Such example, showing an important social benefit of solar systems, should be strongly elaborated to increase public awareness of solar-based rural electrification.

Chapter 8

Proposal of PV System Suited for Laos

Based on the results of the pilot project, we proposed to the counterpart standard PV systems suited for Laos, and we prepared manuals on installation and maintenance of PV systems. Also, we researched the present situation of battery disposal in Laos and proposed a system for the future.

8-1 Development of PV systems in Laos

In Laos PV systems were first introduced to supply power to unmanned systems such as micro-wave stations, telecommunications stations and radio stations. These systems were mainly installed by MCTPC (Ministry of Communication, Transportation, Post and Construction). The number of installation points is 79, and the total capacity is over 122kW. Now, the introduction of PV systems targeted for village electrification has been started on a trial basis by MIH, STEA, EDL and others recently.

- MIH (Ministry of Industry and Handcraft)

MIH had some experience in installing PV systems for hospitals and meeting halls in some villages. They worked with the JICA team and gained experience in large-scale implementation of PV projects. Furthermore, they installed PV systems in three villages in Vientiane province, which is an added pilot project under the JICA study. They are formulating a rural electrification plan using PV systems.

- STEA (Science, Technology and Environment Agency)

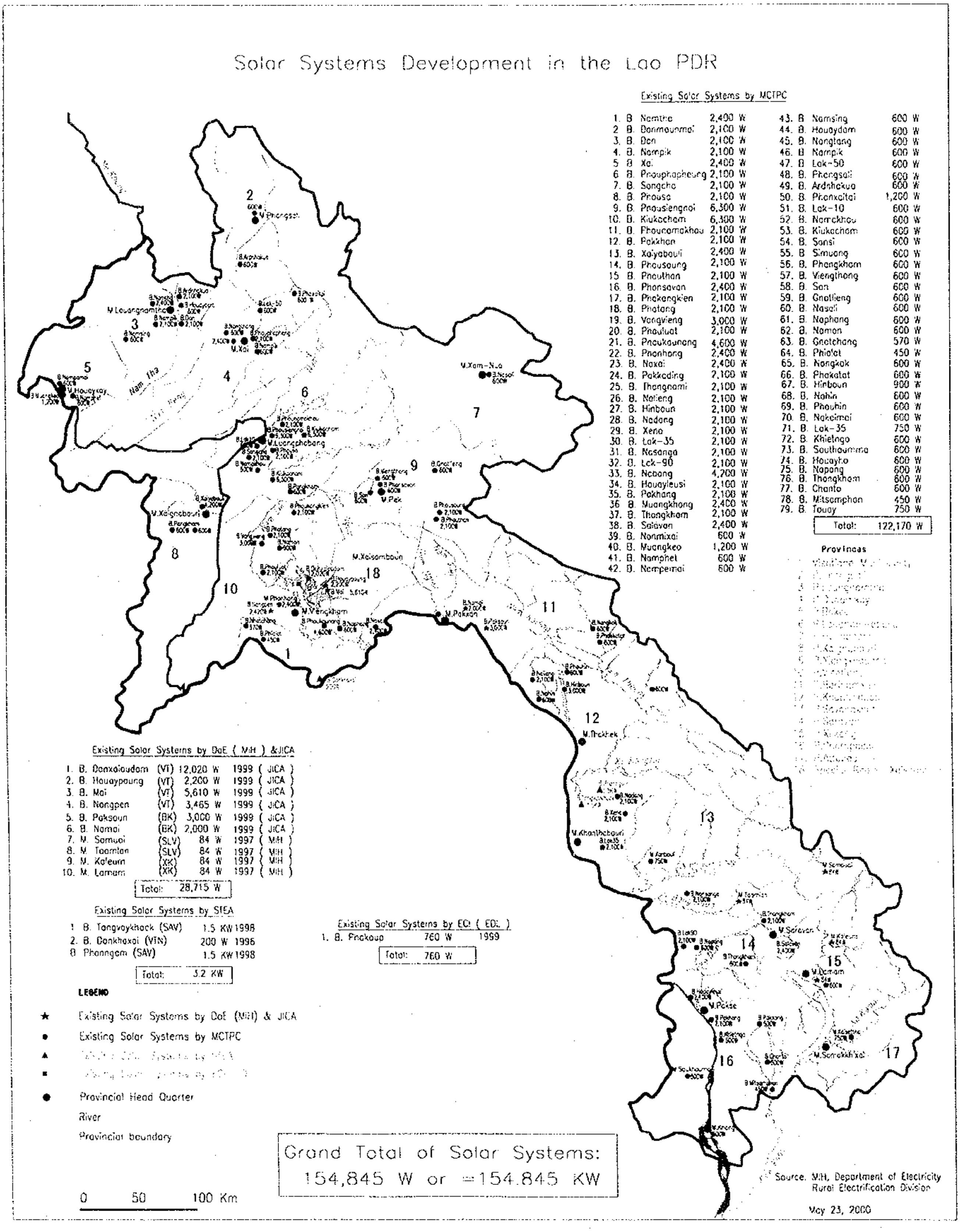
STEA has installed SHS and BCS near Savannakhet. As a search organization, STEA is developing controllers for solar system.

- EDL (Electricite du Laos)

EDL has experience in installing solar home systems as a part of the "off-grid electrification project" supported by the World Bank. But they view that PV-based rural electrification is unprofitable, so the introduction of PV systems is halted.

- Others

About 40 SHS were installed in Kasiya near Luangphaban by the grant from EU. There are some private companies that sell PV systems in Vientiane. Therefore, it is possible to procure PV components in Laos.



Source: MIH, May 2000

Figure 8-1-1 Introduction of PV systems in Laos

8-2 Proposal of Standard PV System

The standardization of the PV system makes it easier to create a simple rural electrification plan for users because it promotes the standardization of various tasks such as fee collection, operation and management systems, education of engineers and preparation of manuals.

8-2-1 System configuration

(1) SHS

SHS consists of PV module, support structure, controller, breaker, fuse, storage battery, switch, fluorescent lamp and plug. As a basic system, we recommend the 50W system, with the capacity of the PV array and the battery at 50W and 70Ah respectively. In this system one 10W FL lamp and one 20W B&W TV can be used for 10 hours and 3 hours respectively at night. For users who want to use more electricity than the basic system offers, we recommend the 100W system, for which the capacity of the PV array and the battery is 100W and 120Ah respectively. In Laos batteries are used as the power supply for hunting lamps and weaving lamps, and the charge demand of these batteries is strong. A function which can charge an extra battery can be attached to these systems as an option. However, an extra battery should be charged only when the main battery is fully charged and the solar panel is still capable of generating electricity.

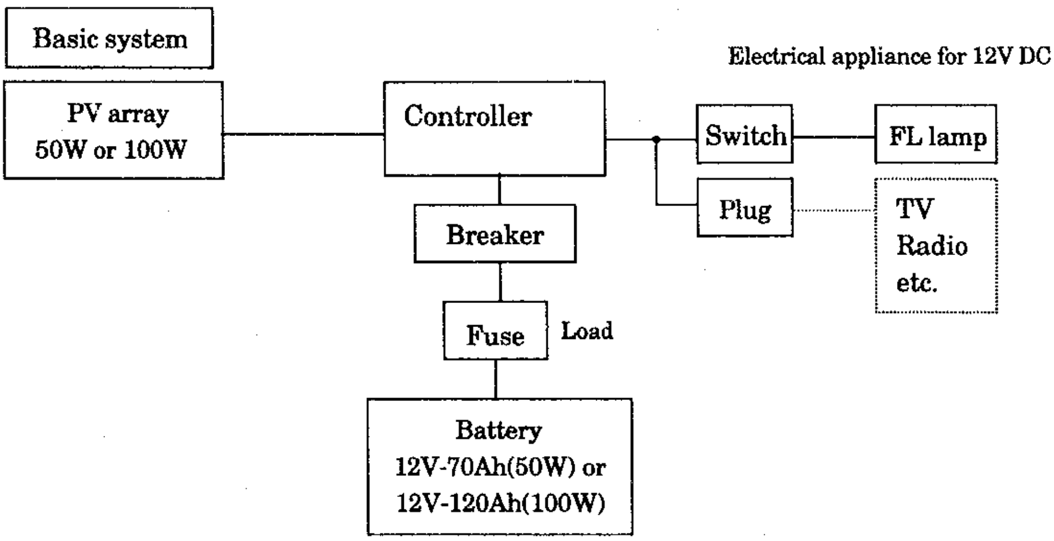


Figure 8-2-1 Basic System (SHS)

