Japan International Cooperation Agency (JICA)

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The Ministry of Industry and Handicraft
Lao People's Democratic Republic

The Study on Rural Electrification Project by Renewable Energy in the Lao People's Democratic Republic

Final Report

Summary

February 2001

PROACT International, Inc.
Shikoku Research Institute, Inc.

Japan International Cooperation Agency (JICA)

MINISTRY OF INDUSTRY AND HANDICRAFTS
LAO PEOPLE'S DEMOCRATIC REPUBLIC

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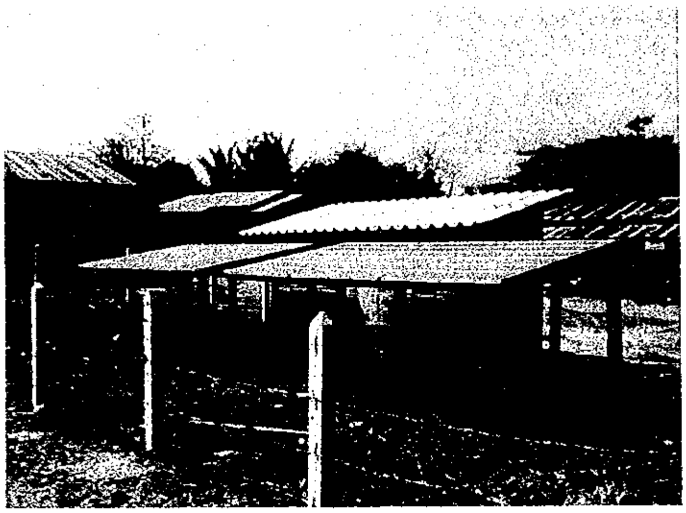
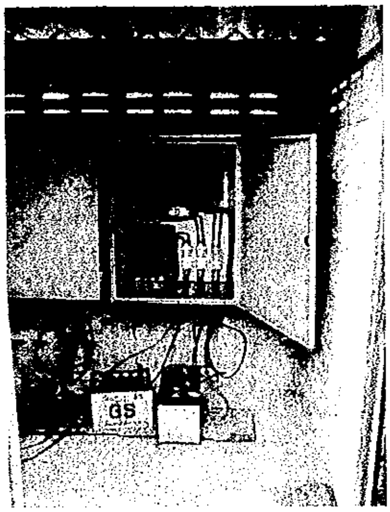
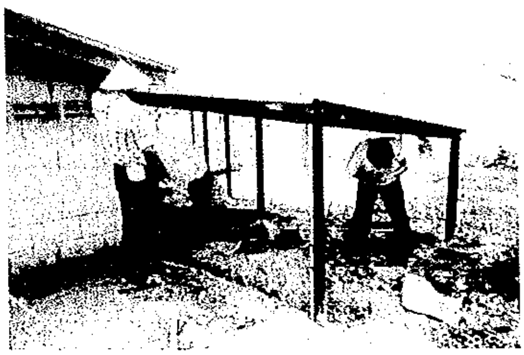
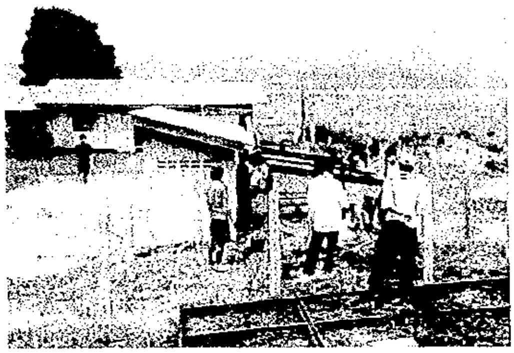
Photovoltaic System Pilot Project Sites