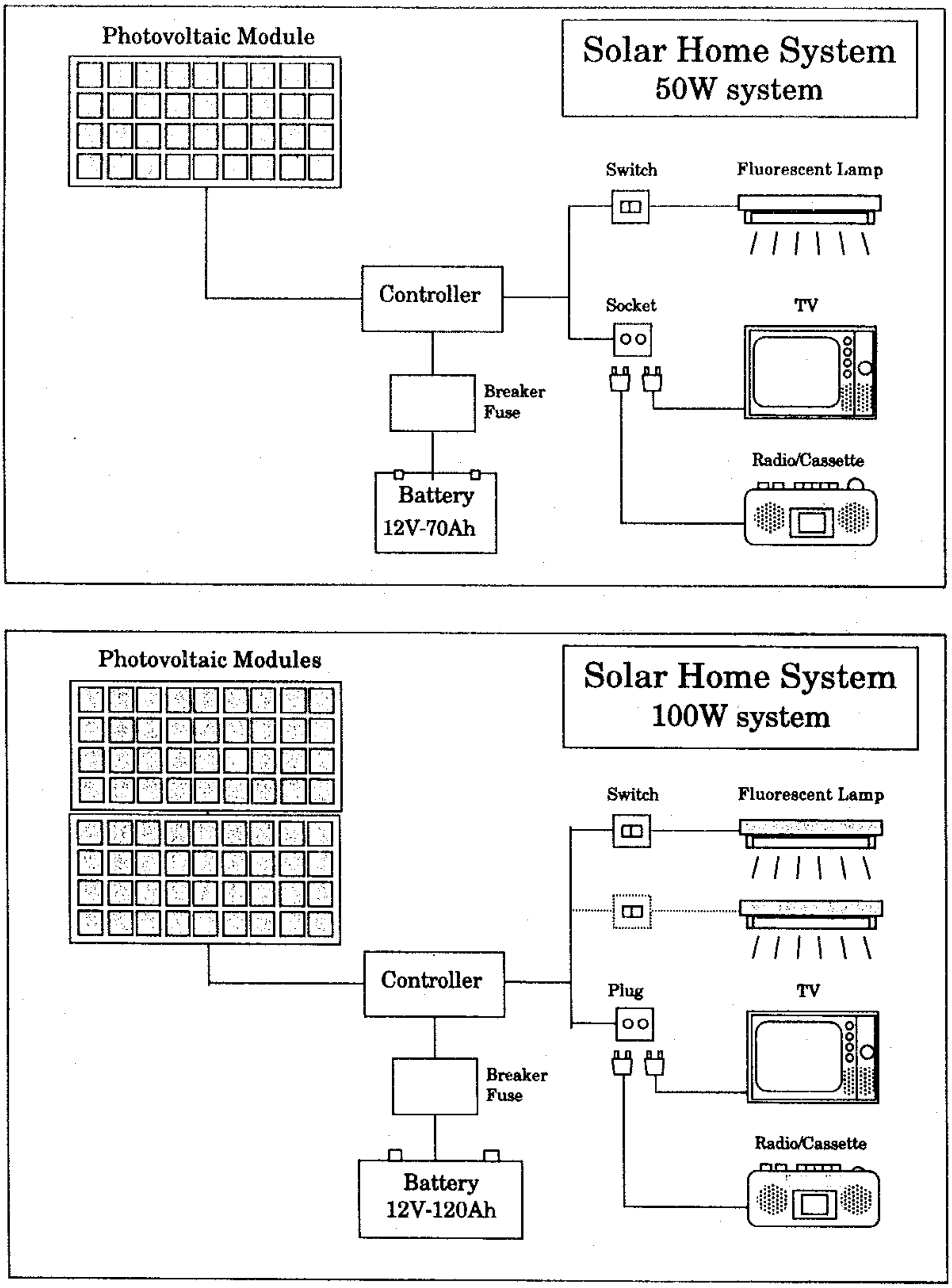


Figure 8-2-2 Image drawing of basic SHS

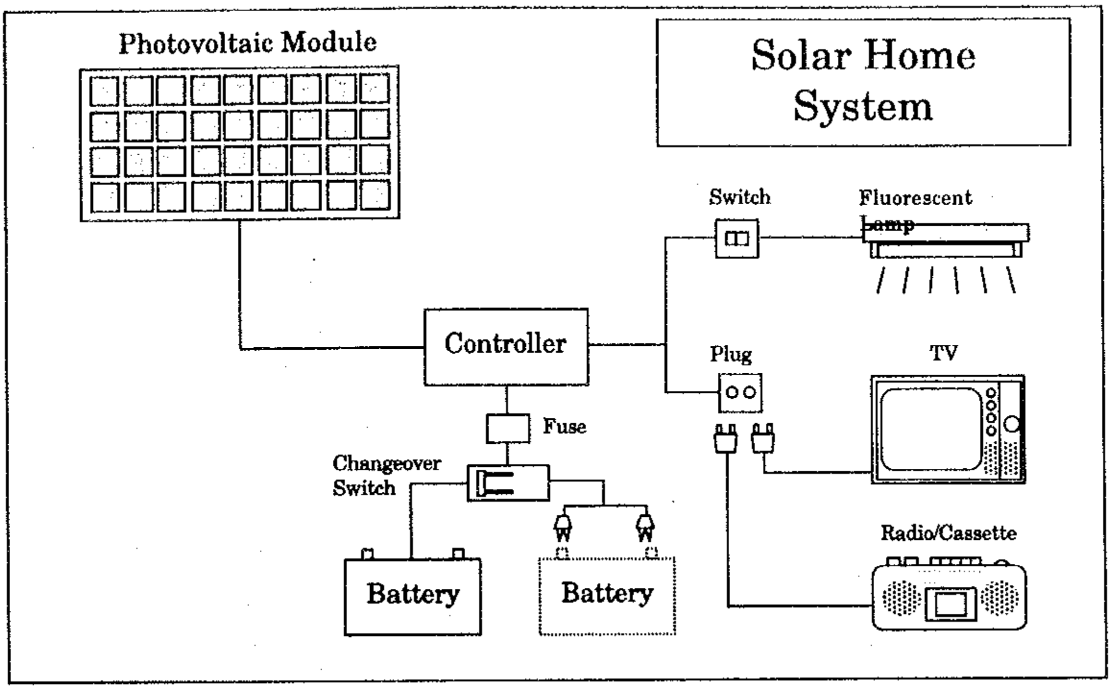


Figure 8-2-3 Image drawing of optional system

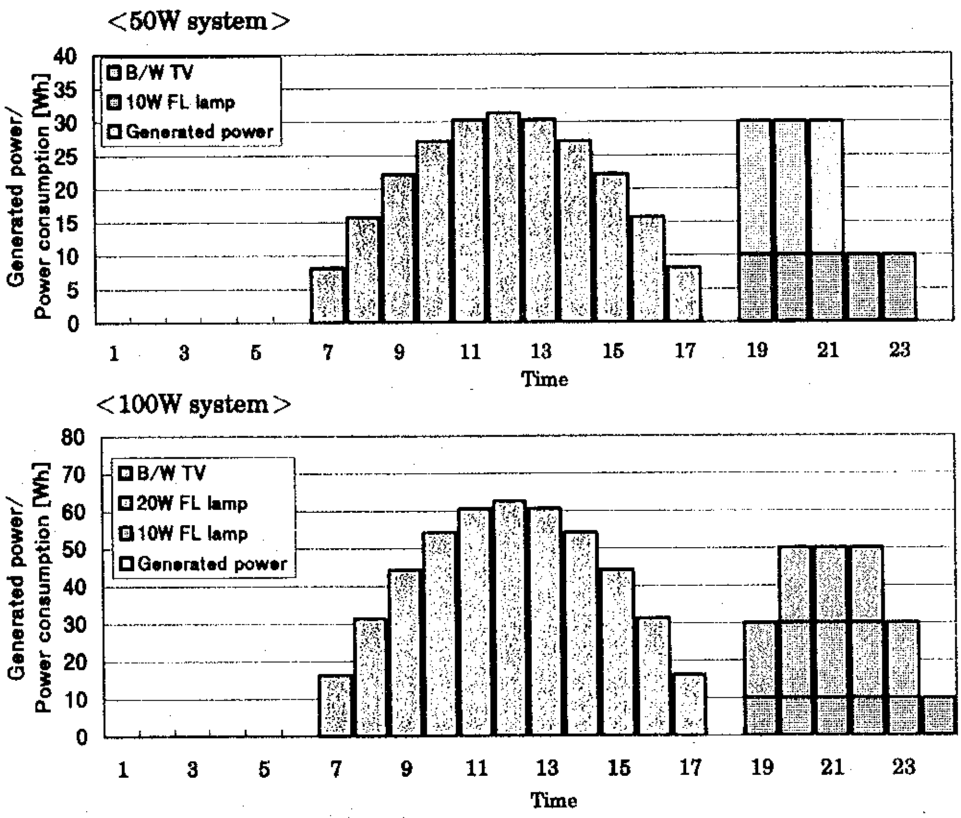


Figure 8-2-4 Example of operation pattern of basic system

(2) BCS

As a basic system, we recommend the capacity of the PV array to be 150W, and that it be able to charge a battery with a capacity of less than 80Ah. The basic BCS system consists of PV modules, support structure, breaker, controller and clips. Two basic systems are connected in parallel when charging a battery whose capacity is from 80 to 150Ah. One changeover switch is used when charging a battery whose capacity is from 80 to 150Ah.

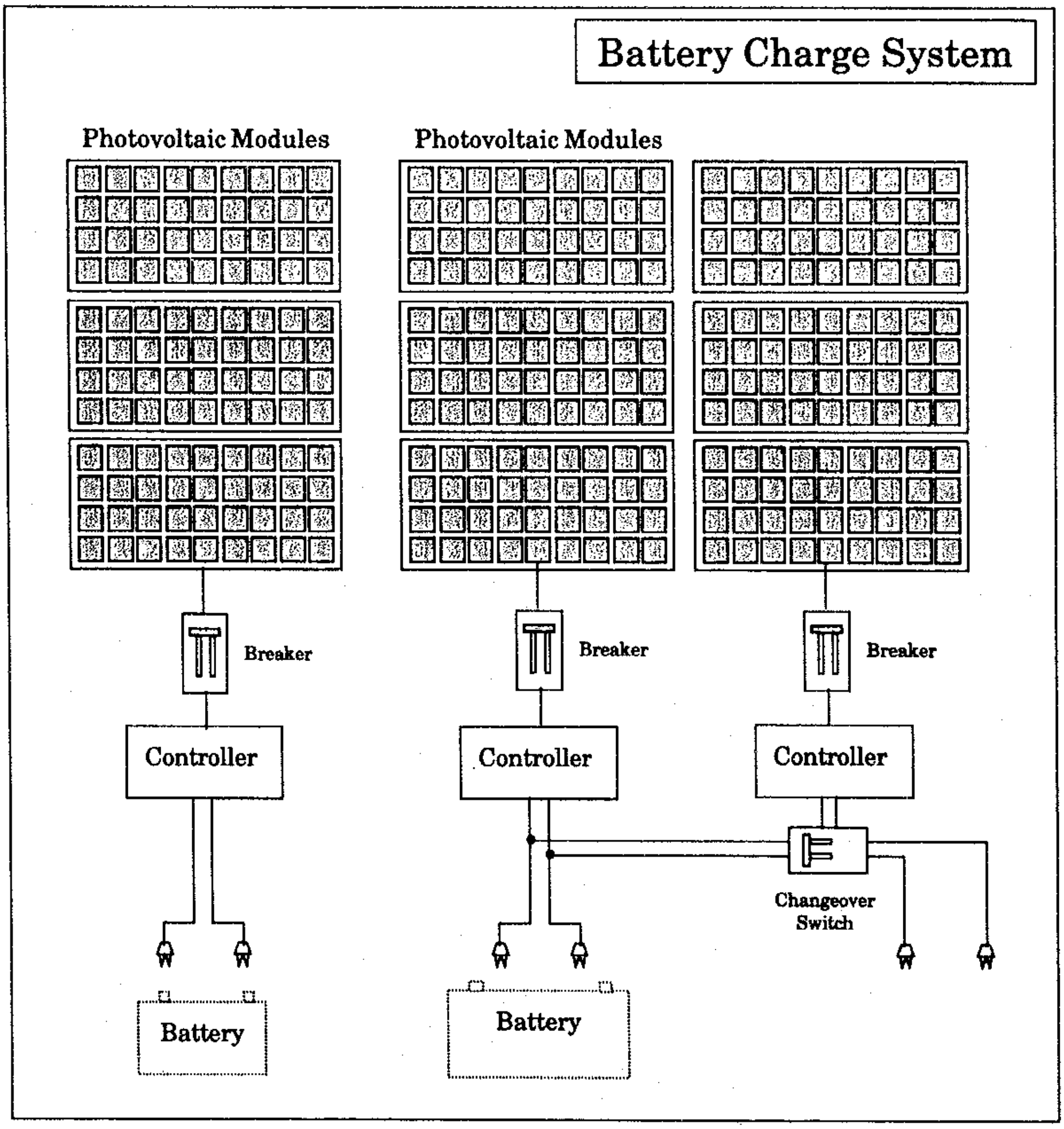


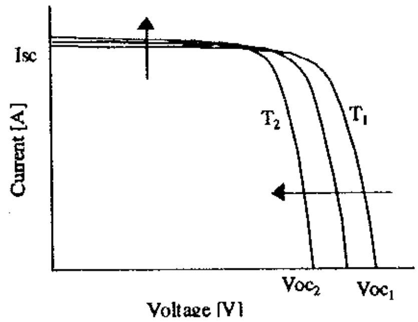
Figure 8-2-5 Image drawing of BCS

8-2-2 Points when selecting parts

(1) PV module

Generally the PV module made from silicon is used for power supply. PV modules made from silicon are classified as crystal and non-crystal types, and their electrical characteristics are affected by temperature. Specifically, voltage changes greatly and therefore, temperature characteristics should be considered when selecting the PV module.

Table 8-2-1 Temperature characteristic of PV module

Type		Temperature coefficient		Characteristic curve
		Voltage change	Current change	
Crystal	Single	-0.32 [%/℃]	+0.09 [%/℃]	
	Poly	-0.30 [%/℃]	+0.07 [%/℃]	
Amorphous		-0.36 [%/℃]	+0.10 [%/℃]	
Characteristic formula		$Voc_2 - Voc_1 = \beta \times (T_2 - T_1) \times Voc_1$ Here Voc_1 : Open voltage of PV module at T_1 (Standard T_1=25℃) Voc_2 : Open voltage of PV module at T_2		

The temperature of the solar cell relates to air temperature and insolation, and there are cases where the temperature on the surface of the cell surpasses 60℃ in the daytime during the summer. The voltage of a solar cell decreases when the temperature of a solar cell increases. For example, when the temperature reaches 60℃, the open voltage of a solar cell decreases by about 14%. Therefore, this voltage drop should be considered when designing a PV system that combines PV modules and a battery. As shown in the following formula, the voltage of the PV array at high temperatures should be higher than the voltage that adds up the voltage drop on the wire, voltage drop in the controller, and full-charge voltage of the battery.

$$Voc_2 > Vb + Vc + Vd$$

Where Voc_2 : Open voltage of PV module at T_2
Vb : Full charge voltage of battery
Vc : Voltage drop of inside of controller
Vd : Voltage drop between PV array and battery

(2) Battery

Lead-acid batteries are used with PV systems in general. There are two types of batteries, a vent type (liquid type) and a sealed type. The vent type battery needs maintenance such as adding water, but it has high reliability and is cheaper than the sealed type battery. The sealed type battery does not need water added. It is therefore being used with unmanned system.

Table 8-2-2 Comparison of characteristics of lead-acid batteries

Type	Vent type lead-acid battery		Sealed type lead-acid battery
	For PV system	For automobile	
Characteristic	For deep cycle charge	For high rate discharge	For low rate discharge
Maintenance	Need to add water	Need to add water	Free
Price	High	Low	Middle
Life expected	DOD 20% 7-10 y DOD 50% 1000h	DOD 20% 2-3 y DOD 50% 300h	DOD 20% 5-6 y DOD50% 700h

Notice: DOD = Depth of Discharge

When selecting the battery, combination with the controller should be considered. Because the full-charge voltage of battery differs a little by the type of battery, a battery whose voltage matches the voltage range of the controller should be selected.

(3) Controller

The life of a battery becomes short when overcharge and over-discharge are repeated. The controller is a device that detects the state of the battery and controls the battery voltage properly. There are two types of controllers: one type detects the current and the other detects the battery voltage. Generally, a controller which detects the battery voltage is adopted because it is cheaper than the controller that detects current. It is desired that the controller have protective functions against adverse current, reverse connection and large current, as shown in Table 8-2-3, let alone against overcharging and over-discharging. And some controllers have a function that automatically adjusts the battery voltage to temperature.

The controller should be selected with attention paid to the following points.

*Check what kinds of functions are needed.

*Check the internal power consumption rate. It should be small in the case of a small-sized SHS.

*Check the threshold voltages. The threshold voltages for overcharge and over-discharge should match the characteristics of the battery voltage.

Table 8-2-3 Function of PV system controller

Function	Explanation
Overcharge protection	Controller judges the state of full-charge and stops the power supply from PV array to battery when the battery voltage reaches the threshold voltage (overcharge voltage).
Over-discharge protection	Controller judges the state of over-discharge and stops the power supply from battery to load when the battery voltage reaches the threshold voltage (over-discharge voltage).
Adverse current protection	Controller protects against electric current flowing into the PV array from the battery at night.
Reverse connection protection for PV array	Controller disconnects the circuit and informs the user when a PV array is connected in reverse.
Reverse connection protection for battery	Controller disconnects the circuit and informs the user when a battery is connected in reverse.
Over current protection	Controller disconnects the circuit when a large current over the setting current flows from a battery with a short circuit on the load side.
Sensing	Controller senses the battery voltage using an exclusive line to compensate for the voltage drop between controller and battery.
Temperature compensation	As the battery voltage changes by temperature, controller adjusts to the proper voltage by measuring temperature.

(4) Lighting instrument

Generally, people who live in unelectrified villages use candles, kerosene lanterns and gas lanterns in the nighttime as lighting instruments. On the other hand, people who live in electrified villages use fluorescent lamps and incandescent lamps. According to a comparison of the luminous efficacy of these various lighting instruments, a fluorescent lamp shows the highest value. Therefore, it was found that the fluorescent lamp has a higher efficiency than the other lamps, and it is the most proper lamp for the PV system, which has limitations in electricity consumption.

A 10W or 20W fluorescent lamp is generally used in households that have a battery in local villages in Laos. The ballasts made in Thailand or China are used for these fluorescent lamps, but they are low in quality. As for other fluorescent lamps procurable in Laos, there are U- shaped power-saving FL lamps, t8W FL lamps used in the JICA pilot project, and the 10W FL lamps used in the EU project in Kasiya village. Therefore, lamps should be selected after finding out their characteristics.

Table 8-2-4 Performance comparison of various lighting instruments

Type of light source	Energy source	Rate of consumption	Total power [W]	Luminous flux [lm]	Luminous efficacy [lm/W]
Kerosene Lantern	Kerosene	0.05 l/h	488	100	0.21
Candle	Wax	7.20 g/h	72	16	0.22
Pressure Lamp	Kerosene	0.08 l/h	813	1300	1.60
Gas Lamp	LPG	34.00 g/h	425	1000	2.35
Incandescent Lamp	Electricity	100 W	100	1200	12
Halogen Lamp	Electricity	25 W	25	500	20
Fluorescent Lamp	Electricity	13 W	13	585	45

Source : Rural Lighting, IT Power and Stockholm Environment Institute

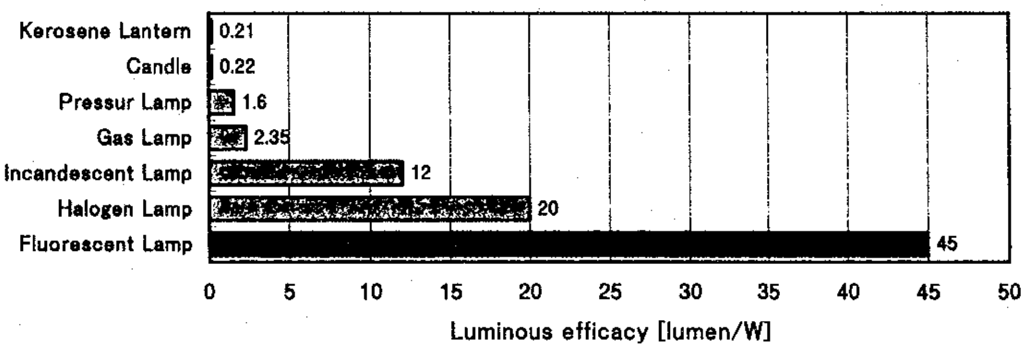


Figure 8-2-6 Comparison of luminous efficacy of various lighting instruments

Table 8-2-5 Comparison of fluorescent lamps that are procurable in Laos

Type	Characteristic	Price (USD)	
		Body	Tube
Goods on the market :10W	*Procurable in the local market *Low quality *Large energy loss	2.0	1.0
U shaped lamp: 11W	*Procurable in the local market *Need to replace all when broken down, because body and tube are jointed.	19 (Germany)	
Made in Europe: 10W	*Expensive because it is imported *Possible to use a tube found on the market	34.5	1.0
Used in pilot project: 8W	*Expensive because it is imported *Need a special tube, but procurable at a few shops	28.0	2.0

8-2-3 Replacement of parts

On the life of the PV system, it is said that PV modules and cable last for 20 years, controllers 10 years, the lifespan for a battery designed for PV system is around seven years, and a battery for an automobile lasts two to three years. Problems with parts such as the controller, switch and lighting instrument appear clearly. Therefore it is possible to work out countermeasures such as replacement and repair early. But the characteristics of a battery deteriorate gradually by repeated charge and discharge. Therefore the life of a battery should be judged by a technician who is trained fully with consideration of weather conditions and the operation status of the PV system. This section explains battery replacement and spare parts.