Battery Charging Station

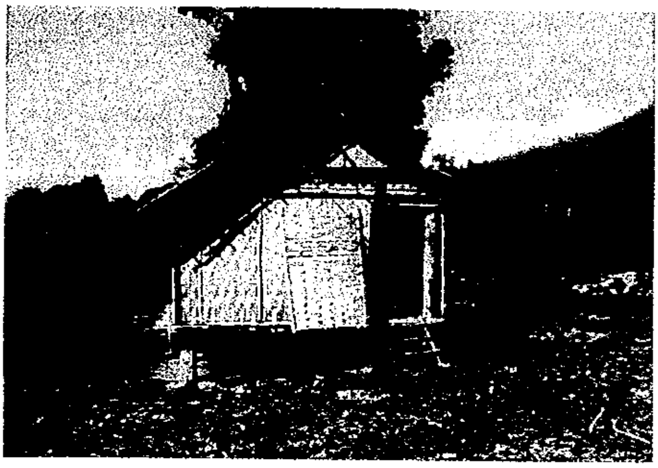


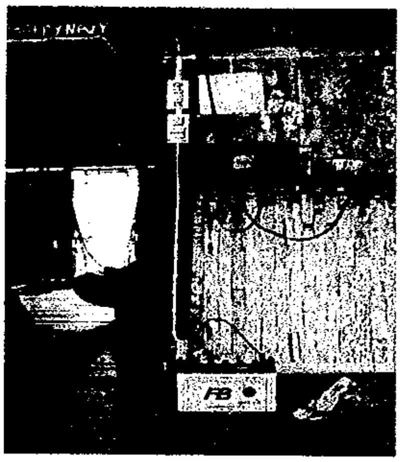


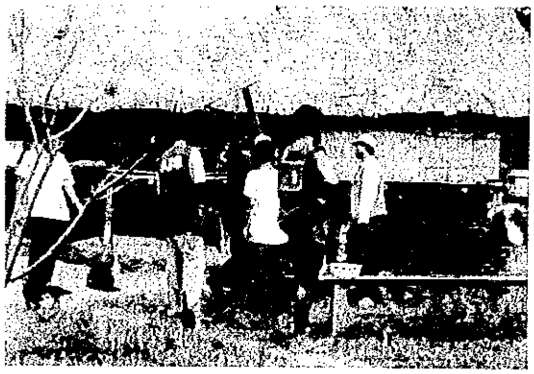


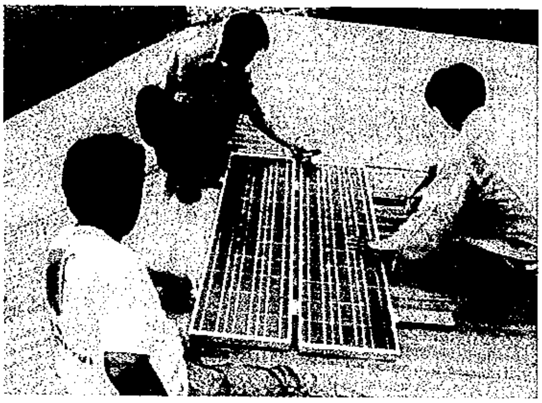


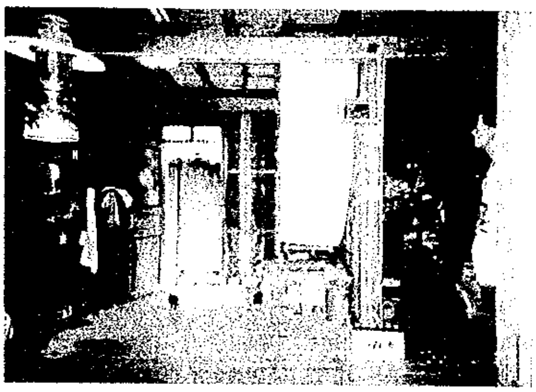
Solar Home System











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1 Goal of Rural Electrification

1-1 Rural Electrification Policy

The Lao government enacted the Electricity Law in 1997, which 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 target of rural electrification stated by the Lao government is to supply 90% of the population by the year 2020. The grid extension alone, which has been promoted by EdL, will not be able to achieve the goal. The participation of new players into the off-grid power supply market is the only way to supplement the grid extension work and to provide electricity to remote 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 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 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 market is growing. Now, it is good timing for the Lao government to undertake a detailed study on the feasibility of introducing solar power 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 advantageous 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, hydro power system operation requires a higher technological base than solar system. This makes small-hydro development more difficult in remote areas. Although hydro power 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.

1-2 Rural Development Policy

Although more than 80% of the population live in the rural areas of Laos, their income level is only about 25% of that of town areas, because of their dependence on conventional agriculture. Therefore the Lao government, viewing rural development as one of the most important issues, established the "Rural Development Committee" as a special organization for the promotion of rural development in 1994. It was reformed into an administrative organization under the Prime Minister's Office in 1996.

Rural development policy in Laos is based on a resolution concerning rural development passed by the national congress in 1994. In the resolution they said it is important to make use of the potential of rural areas in the aspect of nature and society. Besides it is said that all the ethnic groups should change their old agriculture style to a new one in order to improve their lives. In particular they take a Focal Site Approach to realize their objectives. In this approach, an average of three areas (villages) are set aside as model areas for development, and development is intensively promoted in those areas.

Eight subjects (Infrastructure, Agriculture, Education, Health, Village Consolidation, Community Development, Income Generation, Focal Site Management and Emergency Relief) were picked up as significant issues in the National Rural Development Plan (1996-2000). Although the importance of each subject depends on the situation of focal sites, the main subjects are infrastructure and agriculture development. Infrastructure development is indispensable for improving access to social services and markets (to sell agricultural products). That is why most of the focal sites devote a large share of their budgets to infrastructure development. Road construction, electrification and telecommunication are emphasized. In the Rural Development Plan (1996-2000), it was planned to provide electricity to 50 % of the rural population by primarily extending grids. Having electricity is essential to rural development because it will improve medical and educational services in remote areas and also enable villagers to have more useful information through TV or radio. Moreover, electrification will contribute to village development by, for example, providing power to irrigation and household enterprises.

As described above, rural electrification coincides with rural development policy in Laos and should be strongly promoted. However, if they go for only grid extension, it would be difficult to promote rural electrification for geographical and financial reasons. Therefore, off-grid rural electrification by renewable energy also should be considered as a viable alternative in many remote areas in Laos.

1-3 Current Status of Rural Electrification

At present approximately 20% of the villages and 35% of the households are electrified in Laos, mainly covered by the national grid.

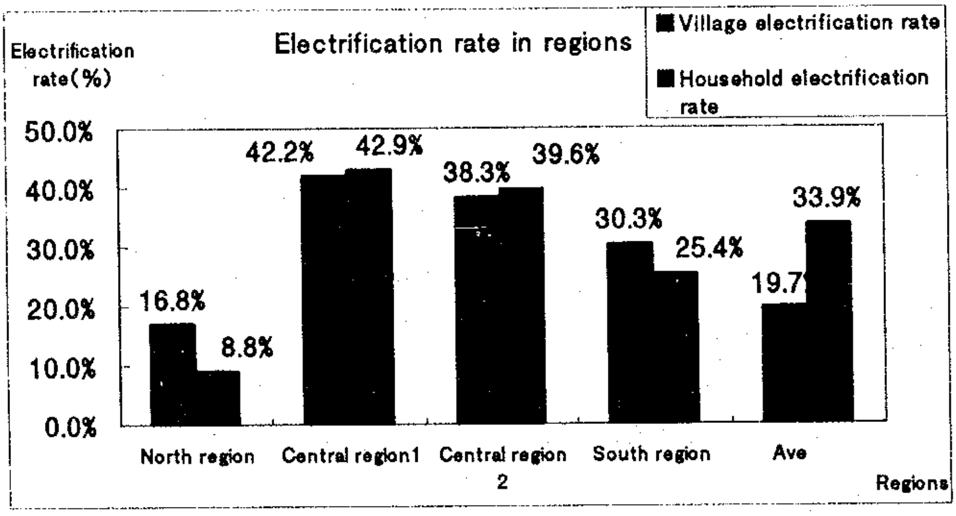


Figure 1-1 Electrification rate in Laos (1999) Source: MIH data

So far rural electrification was primarily promoted by grid extension. As for the grid, EdL formulates a basic plan and implements it. And as for distribution lines for each village, each EdL provincial office drafts a plan and implements it with the EdL head office. Although decentralized electrification by diesel or small-hydro power has been implemented in some villages, there wasn't a basic plan; it had only scattered support from aid projects or from government budgets. At present EdL is promoting rural electrification by grid extension with financing through the World Bank and ADB.