(1) Judgement of battery life

The deterioration of a battery is recognized by users because the usage hours of electrical appliances become shorter than before. At this time, a battery shows the following characteristics:

*Specific gravity of the battery electrolyte does not increase even if the battery is charged fully.

*Difference of the specific gravity in each cell is large.

*Battery liquid decreases quickly.

*Difference of the volume of battery liquid in each cell is large.

*The voltage drop when load is connected or charge is stopped is larger than before.

*Battery temperature is unusually high compared with the ambient temperature.

As general judgement methods, measuring specific gravity and battery voltage are used.

1) Specific gravity

The specific gravity of electrolyte of the batteries used in the pilot system is "1.28". By repeating the charge and the discharge, the specific gravity comes down gradually, and the difference of specific gravity values between each cell becomes large. At this time, the battery should be charged fully and its specific gravity should be checked. If the specific gravity does not recover to the initial value, the battery should be judged to be dead. The specific gravity must be measured with attention paid to the handling method of the measuring instrument and the methods of measurement.

2) Battery voltage

The internal resistance of a battery increases as deterioration of the battery progresses. The battery voltage decreases rapidly when the charge is stopped or the load is connected. When judging the life of a battery, at first, a battery should be charged fully in one or two days on sunny day. Then the battery's voltage during charging is compared with its voltage level five minutes after charging has stopped. The voltage drop of a new battery is around 10%. Therefore, the life of the battery can be judged by comparing the value of voltage drop, and checking the usage of the battery in the past. For judging battery life correctly, it is important that items such as specific gravity, frequency of adding water, and battery voltage are measured constantly and recorded. The procedure to judge the life of a battery is shown in Figure 8-2-7.

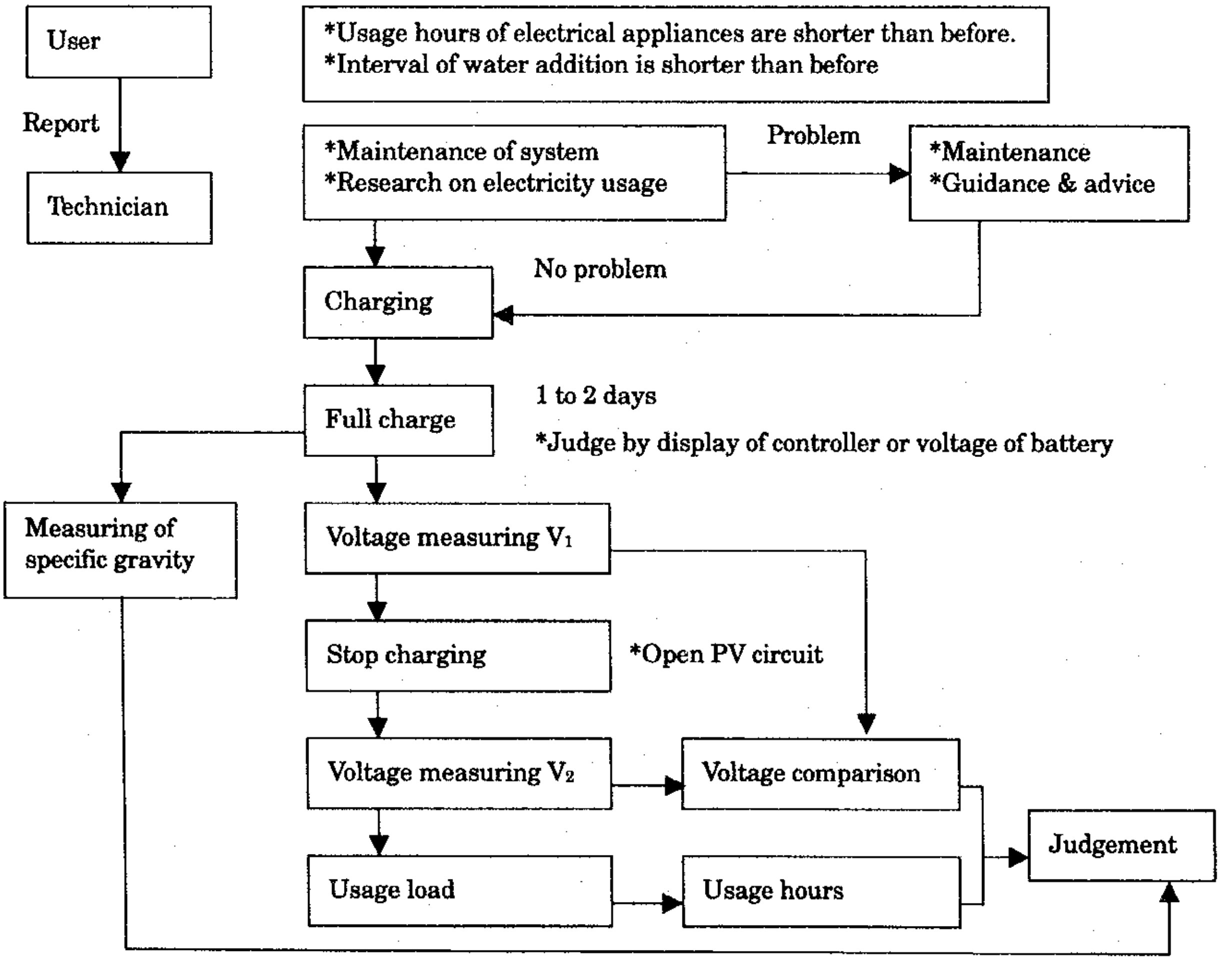


Figure 8-2-7 Process to judge the life of a battery

(2) Spare parts

In the stand-alone PV system, even a simple problem such as controller fault or a cut cable can cause the system to stop. When troubles and faults happen, it is desirable to replace the parts or repair them quickly. To do so, main parts such as the PV module and the controller should be stored by the government, and should be replaced under the supervision of the local engineer as the occasion demands. Other materials should be stored in the village because these materials can be procured in the local market. And these materials should be replaced by the local technician as the occasion demands.

Table 8-2-6 List of spare parts recommended

	Storage place	Materials	Volume
S H S	Government (Central & local)	PV module	0.4% of all
		Controller	4% of all
	Village	Wire	One roll
		Switch and plug	4% of all
		Fuse	10% of all
		Ballast of FL lamp	4% of all
		FL tube	10% of all
B C S	Government (Central & local)	PV module	0.4% of all
		Controller	4% of all
	Village	Cable	One roll
		Breaker	4 % of all

8-3 Improvement of operation and maintenance technology

Through design, construction and evaluation of the pilot project, we executed a technology transfer on photovoltaic technology to our counterpart, and we also executed technical training on the methods of inspection and maintenance for engineers of the VEC by holding workshops at the site. The following things should be considered for the purpose of promoting rural electrification in Laos by PV system.

*Establishment of a system for technical training and communication

*Preparation of technical manuals

*Execution of periodic technical training

8-3-1 Preparation of technical manuals

A technical manual for SHS and BCS was formulated through discussions with the counterpart on the basis of the proposed standard solar system. (See Attachment) This manual shows system configuration, installation method, inspection and maintenance method, trouble-shooting and precautions. It has been translated into Lao. To support the spread of PV systems in the future, the manual will be distributed to local technicians and local engineers. It will contribute to assuring proper operation and maintenance of PV systems, and to their long-term sustainability.

8-3-2 Plan of technical training

The technological progress of PV system is fast, so it is important to collect the latest information and to learn new technology constantly, and these results should be noted by each engineer. To that end, it is desirable to execute technical training and to exchange information with each other constantly based on a long-term plan.

(1) Project manager

The engineers belonging to MIH/DOE take charge of managing PV projects. The project manager is the technical leader who introduces and promotes the spread of PV systems, and is required to have wide knowledge from system design to inspection and maintenance. Through the pilot project, the technology transfer to our counterpart has been completed. However to maintain this technical level and acquire new technology, the following things should be constantly carried out.

*Lecture by experts

*Attend training by international organizations

*Collection of technical information

*Research of products

*Exchange of information with related organizations

(2) Local engineer

The engineers of the MIH province office and ESCO are defined as "local engineers", and they should provide the following services.

*Technical support to PV systems

*Technical training to local technicians

*Repair of trouble that local technicians can not cope with

*Supply of spare parts, etc.

The local engineers are required to have a high level of technological background, and it is desirable to train them by an exclusive training course. The local engineers should be trained not only by the exclusive training course, but also by the project manager about once a year. If a PV system is installed in the office of local engineers, it will be useful for the improvement of technology through the system management and technology transfer to new engineers. Also, this system can be used as a demonstration for surrounding unelectrified villages and as a training tool for local technicians.

(3) Local technician

The members of the village committee are defined as "local technicians". About three technicians were selected at each pilot village. It is difficult for local engineers to frequently go to the site and inspect PV systems because road conditions in the rural areas are so bad. So it is desirable to solve simple troubles in the village. Therefore, knowledge, such as installation, inspection and maintenance, identifying faulty parts, and resolving problems, should be required of local technicians. They should receive hands-on training on the above items from local engineers. Also, it is desirable that local engineers visit the site at least twice a year and continue training local technicians to improve their capabilities.

(4) User

Before starting the operation of PV systems, an operation manual should be handed over to users, and local engineers should explain the methods of inspection, maintenance and operation of PV systems. Local engineers are supposed to give instructions and advice to users when problems occur.

Table 8-3-1 Contents of technical training

Contents of technical training	Local Engineer	Local Technician
Lecture		
*Outline of PV system	O	O
*Principle and basic characteristic of solar cell	O	
*Role and function of equipment of PV system	O	O
*System design	O	
*Installation method of PV system	O	O
*Operation method of PV system	O	O
*Inspection and maintenance method	O	O
*Troubleshooting	O	O
*Monitoring method	O	O
*Project and system management method	O	
Practice		
*Characteristic test of solar cell	O	
*Installation of PV system	O	O
*Inspection and maintenance	O	O
*Replacement of parts	O	O
*Troubleshooting	O	O
*Measurement – Voltage	O	O
–Current, Specific gravity, Temperature	O	

8-4 Disposal of Batteries

Battery is important for storing energy for PV system. But as batteries contain a toxic substance, proper disposal is desired. The handling method for dead batteries should be discussed in anticipating the spread of PV systems in the future. We investigated the handling situation and related laws on battery disposal in Japan and Laos, and we proposed a proper method for the disposal of batteries in Laos.

8-4-1 Situation in Japan

In Japan, based on the "Law on Treatment of Waste and Cleaning" established in 1994., the Ministry of Health and Ministry of International Trade and Industry asked battery manufacturers to develop procedures for disposing of dead batteries. The Battery Association of Japan announced a "recycling program" and developed a recycling project for batteries. This program established a mechanism to collect used batteries, and it is said that the recycling rate of car batteries is over 94%. Waste plastic is recycled or reclaimed, and waste acid or waste alkali is discharged into rivers after proper treatment.

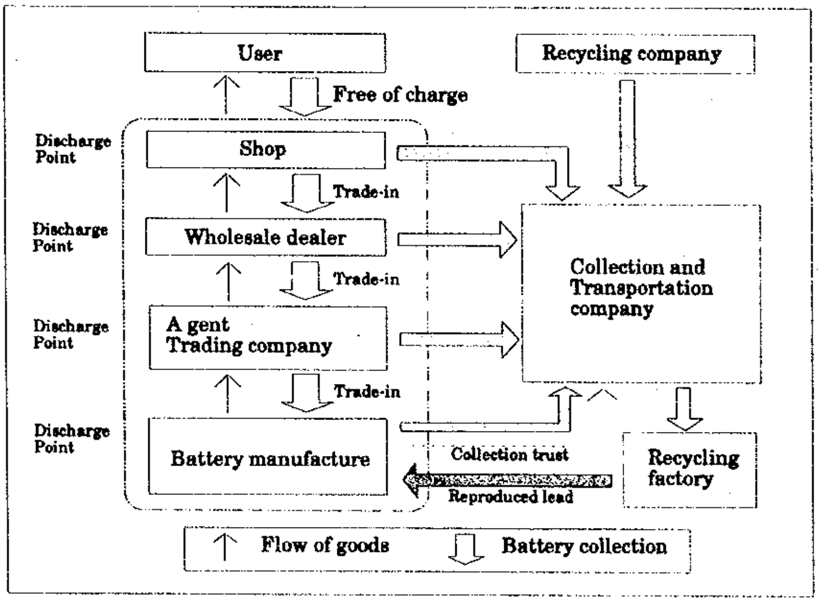


Figure 8-4-1 Collection flow of batteries for disposal

8-4-2 Situation in Laos

In 1999, STEA played a central role in establishing the "Law on Environment Protection". This law provides the methods and rules which are needed for protection, relief and recovery of the environment, and shows the basic principles related to the protection of the environment. This law deals with batteries as a kind of waste, and it shows that batteries should be separated from normal waste and treated. But at present, there is no treatment factory for used batteries in Laos and there is no plan to construct one. Also, it is not decided which organization is in charge. Therefore, the treatment of used batteries is left to private companies at present. Batteries are mainly used for cars and motorcycles. In addition, they are often used as a power supply for hunting lights at the local level and are charged in battery charging shops regularly.

An interview survey on the treatment method of dead batteries was conducted. There are some recycling shops in Vientiane, and they buy dead batteries, take them apart and sell some parts. On the other hand, in local areas, there are several cases in which dealers come to buy dead batteries and users treat batteries by themselves.

Table 8-4-1 Treatment of dead batteries in Laos

	Findings in the interview survey
Recycling shop in Vientiane	*They buy a dead battery from user for around 200kip/Ah. *Collected batteries are separated into "electrode parts" and "plastic parts", then "electrode parts" are sold to a dealer for around 220kip/Ah. *Battery waste liquid isn't treated properly, and it is thrown away.
Paksoun	*They burn dead batteries and take the metal, then they sell metal for user as fishing weights.
Chout 3 village	*A battery charging shop buys dead batteries. 100kip/Ah
Namai	*A recycling shop visits villages regularly to buy dead batteries. 50Ah-3,000kip, 6V-500kip
Houaypong	*A recycling shop visits village regularly to buys dead batteries. 70kip/Ah

8-4-3 Countermeasure

There is no battery production factory in Laos, and batteries are imported from Thailand and other countries. Therefore, there is little demand for reproduction of lead in this country, and the construction of recycling systems like those in Japan seems to be difficult. In the treatment of used batteries, it is required that the government take a leading role and develop a treatment mechanism. But at present, there are no discussions on creating a system because the demand for batteries is small and there are few problems with used batteries.