1-4 Status of Vientiane and Borikhamxay Provinces

In Laos, 83% of the population lives in rural areas where people's livelihoods depend on subsistence-level agriculture. Major income sources are from farming and selling livestock.

The population and economic activities are centered on two geographical areas in Laos.

These areas are along the Mekong River and close to the Thai border in the south and in the Vientiane-Luang Prabang corridor in the north[1]. Vientiane province is located along the Vientiane-Luang Prabang corridor, and Borikhamxay province is located between the Vientiane-Luang Prabang corridor and southern Mekong. The socio-economic indicators show Vientiane province is more urbanized than the rest of the country and has better socio-economic indicators than Borikhamxay province, where the mountainous area is relatively large. (See Table 1-1)

Table 1-1 Socio-economic indicators of Vientiane and Borikhamxay provinces

	GDP 1996		Population 1995			GDP per Capita (kip/person)	GDP per household (kip/HH)	Literacy rate 15 years and above (%)			Infant mortality rate (0/00)	Life Expectancies	
	Amount in current price (million kip)	Share in country	Population	Share in country	Rural population rate (%)			Total	Male	Female		Male	Female
Whole Country	1,707,551	100.0%	4,574,848	100.0%	82.9%	373,248	2,239,486	60.2%	73.5%	47.9%	104	50	52
Vientiane Prov.	100,297	5.9%	286,564	6.3%	82.5%	350,000	2,100,000	72.2%	83.6%	60.7%	102	52	54
Borikhamxay Prov.	21,757	1.3%	165,589	3.6%	92.6%	131,390	801,479	64.9%	77.6%	52.6%	136	48	50

Source: National Statistical Centre, Basic Statistics 1997.
National Statistical Centre, Results from the Population Census 1995.
GDP of Borikhamxay: Brikhamxay Provincial Office, Statistics of Borikhamxay 1996 .
GDP of Vientiane: hearing from Vientiane Provincial Office, February 1999.

Table 1-2 Electrification in Vientiane and Borikhamxay provinces

	(% of household)		
	Electrified by grid	Own generator	Car battery
Whole Country	33.9%	2.3%	2.2%
Vientiane Prov.	55.9%	2.8%	5.5%
Borikhamxay Prov.	30.7%	6.1%	4.3%

Source: Electrified rate by grid : MIH/DOE
Generator and car battery user rate: Results from the Population Census 1995.
(National Statistical Centre)

[1] UNDP, World Bank Energy Sector Management Assistance Programme (ESMAP), Laos Institutional Development for Off-grid Electrification, September 1998.

2 Socio-economic Survey - Pilot villages

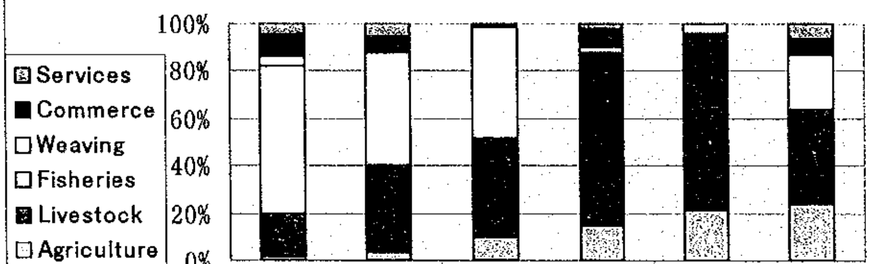
2-1 Overview of Pilot Villages and PV Installation

A total of six villages were selected from Vientiane province and Borikhamxay province as pilot villages. The summary of baseline survey results is shown below.

Table 2-1 Overview of pilot villages

	Households (HH)	Population	Field area (ha)	Average income (1000kip/year/HH)	Kerosene lamp	Battery	Tube Light	TV	Average energy expense: Amount (kip/month)	Average energy expense: % of Income
Donsayoudom	125	708	8	2,823	83%	68%	27%	65%	9,114	3.9%
Houaypong	43	252	11	1,513	72%	53%	49%	28%	3,215	2.5%
Nongpen	48	336	38	863	65%	79%	67%	42%	4,965	6.9%
Mai	57	394	24	1,262	83%	37%	28%	37%	2,578	2.5%
Vientiane average	68	423	20	1,615	76%	59%	43%	43%	4,968	3.9%
Namai	76	436	87	191	96%	33%	14%	18%	1,205	7.6%
Paksoun	96	571	13	707	54%	54%	32%	38%	7,802	13.2%
Borikhamxay average	86	504	50	449	75%	43%	23%	28%	4,504	10.4%
All	74	450	30	1,226	76%	54%	36%	38%	4,813	6.1%

*Estimate for Donsayudom.
*Energy expense includes lightening and electric appliances such as TV.
* Surveyed in October 1998



	Donsayoudom	Houaypong	Nongpen	Mai	Namai	Paksoun
Services	5%	6%	0%	2%	0%	6%
Commerce	9%	5%	2%	6%	0%	7%
Weaving	4%	1%	46%	1%	3%	0%
Fisheries	62%	47%	0%	2%	1%	22%
Livestock	18%	36%	41%	65%	59%	39%
Agriculture	2%	3%	10%	13%	17%	23%

Figure 2-1 Cash income sources of pilot villages

At the six pilot villages, Solar Home Systems (SHS) and Battery Charging Stations (BCS) were installed for those who made applications. The number of installed solar systems is shown below.

Table 2-2 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: After initial installation, additional applications are accepted.

Table 2-3 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 experimental BCS at Houaypong was removed in November 2000.

In addition, the counterpart (C/P) conducted PV installation in three new villages in the Hinheup district of Vientiane province to strengthen their capability of project management for PV electrification. They installed PV systems based on the work flow of PV electrification (See Attachment) which was formulated during the JICA study. JICA team members oversaw their work, giving advice from time to time. The number of installed solar systems in the new villages is shown below.

Table 2-4 The number of installed PV systems in new villages

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

Note: All of installed systems are 55W SHS

2-2 Results of PV Monitoring

2-2-1 Initial payment

The villagers at the pilot villages secured enough cash primarily by selling livestock (Nongpeng), or fish (Donsayoudom, Houaypoung and Mai) to pay the initial charge; 100,000kip for 55W-SHS, and 150,000kip for 110W-SHS. Some people paid from their cash income from weaving. To the question of "How did you feel about preparation of initial payment?" , most of them answered, "Not difficult". (See Table 2-5) Although the value of the Lao currency "kip" was declining at that time, their answers indicated that people could somehow secure that amount of money. This is supported by the fact that there was no household that failed to pay the initial charge.

Table 2-5 Reaction to the Initial payment

	Easy	Not difficult	Difficult	Very difficult	Impossible
Donsayousom	17%	78%	0%	0%	0%
Houaypoung	11%	72%	6%	0%	0%
Nongpen	27%	55%	9%	0%	0%
Mai	0%	100%	0%	0%	0%

2-2-2 Monthly charge and energy expenditure

The monthly payment, 5,000kip for 55W-SHS, and 10,000kip for 110W-SHS, is viewed as not expensive. (See Table 2-6) A typical user's monthly energy expense has been almost unchanged even after the installation of the solar system. Changing from kerosene lamps to a solar system, the quality of energy usage has been undoubtedly improved without cost increase. The prices of kerosene and battery charging have been constantly increasing, which will make solar systems more competitive. After installing some solar systems, many new applications were submitted because the benefits of solar systems were well received among villagers.

Table 2-6 Reaction to the monthly fee

	Villagers reaction to Monthly fee				
	Not payable	very expensive	expensive	not expensive	cheap
Donsayoudom	0%	2%	4%	91%	0%
Houaypong	0%	5%	5%	85%	5%
Nongpen	0%	0%	0%	96%	0%
Total	0%	2%	3%	91%	1%

Note：% of respective households/ total households

2-2-3 Benefits of PV

So far, the introduction of PV has benefited the villagers because they are able to use more electricity than before. Are they satisfied with PV? The answer to this question is shown in the table below. Almost 90% of the households answered "satisfied". The problems are " taking much time to charge" or "cannot use desired electrical appliances".