In this way, it is thought that treating used batteries will be difficult in the near future. But there are some recycling shops in Vientiane and they sell metal and plastic taken out of used batteries to neighboring countries. Therefore, it is thought that to construct a battery treatment mechanism using the recycling shop is proper and realistic. A flow chart for the collection of dead batteries in the near future is proposed in Figure 8-4-2.

< Battery collection flow >

*The village committee collects used batteries for disposal and stores them properly.
*The village committee contacts a recycling shop.
*The recycling shop buys batteries for disposal, takes them apart and disposes of them.
*The government checks whether the batteries for disposal are collected and disposed of properly or not.

At present, as battery waste liquid is being discharged without treatment, the government should guide dealers in the proper disposal of batteries.

But when the price of recycled lead drops due to over supply as the number of batteries for disposal increases, there is some possibility that the recycling system will no longer be viable. Accordingly, it is desirable to establish a treatment system for the disposal of batteries under the leadership of the government. In this case, it is also important to collect the batteries for disposal correctly through the village committees which are to be organized based on the results of the JICA pilot project. Lastly, the collected batteries should be treated under the control of the government.

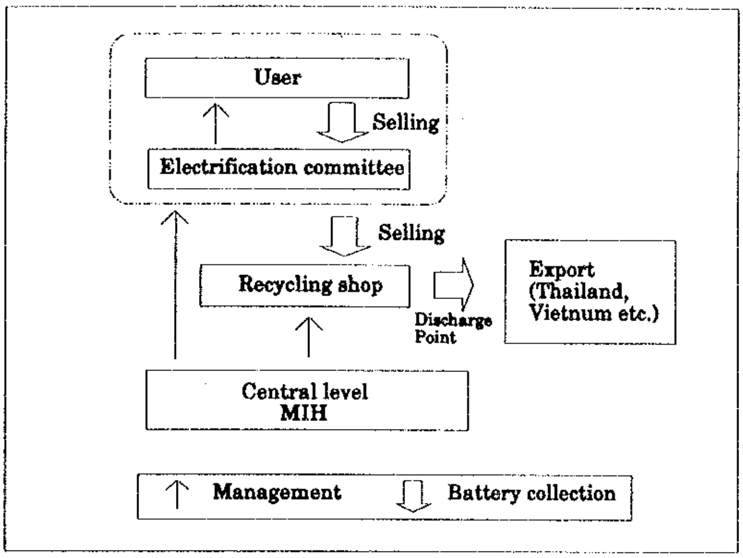


Figure 8-4-2 Draft of collection flow of batteries for disposal (Short-term)

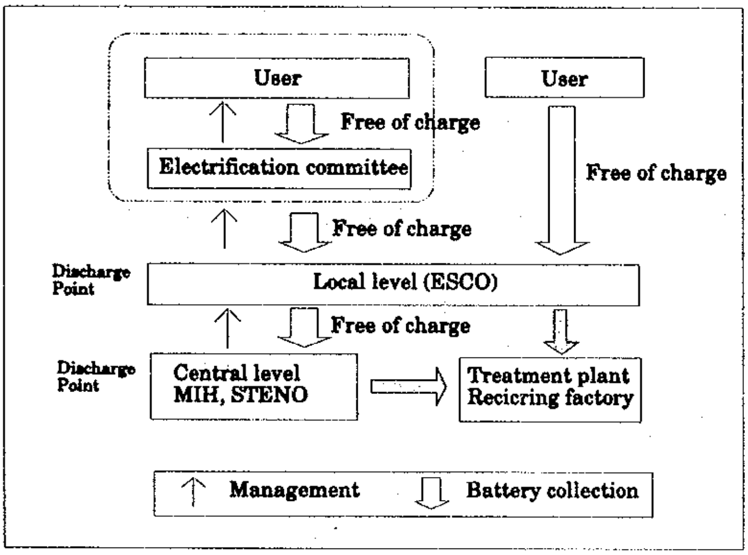


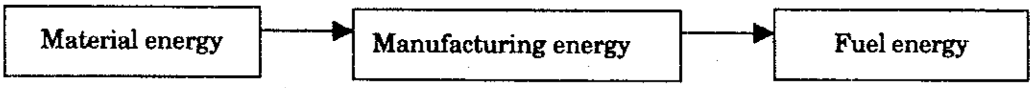
Figure 8-4-3 Draft of collection flow of batteries for disposal (Long term)

8-5 Comparison of CO_2 Emissions

It is said that renewable energy such as solar and small hydro is environmentally friendly, because solar and small hydro do not generate carbon dioxide. However, solar and small hydro also exhaust carbon dioxide during the manufacturing stage. In this section, the amount of CO_2 emissions per kWh of solar system, small hydro, and diesel generator are compared. Electricity demand for one village (50 households) is assumed to be 2,220kWh/year, or 44.4kWh/household-year, which is the same as in the pilot project.

8-5-1 Analysis Method

To estimate CO_2 emissions, the energy input to each system is divided into three categories: energy for materials (material energy), energy for manufacturing (manufacturing energy), and energy for fuel (fuel energy).



In the case of small hydro and diesel generators, the material energy is the energy used to produce steel. In the case of solar, it is the energy to produce silicon and steel. The manufacturing energy is the energy necessary for converting materials into products. The fuel energy of diesel is diesel fuel. In the case of solar, fuel energy means battery.

8-5-2 Assumptions

In this analysis, all emission coefficients are taken from Japanese data. Each emission coefficient is as follows.

Electricity	93g-C/kWh
Crude steel	520g-C/kg
Silicon	189g-C/Wp
Machinery manufacturing	127g-C/kg
PV Module manufacturing	210g-C/Wp
Diesel fuel	855g-C/kg (fuel production to combustion)
Battery	329g-C/piece

8-5-3 CO_2 Emission of Diesel Generator

The capacity of a diesel generator for 50 households is assumed to be 5kW. The weight of a 5 kW generator is about 100 kg. As the fuel efficiency of the generator is 20%, and the fuel consumption per kWh is 0.43kg/kWh. CO_2 emissions of the diesel generator over 20 years are shown in Table 8-5-1.

Table 8-5-1 CO_2 emissions of 5kW diesel generator

	Formula	g-C
Material energy	100kg×520g-C/kg	52,000
Manufacturing energy	100kg×127g-C/kg	12,700
Fuel energy	2,220kWh/y×20 years×0.43kg/kWh×855g-C/kg	16,323,660
Total CO_2 emissions		16,388,360
CO_2 emission/kWh	16,388,360g-C÷2,222kWh/y÷20 years	369g-C/kWh

8-5-4 CO_2 Emissions of Small Hydro

A small hydro power facility mainly consists of steel pipe (penstock), a turbine and generator. The capacity of a small hydro we designed in this study is around 25 kW. This facility can supply electricity to approximately 150 households. As the length of pipe is assumed to be 100 m, the weight of the pipe is 6,000 kg. The weights of the turbine and the generator are 300 kg and 200 kg respectively. In the case of small hydro, fuel energy is not necessary to consider. From these assumptions, CO_2 emissions for the small hydro over 20 years are shown in Table 8-5-2.

Table 8-5-2 CO_2 emissions of 25kW small hydro

	Formula	g-C
Material energy	6,500kg×520g-C/kg	3,380,000
Manufacturing energy	6,500kg×127g-C/kg	825,500
Total CO_2 emissions		4,205,500
CO_2 emissions/kWh	4,205,500g-C÷44.4kWh/y-house÷150 houses÷20 years	31g-C/kWh

8-5-5 CO_2 Emissions of Solar System

Assumptions for the solar system are 50W module capacity, 10 kg weight for the balance of system (BOS) excluding battery, and one battery for one system. The battery will be replaced every two years. CO_2 emissions of the solar system for 50 households over 20 years are shown in Table 8-5-3.

Table 8-5-3 CO_2 emissions of 50W Solar System

		Formula	g-C
Material energy	Module	50Wp/set×50sets×189g-C/Wp	472,500
	BOS	10kg/set×50sets×520g-C/kg	260,000
Manufacturing energy	Module	50Wp/set×50sets×210g-C/Wp	525,000
	BOS	10kg/set×50sets×127g-C/kg	63,500
	Battery	10peices/set×50sets×329g-C/kg	164,500
Total CO_2 emissions			1,485,500
CO_2 emissions/kWh		1,485,500g-C÷2,220kWh/y÷20 years	33g-C/kWh

8-5-6 Results of Comparison

According to the analysis of CO_2 emissions, emission volumes per kWh of small hydro and solar are almost the same (See Figure 8-5-1). On the other hand, the emission volume from a diesel generator is more than ten times that of small hydro and solar.

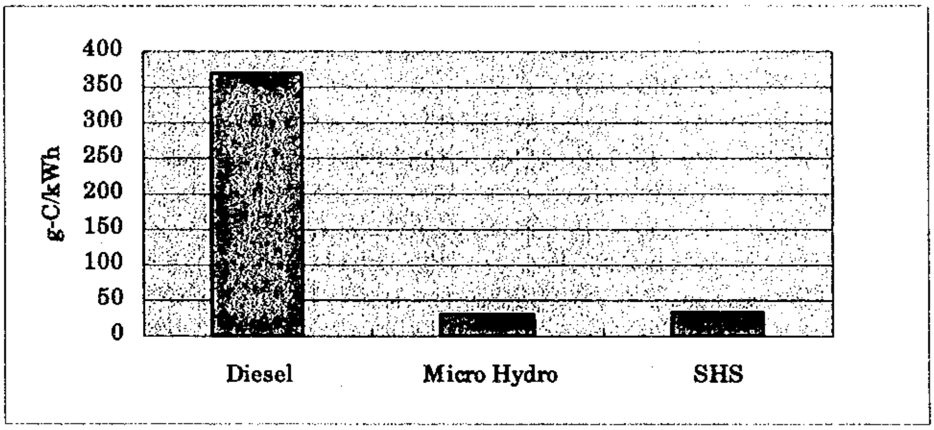


Figure 8-5-1 Comparison of CO_2 emissions of each system

Chapter 9

Rural Electrification Master Plan

9-1 Goal of Rural Electrification

Electric lighting, which is far brighter than kerosene lantern, undoubtedly gives a strong impact on people's lives in remote areas of developing countries. It helps rural families work and study at night and earn more money. Also, it helps them get more information from TV or radio. Unfortunately, rural electrification has been done only in very limited cases in Laos, because electrification projects have mostly centered on populated areas. The widening gap between the living standards of cities and rural areas in Laos has been giving strong pressure to the Lao government to take necessary measures for rural development. Rural electrification is one of the priorities in the menu of rural development. In the power sector today, more emphasis is placed on domestic power supply. The target of rural electrification stated by the Lao government is to supply 90% of the population by the year 2020.

The biggest reason for the slow progress of rural electrification in Laos in the past is financial difficulty. Grid extension or developing diesel plants, which has been the conventional method of rural electrification, cannot generate enough cash flow from rural users to recover investment and running costs. Assistance from the outside authorities is mandatory in form of grant or subsidy. EdL is responsible for electricity network development, but they are reluctant to undertake rural electrification projects because they are now streamlining its operations to improve the profitability. Although the target of rural electrification was set as high as 90% of the population by the 2020, there is no organization to implement rural electrification projects aggressively.

In 1997, the Lao government legislated the Electricity Law, and liberalized small-scale (under 100kW) power development. Various types of organizations, such as private companies, individuals, cooperatives, can develop small-scale power plants by getting permission from province/district level authorities. This means that the Lao government wants to accelerate small-scale power development, which is suitable for rural electrification, by utilizing the resources of various organizations. The related provisions of the Electricity Law are shown in the following.

Chapter II (of the Electricity Law)

Article 9: Sizes of Electricity Enterprises

Electricity enterprises in the Lao PDR are divided into four sizes as follows: (1.2 omitted)

3. Electricity with an installed capacity of more than one hundred (100) - two thousand (2,000) kilowatts is approved by the provincial, prefectural or special zone administrative authorities according to approval from the Ministry of Industry and Handicraft.

4. Electricity with an installed capacity of less than one hundred (100) kilowatt is approved by the district administrative authorities with the approval of the province, the prefecture or the special zone.

Chapter IX

Article 39: Approval to establish an Electricity Enterprise in a Locality or in Rural Area

The provincial, prefectural, or special zone industry and handicraft division will conduct surveys and collect information relative to small scale physical sources of electrical energy with power generating capacity of one hundred (100) to two thousand (2,000) kilowatts to incorporate such into the local electricity building and development plan within the areas of its administrative authority.

The provincial government, the prefecture mayor or the chief of the special zone shall be the party which approves applications to establish electricity in the locality within their area of responsibility according to technical approval from the Ministry of Industry and Handicraft.

The district industry and handicraft bureau shall conduct surveys and collect data relative to physical electricity energy sources within the areas of their administrative control. The district chief shall approve applications to establish rural electricity according to the technical approval of the provincial, prefectural or special zone industry and handicraft division.

Article 41: The fund to Develop Electricity in the Localities and in Rural Areas

The State establishes a fund for assistance and for loans for carrying out works in building, installing and developing electricity in the locality and in rural areas.

The Fund for Developing Electricity in the Localities and in Rural Areas comes from the following funding sources.

1. The State budget
2. The State and the people
3. The people
4. Domestic and foreign assistance

In addition, the State may have a policy if exempting or minimizing taxes and duties, proving import credits for vehicles and equipment, for construction and for electricity operations in the localities and in rural areas.

However, necessary policy measures, such as financial assistance or tax incentives, to facilitate small-scale power development are not developed yet. Without such assistance, it is difficult to promote the development of small-scale power plants, because, in general, such plants usually have economic disadvantages. Small-hydro has a high capital cost, and diesel generators have high O&M cost. Although the Electricity Law built a foundation to accelerate off-grid development, it is unlikely that many projects will start in the near future. Under this situation, the Lao government began to consider using solar power technology (photovoltaics; PV) as an alternative to the conventional small-hydro or diesel power to supply a minimum level of electricity to those who live in darkness.

The production cost of solar panels is continuously decreasing and other PV system components are also getting cheaper and becoming more reliable. PV, therefore, is viewed as very promising for rural electrification both technically and financially. In developing countries, the number of solar system users is increasing rapidly. The PV market is growing, which pushes price reduction of PV system and further demand creation. Now, it is good timing for the Lao government to undertake a detailed study on the feasibility of introducing solar systems into Laos. And if it turns out to be feasible, the Lao government is required to develop a comprehensive plan to implement solar-based rural electrification projects all over the country.