Table 2-7 Satisfaction and good points of PV

	Satisfied with PV	Good points of PV							Good points of Kerosene		
		Cost perfor mance	Conven ience	Saving time	Safety use	No smell	Status	Others	Cost perfor mance	Insect guard	Others
Donsayoudom	83%	62%	91%	47%	66%	32%	19%	6%	4%	60%	0%
Houaypong	90%	75%	95%	70%	85%	60%	40%	0%	0%	15%	0%
Nongpen	100%	25%	96%	14%	14%	7%	0%	11%	0%	71%	0%
Total	89%	54%	93%	43%	55%	31%	18%	6%	2%	54%	0%

Note : % of respective households/ total households

One of the good points for the PV system is "convenience". Over 90% of the households chose this answer. We can easily understand it. For the villagers living on the Nam Ngum Lake, it takes one day to go to charge batteries at the dam; they cannot do any work on that day. With SHS, they can save the opportunity cost of having to go for charging, which is a big advantage for them. Furthermore, they do not have to worry about abrupt black-outs. They can enjoy longer lighting hours since they are free from the worry and the inconvenience of having to go for charging.

Impacts of PV introduction on cost of living and cash incomes are studied. In total, 10% of the households responded "living expenses increased".

Table 2-8 Impacts on household economy

	Cost of living Increased	Where to charge existing battery? (Share of HH)					Income Increased	Sources of Income Increased (Share of HH)			
	Share of HH	own SHS	neighbor SHS	BCS town	BCS village	others	Share of HH	handicraft	weaving	fishing	others
Donsayoudom	2%	40%	0%	2%	15%	2%	74%	4%	6%	17%	21%
Houaypong	30%	10%	15%	25%	25%	0%	90%	10%	5%	30%	10%
Nongpen	11%	14%	43%	0%	0%	0%	96%	0%	36%	11%	11%
Total	10%	27%	15%	6%	13%	1%	83%	4%	14%	18%	16%

Note : % of respective households/ total households

On the other hand, there are households whose income increased, such as weaving in Nongpen and night fishing in Houaypong and Donsyoudom. There are also cases in which people increase their incomes by making fish balls, running tailor shops and other shops at night. Also in Nongpen, houses with 110W-SHS started a battery charging business. Some households bought new electrical appliances. As can be seen in the table below, once one light is installed, electricity demand expands because people want to have another light, a cassette player, TV and audio system.

Table 2-9 New appliances bought

	New appliances bought (Share of HH)					
	Another light	Radio	Cassette	TV	Fan	Others
Donsayoudom	25%	0%	15%	8%	0%	4%
Houaypong	0%	0%	15%	5%	5%	5%
Nongpen	4%	0%	4%	7%	0%	4%
Total	14%	0%	12%	7%	1%	4%

Note : % of respective households/ total households

In Paksoun, where a 3kW BCS was installed in February 2000, the share of households having batteries increased from 50% before installation to over 90% after installation.

2-2-4 Maintenance by villagers and the village electrification committee

(1) PV use by villagers

Villagers get used to using batteries and 97% of the respondents answered that they are "easy" to use. When villagers cannot take care of their batteries for themselves, the Village Electrification Committee (VEC) will support the villagers. The expectations placed on the VEC by villagers are sales of spare parts, repair work, and user training.

Table 2-10 Operation of PV and expectations of VEC

	PV Operation	Distilled Water Check			Expectation of VEC				
	Easy	Self	Neighbor	VEC	user training	spare parts	advice	repair	others
Donsayoudom	94%	9%	0%	85%	19%	85%	4%	30%	2%
Houaypong	100%	35%	0%	65%	25%	55%	10%	50%	10%
Nongpen	100%	21%	0%	93%	21%	86%	0%	64%	4%
Total	97%	18%	0%	83%	21%	79%	4%	44%	4%

Note : % of respective households/ total households

(2) Member selection and task sharing

Most VEC members, three or four persons in each village, were recommended by others and selected in the village meeting. Each VEC is basically composed of a leader, a cashier and a technician. However, fee collection and maintenance work are assigned to two or three core members.

2-3 Social Impacts

An impact survey was conducted in June of 2000. This survey was aimed at assessing the change of life, and positive and/or negative effects of PV. There were many positive comments such as "good for nighttime studying/work", "cooking is easier under lighting", "able to get useful information from TV or radio". In terms of household economy, the introduction of PV resulted in a decrease of energy expenses in many cases. Some villagers commented that shorter sleeping hours, insects gathered toward lighting, and noise from speakers would be problems, although the problems were not that serious.