Small-hydro power also uses renewable energy resources. It can supply alternate current (AC), which is more useful than direct current (DC) from a solar system. On the other hand, it is more dependent on geographic conditions, because water head and discharge are needed. In contrast, solar systems can be installed almost everywhere. Also, hydropower system operation requires a higher technological base than solar system. This makes small-hydro development more difficult in remote areas. Although hydropower may have such disadvantages, its development near inhabited areas should be pursued to the fullest extent because the target areas of rural electrification are located in mountainous regions which are generally rich in hydro resources. There are possibilities to achieve cost reduction in small hydro development by introducing simple design and standardization.

The following discussions are mainly based on the results of the JICA pilot project and aiming at promoting rural electrification by solar power.

9-2 Focal Points

In order to formulate a mid- and long-term rural electrification plan, there may be three different viewpoints: economics, technology and organization. To establish a feasible master plan, it is necessary to show that sustainability is secured on all of these points. If one of these factors is inadequate, the development of electricity supply facility would eventually fail. There have been many such cases in the past where power plants stopped operation and never went back to normal because of inadequate operation and maintenance. Therefore, it is very important to check the sustainability of the project beforehand.

The most important economic issue is "cost recovery". In principle, rural electrification costs should be borne by users (rural villagers) to avoid reliance on aid from the outside. To develop an affordable tariff and to secure cash-flow for 100% cost recovery is the ultimate goal. Shortage of income will result in poor system maintenance and system stoppage in the end.

There many technological issues, but the theory is to use appropriate technology for remote areas. In particular, methods of maintenance should be viewed as first priority in selecting design and equipment for rural electrification projects. Simple design for easy operation and maintenance is the key to success, because skilled technicians, who can fix technical problems, are difficult to get in remote villages.

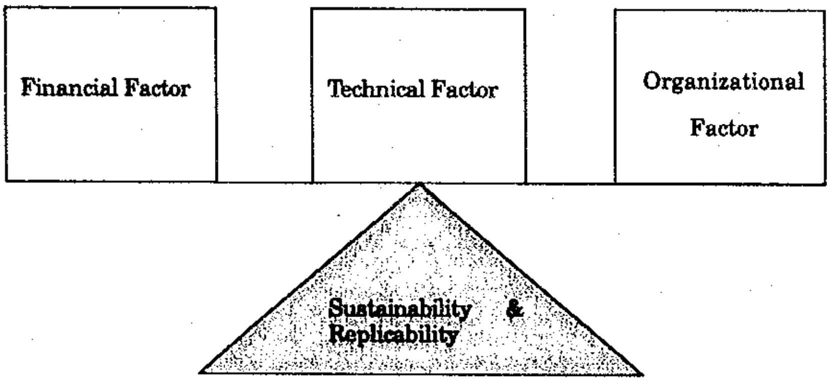


Figure 9-2-1 Three key aspects of rural electrification

Organizational consideration is also important to design a feasible rural electrification plan. Two kinds of organizations need to be studied; one is the organization, public or private, to implement rural electrification projects (service provider), and the other is the organization of beneficiaries (user). The user organization is expected to play a key role in financial management (fee collection) and technical management (maintenance) of PV systems, which will reduce overall running costs. Also, how to motivate people to establish and manage such organizations is very important and requires a careful examination. To better understand social and economic aspects of rural Laos is necessary to develop a workable organizational structure for rural electrification.

In order to develop a master plan for solar-based rural electrification, it is necessary to show concrete ideas for those three issues. We always need to check the feasibility of proposed ideas by asking " Is this system sustainable for long time?" or "Is this system replicable in other areas?"

9-3 Rural Electrification by Renewable Energy

9-3-1 Evaluation of Solar System

Penetration of solar systems into Laos depends largely on people's acceptance. In particular, tariff and required operation/maintenance are most important issues. The results of this JICA study suggest that solar systems are well received by rural people and hence will spread in the remote areas of Laos in the future. Local people showed that they can afford, and also operate and maintain their PV systems as long as certain requirements are met.

(1) Economy

As for the economic issue, the biggest concern among villagers is tariff, initial payment and monthly charge. Basically it is important to adopt the principle of setting tariffs to cover all the incurred costs. Government subsidy should not be considered. As the price of a solar home system (SHS) is going down, a typical 50W system would cost about $300 (customs duty exempted) by 2005. With this price, combined with a long-term lease mechanism, solar home systems will become affordable to many rural villagers. Of course, average local people cannot afford it if no installment plan is offered. They need some arrangement such as an installment plan or a long-term lease in order to make the monthly payment below the level they can pay. In this study, we confirmed to what extent they are willing to pay for a solar system. A standard tariff schedule that has $20 as the initial charge and $1.50 as the monthly charge respectively was accepted. It can be pointed out that the demand for electricity is so high that they are willing to pay more than their current energy expenses.

To promote solar systems in remote villages in Laos, it would be recommended to set the monthly tariff below $2.00. To achieve this goal, introduction of a long-term lease, a

20-year lease for example, would be necessary. Thanks to recent technological improvements, solar systems require only limited maintenance and their running costs are very small. The dominant cost component is the initial investment. The 20-year lease is very long and will not be acceptable in a practical sense. Private entities will show little interest; hence, the public sector, which can obtain long-term funds and aid from other countries, is expected to play a major role at the initial stage and then gradually hand over responsibilities for solar systems to the private sector.

As for the battery replacement cost, we decided not to include it in the tariff because people will abuse their batteries if the replacement cost is included. Each user is supposed to replace batteries on his own. In this case, a car battery, which is available even in remote areas and much cheaper than a solar battery, will be used. Although a solar battery which is specially designed for solar systems is better than a car battery in terms of quality and product life, it is far more expensive. Its life is long, but its long-term cost is higher than that of car battery. Therefore, car batteries would be recommended for rural electrification.

Battery Charging Station (BCS) is another type of solar system. With BCS, users must carry their batteries for charging, which is not convenient. BCS, therefore, needs to have a lower fee than SHS, which will be possible because fewer solar panels are required than in the case of SHS. BCS has some advantages. For example, people can change the frequency of charging depending on their income. On the contrary, SHS has one fixed charge regardless of the user's income. Its pricing is not flexible. In rural areas of Laos, battery charging service is common. In some cases, they charge as much as 2,000 kip for one-time charging. It may be possible that the private sector would develop BCS commercially, because with such pricing the initial investment can be recovered in less than ten years. Therefore, private investors or entrepreneurs may consider investing in BCS at an early stage. The Lao government will need to provide necessary assistance to promote commercial development of BCS in remote areas.

One important issue relating to tariff is the collection system. In this study, we prepared a SHS lease contract form written in Lao, not a verbal commitment, and asked each applicant to sign the contract to make him understand his responsibility to pay the tariff every month. Furthermore, for the tariff collection and record keeping we subcontracted the Village Electrification Committee (VEC) with a small amount of commission. This system has been working very well. On the other hand, BCS needs a more business-like arrangement. We signed a contract with VEC based on an assumption that VEC will act as the operator of BCS and try to get more customers and coordinate the BCS-sharing scheme among users. So far, the tariff collection ratio has reached surprisingly over 95%. It can be said that this formal contract procedure is important to ensure people's commitment to pay.

One good point of the long term leasing system is that it meets the requirements of grant project, which is most likely in case of early rural electrification. Grant project, in general, requires the (Lao) government to hold facilities and equipment, which are provided from donor, and not to give them to individuals. Leasing is better in this sense than installment.

(2) Technology

As for technology, the basic specifications of SHS have been proposed based on the results of the pilot project. In rural areas of Laos, 50W class SHS combined with controller and regular size (70Ah) lead-acid battery is recommended. There is ample room for cost reduction in the future. SHS is composed of small components, so that it can be installed by the user. BCS, on the contrary, has a large structure and requires skilled workers for installation. Local Lao contractors have demonstrated that they can do this job.

There are many people in the remote areas who are now using batteries as a means of electricity supply. Wide-spread experience of handling batteries facilitates technology transfer for the operation and maintenance of solar systems. A solar system has no moving parts, which makes its daily operation and maintenance easy. This point is important in the case of rural electrification. In our experience with the pilot project, it has been proven that rural villagers can operate and maintain solar systems properly on their own. In particular, the quality of electronic controllers has been improved significantly, enabling easy handling (almost maintenance-free) and reliable operation of solar systems. Each user must check battery liquid and connections regularly. All these tasks can be easily undertaken if well-organized manuals and guidance from the VEC members are available.

Thus it would be possible to create a situation in which every user can be responsible for his solar system. Also, it is very important to store sufficient spare parts, such as fuses and fluorescent tubes, for saving maintenance costs. In case of serious malfunctioning such as failure of controller or damage to solar panel, the only measure to cope with these problems is to replace the damaged item with a new one. In this regard, it is also important to keep spare parts. Replacement work requires no special knowledge or expertise.

(3) Organization

The organizational issue has two different aspects. One is the organization for the implementation of rural electrification projects. The other is the organization on the user side. Even in Laos, EdL is now undergoing the streamlining of its operations to achieve a sound financial structure. Under these circumstances, it is becoming more and more difficult for EdL to promote rural electrification on their own initiative. Although EDL recognizes the urgent necessity of providing lighting and power in remote villages, they decline to invest because their financial condition will get worse if they undertake rural electrification projects. In many developing countries, rural electrification, which is regarded as a high priority issue, is separated from the power business and is being promoted by the government. Thailand, Indonesia and the Philippines fall into this category. (See Figure 9-3-1)

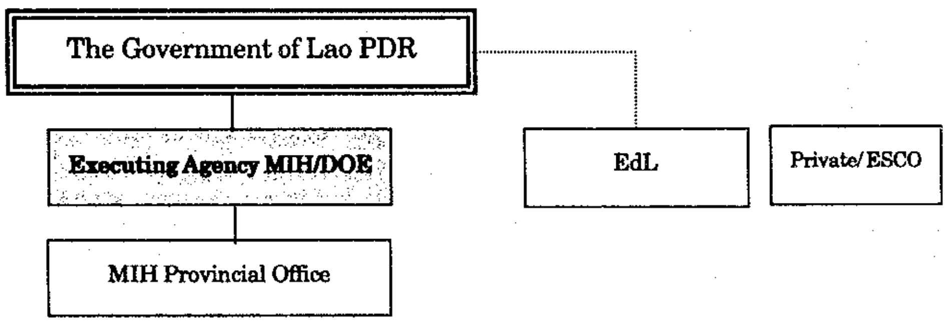


Figure 9-3-1 Organizational framework on rural electrification

At the moment, it is difficult for EdL to become the central organization which will implement rural electrification projects. Instead of EdL, MIH/DOE is expected to play a key role taking advantage of expertise gained in the pilot project. Gradually MIH will hand over its authority to local governments and the private sector to accelerate rural electrification. This idea matches the assumption that in the early stage of rural electrification the public sector is supposed to implement projects which will be, most likely, funded by grant aid from foreign countries. Of course, private sector involvement in some limited cases will be possible and strongly supported. And in the long run, it is expected that the income of villagers will grow and the private sector, or ESCO, will be dominant in providing PV-based electricity supply in remote areas.

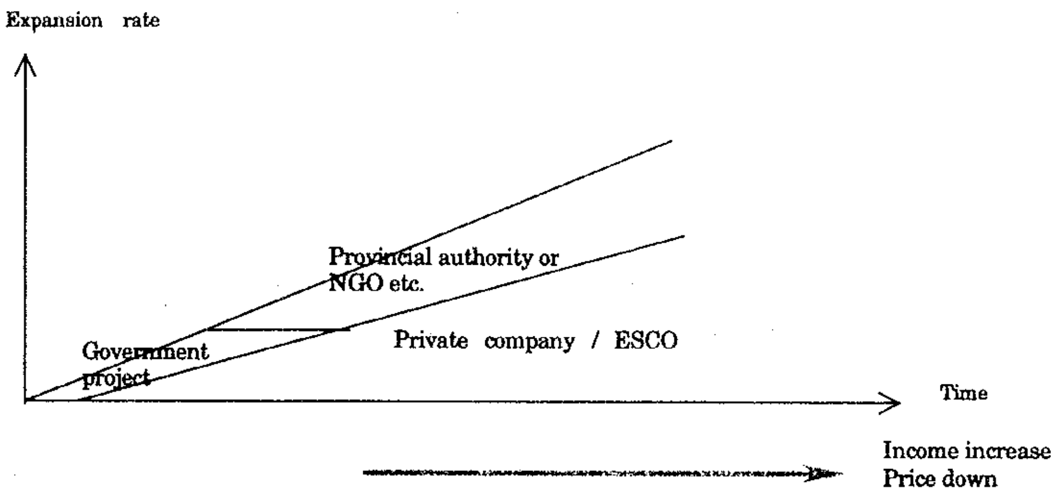


Figure 9-3-2 Expansion of solar-based rural electrification in Laos (Image)

On the user side it is also appropriate to establish an organization to do many tasks such as fee collection, periodical checking and minor repair efficiently. In the case of BCS, there are many users and a coordinating body is required. Remote villages in Laos have strong unity among villagers. The houses are built close to one another. Village leaders are respected and have leadership. Based on these conditions, we proposed the idea of a "Village Electrification Committee", which was supposed to act as the "core organization" to underpin the PV project. This idea was well received. It motivated local people and created a sense of participation. It turned out that the VEC was able to handle many issues after some guidance and training to ensure sustainable operation of solar systems. The reason for the success of the VEC can be explained by the following points:

① Strong unity of villagers and background of cooperative work
② Electricity being high priority and people's strong commitment
③ Simple work procedure and intensive training
④ Status and compensation

Villagers in rural Laos have a common background for this kind of collaboration. This idea will be accepted easily in future projects as well. In a practical sense, this type of user organization is important because it contributes to overall cost reduction and higher sustainability of solar-based rural electrification. In undertaking electrification projects in the future, the establishment of village level organization will be indispensable.

9-3-2 Small Hydro Power

There are many examples of small hydropower development in developing countries for rural electrification. Unlike solar power, hydropower can provide alternate current (AC) so that people can use many electrical appliances. However, truly attractive small hydro sites located close to village center will be limited. As a characteristic of hydropower, the initial investment is quite large and, therefore, needs a long time for cost recovery. This problem makes small hydro development difficult to realize on a commercial basis. Also, small hydro development requires skilled contractors who undertake the construction work of main structures such as weir, channel and powerhouse. Even after commissioning, special knowledge and expertise is necessary for operation and maintenance, which is a tough condition for rural villages. In Laos, there have been only some 30 small hydro power stations developed by aid from overseas so far. There are many examples where poor maintenance caused fatal damage to the equipment of small hydropower. Despite all those difficulties, it is recommended that small hydropower development be pursued more aggressively than before to promote rural electrification in Laos. Providing intensive training to develop local experts should be always considered when implementing small hydro projects.

9-4 Strategy for Rural Electrification

9-4-1 Rural electrification guideline

There are many factors such as demand size, cost, and geographical conditions, that will determine the methods of rural electrification. A guideline for rural electrification may be necessary to provide criteria to select the appropriate system to meet local people's needs.

(1) Demand for electricity

In general, the basic demand for electricity in developing countries consists of lighting, TV and/or radio (cassette), which represents the minimum demand of a household. The demand is less than 100W, and appliances working with DC are widely available. To meet such small demand for electricity, a solar system is very effective. However, with increasing income and improvement of life style, people tend to use more electricity. Furthermore, the need for irrigation or small productive applications results in an increase of electricity demand. When average demand per household exceeds 150W, people will use color-TVs, electric fans, or refrigerators. In that case, a solar system is not recommendable because an inverter would be necessary to convert DC to AC, and also the system capacity must be increased. This will not be justified economically. Instead, a diesel or a small hydro generator should be considered.

(2) Economy

The result of economic analysis of different methods of rural electrification suggests that economic advantages vary significantly depending on site conditions such as demand size, distance from grid, etc. In other words, there is no absolute system applicable to rural electrification.

As for diesel, the initial investment is relatively small but there is a large amount of uncertainty on fuel cost and maintenance cost. Also, it should be noted that in rural areas the transportation cost and storage cost of diesel fuel is very high. The life cycle cost of diesel often ends up higher than expected due to all those factors.

Solar power is suitable for a village where the demand for electricity will remain less than 100W per household for a long time. However, it often cannot deal with demand increase or demand for AC power. Also it may not be economical in a large village where a centralized system may have lower costs.

Economic advantage of small hydropower depends on site conditions. In general, an attractive small hydro scheme is believed to have a lower life-cycle cost than diesel generation, even though its initial investment is quite large.

Grid extension is regarded as the most desirable way of electrification. If the distance to the target village, however, is long and the investment cost per household exceeds the benchmark of $500, other methods may become more economical. Since a rough estimate of grid extension cost per kilometer is $10,000, more than one hundred users are required if the distance is 5 kilometers. If the distance is 10 kilometers, two hundred households would be necessary.

(3) Technology

In order to achieve long-term sustainability of the installed electricity supply system, it is always important to secure a sufficient maintenance mechanism. Diesel generators and hydropower stations require special knowledge and skill for maintenance, which is an obstacle to develop those power plants in remote areas. The importance of pursuing an easy-maintenance design should be always stressed. On the other hand, a solar system can operate without any special maintenance work for a long time. In this regard, it may be best to choose solar system for remote villages, where technicians are not easily available, as a means of supplying minimum required electricity quickly.

9-4-2 Strategy for Solar-based Rural Electrification

(1) Basic System

It is recommended to make 50W class SHS as the standard system for the rural areas of Laos. SHS has almost no preference on location and is easy to install and maintain. All those advantages would make SHS desirable and sustainable as long as its tariff is acceptable among rural villagers. For the lower income segment, less expensive BCS would be recommended. BCS can be relocated easily when a grid extension plan is decided upon. At the moment an urgent task is to reduce the system cost of SHS and BCS. The following measures are all needed to cut down initial investment and running costs.

①Component cost reduction by customs duty exemption, etc.
②Installation cost reduction (user contribution)
③Capital cost reduction by securing a grant or low-interest loan
④Running cost reduction by appropriate maintenance and village participation

(2) Development process

In the short term, MIH/DOE should take the initiative to implement solar-based rural electrification projects taking advantage of their experience in the JICA pilot project. Then, MIH is expected to transfer their know-how to provincial offices and private companies (ESCO) to expand rural electrification. The private sector will grow with support from the government in the long run and play a leading role in developing solar systems in remote areas. Thus, role-shifting from the public to the private sector is our basic idea.

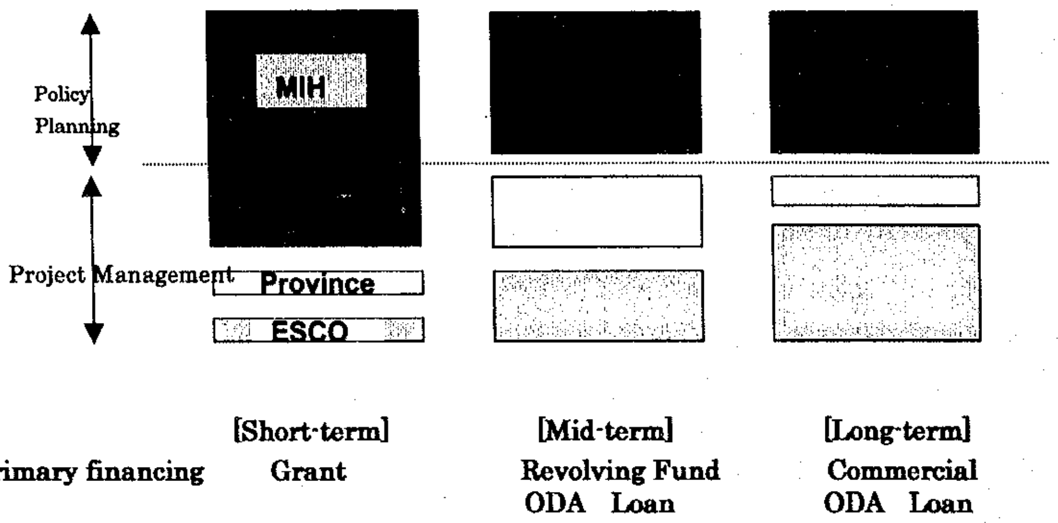


Figure 9-4-1 Three-phased approach for solar-based rural electrification

(3) Financial Planning

The pilot projects in this study proved that rural villagers are willing to pay for electricity more than we expected because their needs are very strong. The system cost, however, is still high, and a long term financial arrangement such as leasing would be required so that solar system users can pay for the total cost over time. However, the cost recovery period would be quite long, which is not attractive to private investors. For this reason, private undertakings would be difficult in the short term. In principle, it is important that the Lao government makes the utmost effort to secure state budget for implementing rural electrification projects, which is a priority policy issue. Given the financial condition of the Lao government, however, it would be difficult to imagine that the rural electrification projects will be funded by the state budget. It is strongly recommended that the Lao government secure enough funds from foreign aid organizations. Grant aid would be the most likely source of funds at this moment.

Revolving Fund

Even in the case of rural electrification funded by grant, it is possible to collect service charges including some capital costs, which in theory are not incurred, from users. In doing so, the difference between revenue and actual costs will be accumulated over time. In the pilot project, PV system users pay the initial charge and monthly charge, which are calculated from assumed model costs. Therefore, a total of 40 million kip (about $5,000) has been accumulated (as of November 2000), and two million kip is to be added every month. If the Lao government manages this fund as a special account for rural electrification, they can reinvest in new projects on their own initiative. This scheme is called "Revolving Fund" and matches the philosophy of the Electricity Law.

(4) Tariff and Promotion Body

With these measures and the anticipated production cost reduction of PV modules, it would be possible to cut the total cost of one 50W SHS into almost half. The target price will be less than $300 per unit. The first step of the solar-based rural electrification program is to achieve this target price and introduce a long-term lease system. Only the Lao government is able to do all this. With a 20-year lease, for example, the monthly fee of a 50W SHS will be about $2.00, which will make it affordable to rural villagers. BCS will be operated just like a local battery charging shop. Average BCS users will pay about $1.00 every month, which is almost equal to their current monthly energy expenses. It is strongly requested that SHS and BCS be implemented as demonstration projects in many provinces under government initiative.

The next step is to increase the involvement of provincial authorities. In this stage, provincial governments are expected to play a leading role. At the same time, other organizations such as village cooperatives or NGOs will carry out some projects. In the long run, with rising income and decreasing system costs, many private companies will enter the market and expand their businesses and the government will support them by providing tax incentives, low-interest loans or subsidies.

In the early stage of this study, it was thought that EdL would be the primary organization to implement off-grid rural electrification projects. However, this idea turned out to be impractical because EdL could not justify rural electrification projects from a commercial viewpoint. Therefore, MIH/DOE is expected to play a leading role. In September 1999, MIH/DOE formally established the Rural Electrification Division, which will become the central core unit for rural electrification in Laos. The division is still small and gaining experience step by step. In order to improve MIH's capacity to manage rural electrification projects, an additional project was implemented in late 2000. The effort for organizational strengthening should be continued by implementing a series of rural electrification projects.

In Laos there are more than 7,000 villages that have no electricity. It is unrealistic for the central government alone to implement solar-based rural electrification. Rather, provincial governments are strongly encouraged to take the initiative to build capacity. MIH/DOE is requested to transfer know-how to the provincial governments in undertaking several model projects in each province.

After several years, entrepreneurs and private organizations will start to get into the market. They are expected to undertake rural electrification projects with their own plans. In this stage there will be many types of rural electrification projects done by different organizations as follows:

①MIH/DOE projects (Model projects)
②Provincial government projects
③Village cooperative projects
④Private company projects
⑤Foreign aid projects
⑥Purchase of SHS by individuals

When commercial rural electrification projects become common and are undertaken at many sites, the role of the government (central/provincial) will change from executor to coordinator, giving guidance, assistance, and regulation when needed.

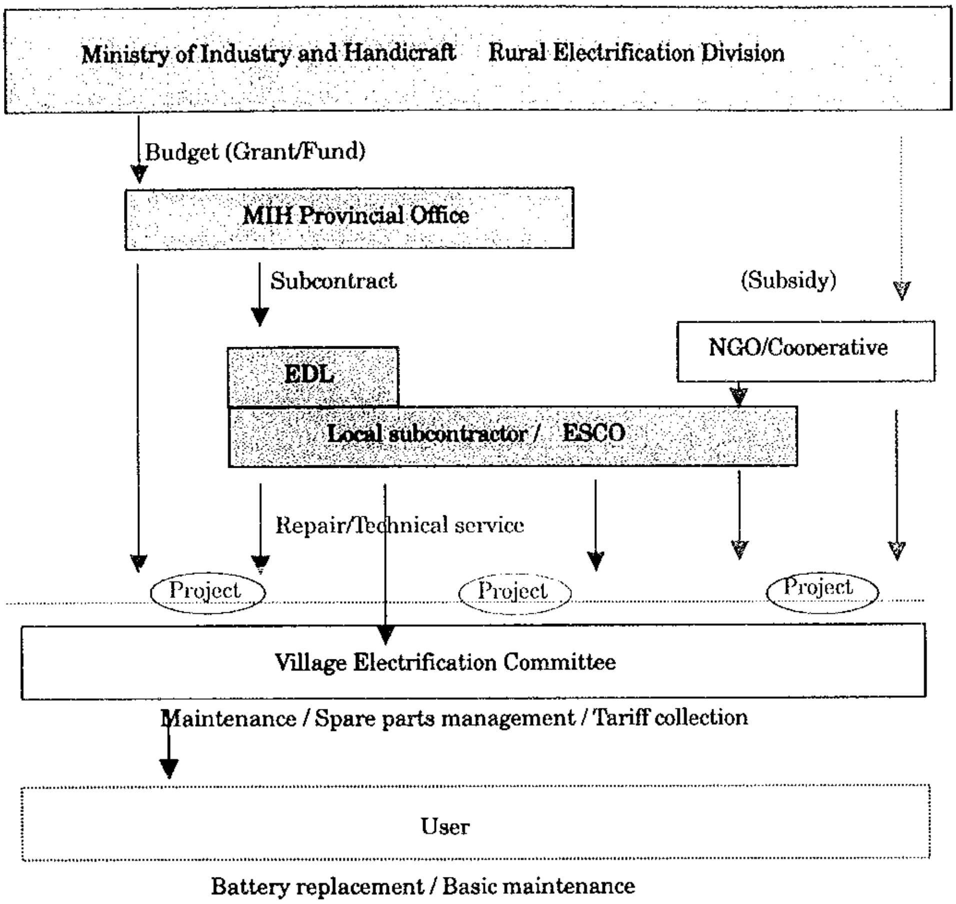


Figure 9-4-2 Management structure of public rural electrification project

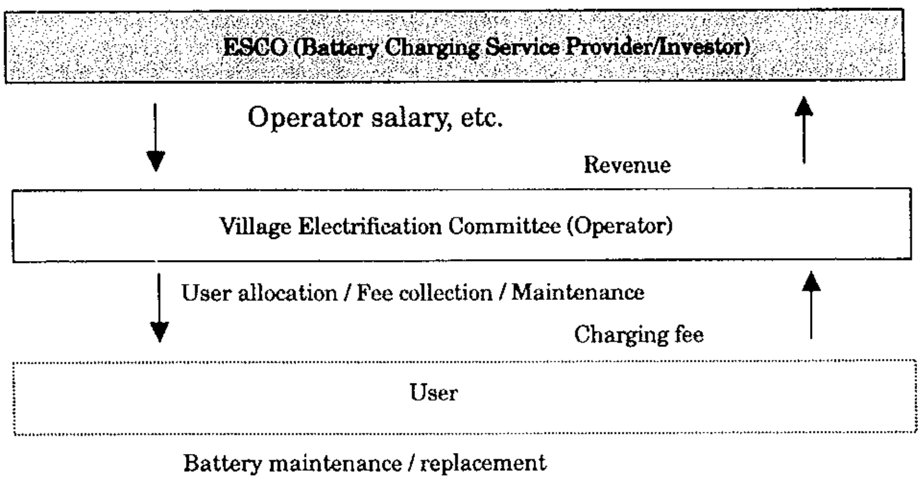


Figure 9-4-3 Management structure of commercial BCS project

9-5 Work flow of Solar-based Rural Electrification

A typical work-flow of a solar-based rural electrification project is shown in the attached flow chart (See Appendix). It is based on the results of the pilot projects and modified for more efficient project management. Private companies as well as the government are expected to undertake solar-based rural electrification projects following the workflow. There will be some differences between the management of the pilot project, which was experimental, and that of future projects. (See Table 9-5-1)

Table 9-5-1 Management of solar-based rural electrification in Laos

	Pilot Project	Future projects (assumed as government project)
Preliminary survey/ Site survey	(1) Site survey Implemented by JICA/MIH (2) Residents meeting JICA is initiative to organize with MIH support.	(1) Site survey Implemented by MIH (Local Office) (2) Residents meeting Organized by MIH (Local Office)
Installation	(1) Technical training for pilot village people Mainly conducted by JICA/MIH and EDL (2) Installation work Mainly implemented by sub-contractor according to the plan of JICA/MIH and supported by EDL. Through installation work, technical transfer in OJT *Installation work management *Techniques of installation (3) Inspection and trial operation JICA/MIH conducted with Sub-contractor, and gave training to village and EDL.	(1) Technical training for village people Mainly conducted by MIH (Local office) to explain system and how to use (2) Installation work Mainly done by village people Complicated work to be consigned to sub-contractor (3) Inspection and trial operation Village people training to make them inspect voltage, current and others with PV manual Complicated work to be consigned to sub-contractor
Maintenance	Implemented by mainly JICA/MIH and sub-contractor Training is provided to village people OJT. Sub-contractor is responsible for 6 month warranty.	To be carried out by village people who went through basic training To be supported by MIH/EDL. Call technicians to fix serious problems
Administration and financial management	Done by MIH based on the plan of JICA study team VEC deals with system troubles VEC collects monthly tariff Money management by JICA/MIH (Deposit at Bank) Committee member expenses Training and maintenance expenses	MIH is responsible for general plan and management Day-to-day work is done by Local office VEC deals with system troubles VEC collects monthly tariff Income from PV payment is managed by MIH as special fund: note) Overhead cost Committee member expenses Training and maintenance expenses

: Note) in the case of ESCO's projects, it is not applicable.

9-6 Expansion in Vientiane and Borikhamxay provinces

The pilot project revealed a good potential of PV-based electrification in rural Laos. The following analysis aims to estimate how many people will apply for PV systems by the year 2010. Assuming that there is a correlation between actual energy expenses of household and PV system affordability, we studied the income and consumption data of Vientiane and Borikhamxay provinces. This analysis was conducted by the following steps.

1) Assume that households paying more than the monthly charge of PV for energy every month will accept PV.
2) Assume that the distribution of household energy expense of the pilot villages represents that of both provinces.
3) Calculate the proportion of households spending more than 12,000 kip/month for energy and those spending 6,000 to 12,000kip/month. The first segment will apply for SHS and the second segment will go for BCS.
4) Estimate the number of households that will apply for solar systems by multiplying the above figure (%) with the number of households that are not to be electrified until 2010.

Figure 9-6-1 shows the distribution of household energy expense of the six pilot villages in Vientiane and Borikhamxay provinces. The energy expense data are as of October 1998. The monthly fees of SHS in the pilot project were revised in June 2000 to 12,000kip for 110W-SHS and 7,000kip for 55W-SHS. Market price of battery charging service has been steadily rising so that people are now paying 6,000kip or more per month depending their frequency of charging. Thus, the benchmarks of 12,000kip for SHS and 6,000kip for BCS are quite reasonable. The two figures are converted by using a deflation factor (CPI) to 5,168kip and 2,584kip, as of October 1998, respectively.

In the graph (Figure 9-6-1), the percentage of households paying more than 5,168 kip/ month can be found on the cumulative curve of year 2000. From the marked point as "SHS affordable" on the curve, we can say that about 35% of the households can apply for SHS. In the same way, it can be said that about 70 % of the households are able to apply for solar systems (SHS or BCS).

Furthermore, the cumulative distribution curve for the year 2010 is estimated as shown in the graph assuming an annual growth rate of energy expense of 4%. This growth rate is based on the past trend of per capita income increase. This result indicates the potential that about 80% of the households can apply for solar systems and, among them, about 45% of the households can afford SHS leasing in 2010. This is a remarkable conclusion. In this way, we can estimate the potential number of households in the whole country that can be electrified by solar systems by 2010.

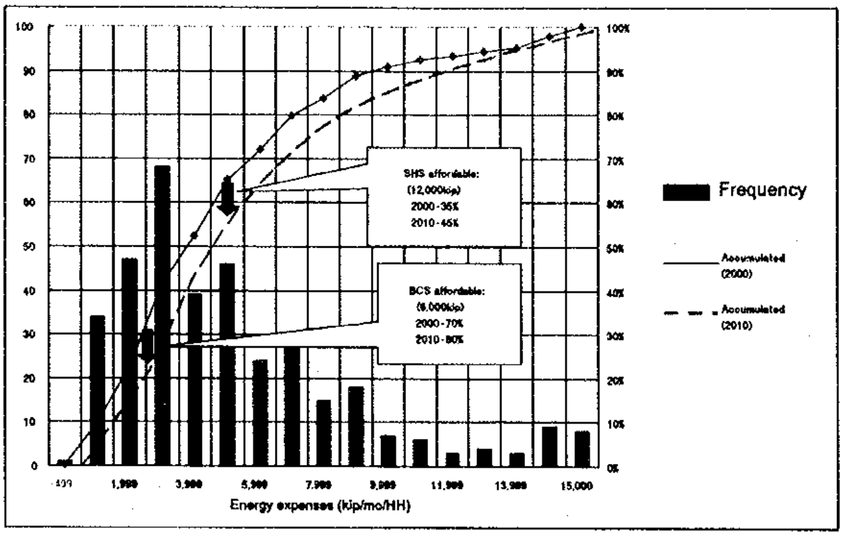


Figure 9-6-1 Distribution of energy expense of pilot villages and PV potential

9-7 Ten-year Development Plan

From now on, the Lao government needs to clearly define its strategy and prepare policy measures for rural electrification. At the moment, it is premature in Laos to expect that private initiative would be playing a key role. Commercial projects are hard to imagine, although they should be pursued persistently. Hence, the Lao government should take the initiative to implement rural electrification projects. Foreign aid would be the most likely source of funding because donor countries are going to increase funding for renewable energy projects. The Lao government is expected to secure such aid and develop appropriate measures and rules for implementation.

In order to achieve the electrification goal, which is to electrify 90% of the population by 2020, it would be necessary to electrify about 65% of the population by 2010. To examine necessary financial obligations for solar system implementation up to the year 2010, the following factors need to be reviewed.

① Grid extension plan
② Small hydro power and diesel development plan
③ Income level in rural areas
④ Household increase rate
⑤ Battery users and pico-hydro users

As for grid extension plan and small hydro and diesel plan, necessary data can be obtained from MIH and EdL. By referring to the statistical data published by the National Statistical Center, we can calculate or estimate the growth rates of income and number of houses quite easily. Data on battery (without PV) and pico-hydro usage is also published, but may not be accurate, because it is difficult to identify such users who live in remote areas. Those users, who are increasing in number, should be treated as "electrified" in the same way as solar system users. In the long run, those users will decrease in number because they will be either grid-connected or electrified by PV or small hydro.

Table 9-6-1 shows our view of electrification target numbers, which is based on the above assumptions, for the whole country and for each province up to the year 2010. According to this table, approximately 80,000 households must have been electrified by solar system by 2010. Assuming $300 as direct cost, plus 50% overhead for a village-size solar system, a rough idea about the total financial requirement over the next ten years is $36 million.

Table 9-7-1 Electrification plan up to 2010 (Forecast)

Code	Name of Provinces	Data 1999 Vill.	HH	Popul.	Electrified by 1999 (grid/diesel/SHP) Vill.		HH		Total yearly consumption (kip/HH/yr)	HH growth (%/yr)	Battery/ Pico Hydro	Forecast 2010 HH	Grid/SHP Electrification (HH)	Grid Rate	PV Electrification (HH)	Battery/ Pico Hydro	Elec. Rate
1	Vientiane Mun.	489	84,923	531,109	407	83.2%	78,727	**92.7%**	1,807,581	3	3,098	117,553	117,146	**99.7%**	0	0	**99.7%**
2	Phogsaly	664	25,865	152,820	20	3.0%	1,702	**6.6%**	634,489	2	725	32,160	6,120	**19.0%**	3,906	1,015	**34.3%**
3	Luangnamtha	485	20,851	114,519	41	8.5%	2,458	**11.8%**	710,300	2	920	25,926	6,525	**25.2%**	2,910	1,288	**41.4%**
4	Oudomxai	816	39,407	210,820	41	5.0%	3,390	**8.6%**	620,753	2	1,081	48,998	11,427	**23.3%**	5,636	1,513	**37.9%**
5	Bokeo	399	19,238	113,493	16	4.0%	1,747	**9.1%**	854,791	2	1,399	23,920	12,791	**53.5%**	2,003	1,959	**70.0%**
6	Luangphrabang	839	59,107	365,333	174	20.7%	14,423	**24.4%**	800,111	2.5	2,234	77,554	29,906	**38.6%**	8,576	3,128	**53.7%**
7	Houaphan	729	28,456	198,787	64	8.8%	4,914	**17.3%**	590,904	2	2,354	35,381	14,304	**40.4%**	3,162	3,296	**58.7%**
8	Xayaboury	595	50,754	297,652	74	12.4%	7,119	**14.0%**	1,249,959	2.5	1,309	66,594	37,131	**55.8%**	6,187	1,833	**67.8%**
9	Xiengkhuang	475	27,965	199,816	44	9.3%	3,940	**14.1%**	938,526	2	1,922	34,771	10,221	**29.4%**	4,419	2,691	**49.8%**
10	Vientiane Pr.	508	47,179	277,733	249	49.0%	26,372	**55.9%**	1,207,960	3	1,665	65,307	42,702	**65.4%**	4,747	2,330	**76.2%**
11	Bolikhamxay	485	27,928	165,343	92	19.0%	8,562	**30.7%**	1,077,205	3	1,549	38,659	19,424	**50.2%**	4,039	2,169	**66.3%**
12	Khammoune	801	53,096	281,512	267	33.3%	22,994	**43.3%**	989,771	2	903	66,018	34,869	**52.8%**	5,607	1,264	**63.2%**
13	Savannakheth	1,533	104,821	671,581	329	21.5%	39,512	**37.7%**	924,790	2	5,225	130,332	78,014	**59.9%**	9,417	7,315	**72.7%**
14	Saravan	742	41,645	256,550	132	17.8%	9,566	**23.0%**	838,942	2	1,604	51,780	25,609	**49.5%**	4,711	2,246	**62.9%**
15	Xekong	337	10,146	63,836	14	4.2%	1,559	**15.4%**	787,696	2	687	12,615	5,457	**43.3%**	1,074	962	**59.4%**
16	Champasak	901	84,055	501,061	202	22.4%	26,254	**31.2%**	884,375	2	2,890	104,512	47,340	**45.3%**	10,291	4,046	**59.0%**
17	Attapeu	188	14,619	87,182	14	7.4%	896	**6.1%**	769,470	2	412	18,177	4,969	**27.3%**	1,981	576	**41.4%**
18	Xaisomboun Sp.	129	9,604	54,112	6	4.7%	200	**2.1%**	741,998	2	752	11,941	4,862	**40.7%**	1,062	1,053	**58.4%**
	Total:	**11,115**	**749,659**	**4,543,259**	**2,186**	**19.7%**	**254,335**	**33.9%**	1,006,149		**30,728**	**962,197**	**508,815**	52.9%	**79,729**	38,683	**65.2%**

Sources: Ministry of Industry and Handicraft.

National Statistical Centre, The households of Lao PDR, Social and economic indicators , Lao Expenditure and Consumption Survey 1997/98 (LECS2).

*Forecast of PV Electrification and Battery/Pico users in 2010 was done by JICA study team.

9-8 Implementation Plan

9-8-1 Status of Master Plan

Solar systems are drawing a lot of attention because they are widely recognized as being suitable for electrifying remote villages where grid extension is not feasible. Now, the Lao government is requested to formulate a clear-cut policy on the promotion of solar systems as a means of rural electrification in rural Laos. Their mission is not only to undertake many electrification projects on their own but also to develop an appropriate business environment to facilitate the entrance of private companies into the market. The ten-year master plan for solar-based rural electrification should be developed with such objectives. In the plan, the overall target figure of solar system development up to 2010 with a breakdown into the public and the private sector should be clearly addressed.

As stated in the previous section, in order to achieve the ultimate goal of electrifying 90% of the population by 2020, the Lao government needs to work hard and achieve the mid-term goal of electrifying 80,000 houses by solar systems by 2010. The government must overcome many difficulties with a strong commitment and clear strategy. In this regard, more concrete ideas are called for to develop a comprehensive program for accelerating solar-based rural electrification in Laos.

9-8-2 Public Sector

(1) 1st Phase (2001-2004)

In the first phase of solar-based rural electrification, most of the projects will be implemented by the government because their profitability is uncertain and the private sector has not grown yet. The government body which is responsible is our counterpart, the Ministry of Industry and Handicraft. In this stage, the overall objective is to increase pubic awareness about solar system by undertaking projects nationwide. Also, it is important to create a business environment to facilitate commercial ventures in the future. This period, from 2001 to 2004, is assumed to lay the groundwork, which is critical for the successful implementation of solar systems over the next ten years.

In 2001, MIH/DOE must formulate a 10-year program for solar-based rural electrification and start some projects. In particular, it is necessary to have a clear vision on financing the program. The state revenue of Laos is insufficient, and therefore, the Lao government has difficulty in setting aside fund in the national budget for this rural electrification program. The state revenue only covers administrative expenses of the government, and the deficit is covered by aid from overseas. Therefore, Laos relies on foreign aid, grant and loan, to implement development projects. In case of rural electrification, the situation is the same. MIH's first priority is to secure funds from overseas aid organizations. In particular, following the JICA pilot project, the Japanese government is expected to continue its support by providing a grant aid on rural electrification. In addition, the EU and Australia are said to have an interest in solar system development in Laos. The World Bank and GEF, which are implementing an experimental off-grid electrification project in Laos, are also likely to increase their financial aid in the second stage.

MIH/DOE is supposed to select target areas and villages for each year. It is recommended that around 10 villages will be selected from each of 17 provinces (including the Xaisomboun Special Region). For 2001, it is an urgent task to decide target villages quickly. MIH/DOE has already identified candidate villages in Oudomxai, Luangnamtha and Phongsaly provinces. The first two or three projects in each province will be conducted by MIH/DOE, which has gained enough expertise in solar-based rural electrification. The provincial authorities will learn the process of project management by working with MIH/DOE. This process is really important for the provincial governments to develop their own capability. After that, the provincial authorities will take over and carry out the remaining projects. In this stage, it is also important to involve private companies. They may be hired as subcontractors. They can learn a lot about solar-based rural electrification and start to consider their own ventures for the future.

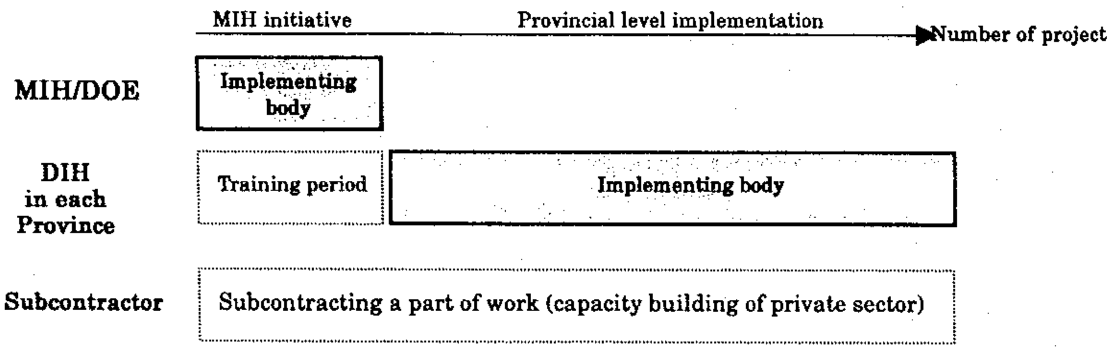


Figure 9-8-1 Project implementation in the first stage

MIH/DOE is supposed to complete solar-based rural electrification projects in 17 provinces in four years. This means that four or five provinces will be targeted and around fifty villages will be electrified every year. Assuming the average number of households in one village is one hundred and 70% of them will apply for solar systems, around 3,500 houses will be electrified by solar energy in a year. In 2001, the number would be smaller than that and realistically 2,000 houses will be the goal for electrification during 2001. During the first phase, which is from 2001 to 2004, as many as 12,000 houses will be electrified by solar system.

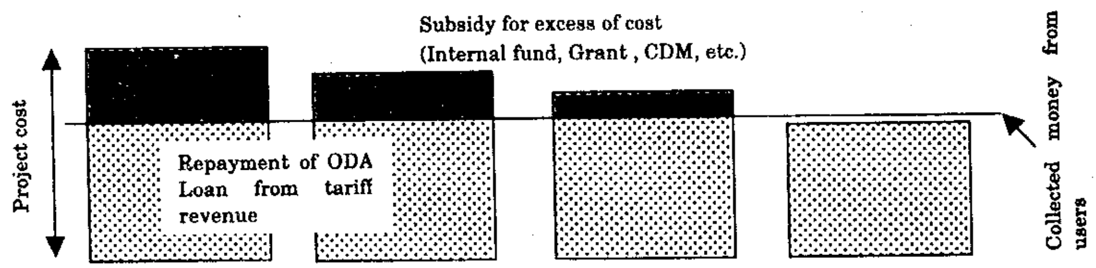
The budget necessary for the project can be estimated by multiplying the anticipated unit costs of SHS and BCS by the number of users. According to the cost estimate done in Chapter 6, it can be said that the project cost per household in this stage is around $400 including overhead; assumption is $350 for SHS, $280 for BCS per household, the ratio of SHS and BCS being 6 to 4, and 25% overhead. The total sum of funds (grants) required for the first phase, therefore, is around $5 million. It should be noted as well that a comprehensive capacity building and training program is essential to the ultimate success of the solar-based rural electrification in Laos. The program should be combined with the electrification projects.

(2) 2nd Phase (2005-2007)

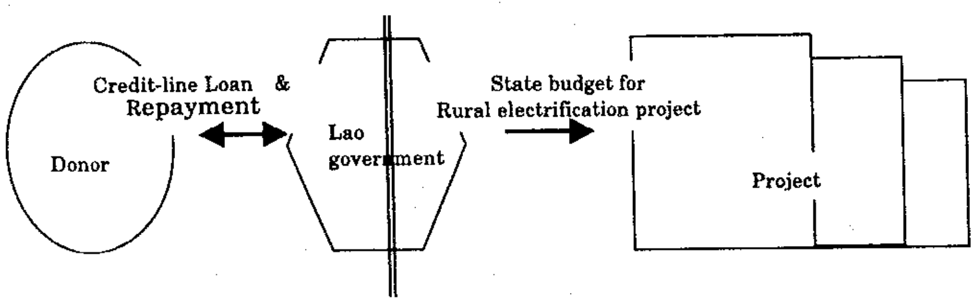
In the next phase, the model projects at each province will have been completed and project management know-how will be transferred to the provincial authorities. Subsequent solar-based rural electrification projects will be undertaken under provincial initiative. As there will be many requests for solar systems submitted from remote villages, it will be necessary to expand target areas. The northern part of Laos, which is underdeveloped, should be treated as the priority area and deserve special budget allocation.

In this stage, the Lao government must continue to secure financial aid from overseas. At the same time, it would be possible to use the internal funds, "revolving funds", which will be secured by accumulating solar system user payments. A rough estimate of annual cash inflow is $200,000, assuming the $4 million net investment (excluding the overhead) in the 1st phase is replenished in twenty years. Grant money is not appropriate for the large-scale projects to be implemented in the second phase. Rather, getting more funds on lenient terms such as loans from the World Bank or JBIC must be considered. Laos has set a limit for overseas borrowing at about $200 million. A loan from foreign aid organization for rural electrification will be possible, because the required amount of total investment is relatively small.

Rural development has become one of the priority topics among aid organizations, and major donors have been shifting their focus to Basic Human Needs (BHN) projects such as rural development. Furthermore, they have established special long-term low-interest financing schemes for encouraging renewable energy development. There is a high possibility for the Lao government to successfully obtain such funds. Strictly speaking, rural electrification does not go along with financing by loan which always requires "return on investment". But donors are studying new ideas to justify their funding for BHN projects by loan. Figure 9-8-2 illustrates some proposed schemes in this regard. Another possibility for Laos is to use the Clean Development Mechanism (CDM), which aims to reduce CO2 emissions by undertaking renewable energy projects (or energy conservation projects) in developing countries with funds from developed countries.



1) Combination of loan and subsidy



2) Credit-line loan method

Figure 9-8-2 Ideas of ODA loan for rural electrification project

Thus, Laos is expected to diversify sources of funds, such as loans, internal funds, and grants, in this stage. Projects financed by loan need to be more cost conscious and require business-like management processes. MIH/DOE may not effectively handle all the projects in this manner. Rather, establishing a special "Agency", which is going to manage the funds and to plan and oversee many rural electrification projects should be considered. The Agency would belong to MIH/DOE and have a regional office, which is responsible for project implementation, in each province. This new organization might be incorporated into EdL. But the profitability of rural electrification will still remain low, so that establishing the Agency under MIH is more realistic. The new Agency having dedicated staff who have skills and experience, is expected to plan and take responsibilities for many projects. They are supposed to electrify 5,000 homes per year, or 15,000 homes in the 2nd stage. The average cost per household would go down to $300, including overhead, which is lower than in the 1st stage by more than 20%. Taking the cost reduction into account, the total budget for this stage is estimated to be $5 million. To finance this, a total of $3 million is expected from overseas loans. The internal fund would provide $1 million and another $1 million needs to be secured from grants.

At this stage, it would become necessary to replace batteries which have expired life. In order to avoid environmental problems and to ensure the recycling of useful materials, the government should develop an appropriate guideline for the disposal of used batteries. It is recommended that the villages electrified by PV be instructed to recycle used batteries. As a rule, the village electrification committee in each village needs to store used batteries and to sell them to dealers for recycling. This process would be run on a commercial basis, and be easily introduced. If there is no dealer to take used batteries in the region, there is a need to establish an appropriate organization to handle this issue.

(3) 3rd Phase (2008-2010)

The 3rd phase, which is from 2008 to 2010, is viewed as the period to accelerate solar-based rural electrification nationwide by making the private sector play a major role. In this stage, the public sector is supposed to do some projects in those difficult areas which are not easily accessible or where people have little cash income. The households to be electrified by the public sector's projects would decrease to around 4,000 per year. The source of financing for those projects will be mainly coming from the internal funds, whose annual income will have grown to as much as $400,000 per year. The dependence on overseas aid would be smaller than in the previous stages. The continuing cost reduction will lower the average cost per household to $250, including overhead. The public sector will need a total of $3 million, and is expected to secure at least $2 million from loans.

The above scenario is based on realistic assumptions. As for financial arrangement, it is common to negotiate with aid organizations the whole budget for a long-term program. For example, a project loan for the 2nd and 3rd phases will be a typical deal. If Laos is going to negotiate the loan with an aid organization, the whole amount would be only $5 million, which is much smaller than other project financing. It would be possible to discuss additional financial requirements for supporting commercial ventures to undertake their PV projects at the same time. In particular, the private sector is expected to do a lot of electrification projects in the 3rd phase, averaging 10,000 homes each year. They need commercial loans of $2 million to $3 million. To manage such commercial loans would be another important task of the "Agency".

9-8-3 Private Sector

(1) 1st Phase (2001-2004)

In the 1st phase, the private sector will start some small projects such as building a BCS in a high-income village, which is regarded as fairly profitable. There are some companies in Laos running PV businesses on the expectation that solar-based rural electrification will grow in the future. They have carried out some small projects and gained skills and experience. In order to make private companies major players in the long-term, the government is requested to support them by giving tax exemptions to them on PV equipment and conducting campaigns for PV system dissemination.

Furthermore, when the government undertakes solar-based rural electrification projects, it is important that they have a long-term view and take strategic action to develop capable private companies which will become core service providers, or Energy Service Companies (ESCOs), in the future. For example, it would be recommended that the government use dedicated private companies for installation work, maintenance service, and fee collection by subcontracting, so that the companies will be able to gain business know-how for their own undertakings in the future. At the same time, over-heated competition among many new entrepreneurs should be avoided to achieve sound development of the private sector. One idea is to give a concession to a designated company in each specified region. In the first year, there will be about 500 homes that will be served. With support from the government, the private sector will gradually increase their customers and in 2004 it is expected that about 2,000 new customers will be acquired. In the 1st stage as a whole, there about 5,000 households will get PV-electricity supply service from private companies.

(2) 2nd Phase (2005-2007)

In the 2nd phase, the private sector will rapidly expand their operations because the business conditions will turn favorable. Thanks to the projects done by the government, many local shops will carry PV equipment and the number of technicians who have skills with PV system installation and repair will increase. The penetration of the market economy and increased productivity in rural areas will lead to higher income for farmers. At the same time, the cost of PV systems will decrease continuously. Hence, the demand for PV systems in remote areas will grow substantially. The private sector will add 3000 to 5000 customers every year, which will be almost equal to the project size of the public sector. To help achieve this, the government is requested to secure funds from aid organizations and to provide financial assistance, such as low-interest loans or subsidies, to the private sector. In addition, it is necessary to help rural people apply for PV-electricity by establishing a micro finance scheme.

(3) 3rd Phase (2008-2010)

In the 3rd phase, the further reduction of PV system costs and the expansion of PV related businesses will facilitate the rapid growth of private business in PV-based electricity supply. The private sector will surpass the public sector. In order to achieve the goal of 80,000 PV users by 2010, it is necessary during the 3rd phase that the private sector acquires 24,000 new users. The government is expected to prepare for providing a substantial amount of investment through their financial support programs. The required amount of investment, assuming 10,000 homes in a year, would be around $3 million. The Lao government, therefore, needs to increase the volume of loans to the private sector. The loan program for rural electrification should be also applied to small hydro development projects. In addition, it will be necessary for the government to check private companies who are running PV businesses to ensure that their services are satisfactory to users.

Table 9-8-1 Ten-year solar system introduction plan

	First Phase 2001-2004	Second Phase 2005-2007	Third Phase 2008-2010	Total
Public Sector	12,000	15,000	12,000	39,000
Private Sector	5,000	12,000	24,000	41,000
Total	17,000	27,000	36,000	80,000

Note : Figures for the public sector indicate the goal of government and provincial projects.
Figures for the private sector largely depend on economic conditions, etc., and therefore may fluctuate.

Table 9-8-2 Recommended policy measures

Finished	First Phase	Second Phase	Third Phase
Enactment of the Electricity Law	*Securing grants *Import duty exemption on PV materials *Rules for managing the revolving fund *Public promotion of PV *Capacity building program for the private sector *Concession program *Simplification of enterprise establishment process	*Securing loans * Establishment of the "Agency" *Subsidy and loan programs for the private sector *Micro finance scheme *Measures for used battery disposal	* Increasing overseas loans *Strengthening of the "Agency" *Expansion of financial assistance programs for the private sector *Regulation to ensure good quality service

Note) Projects implemented directly by the government or provinces are excluded.

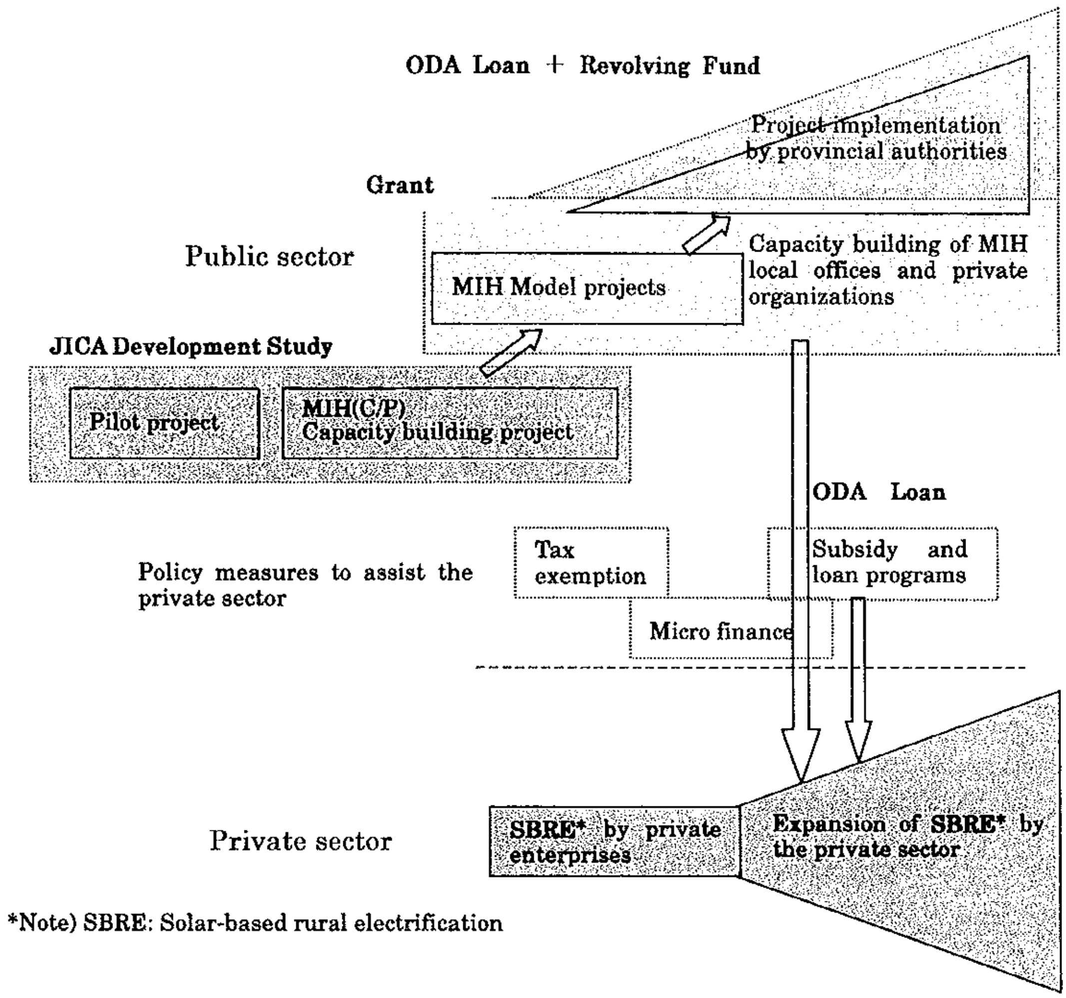


Figure 9-8-3 Strategy for solar-based rural electrification