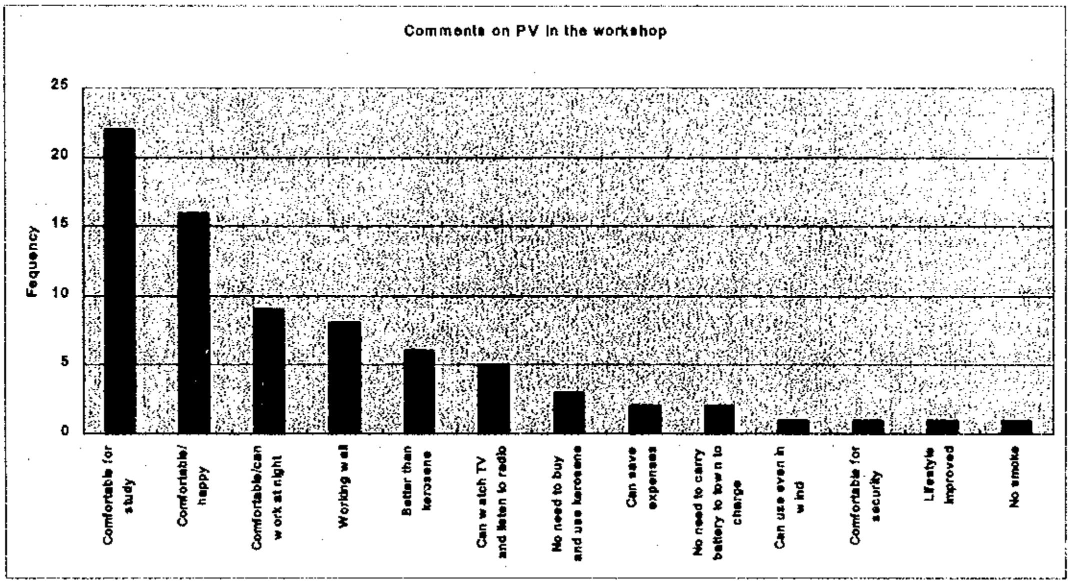


Figure 2-2 Comments at workshop

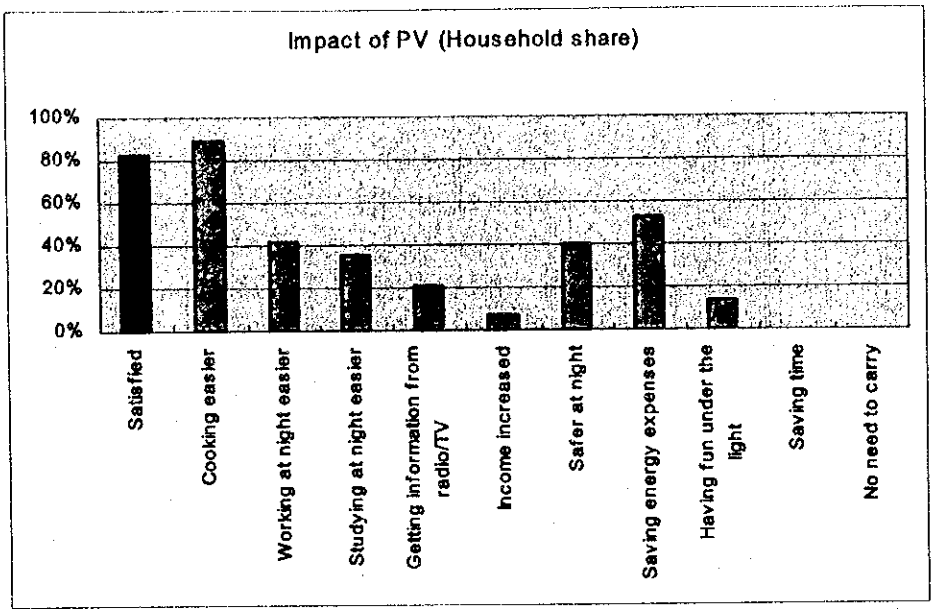


Figure 2-3 Impacts of SHS

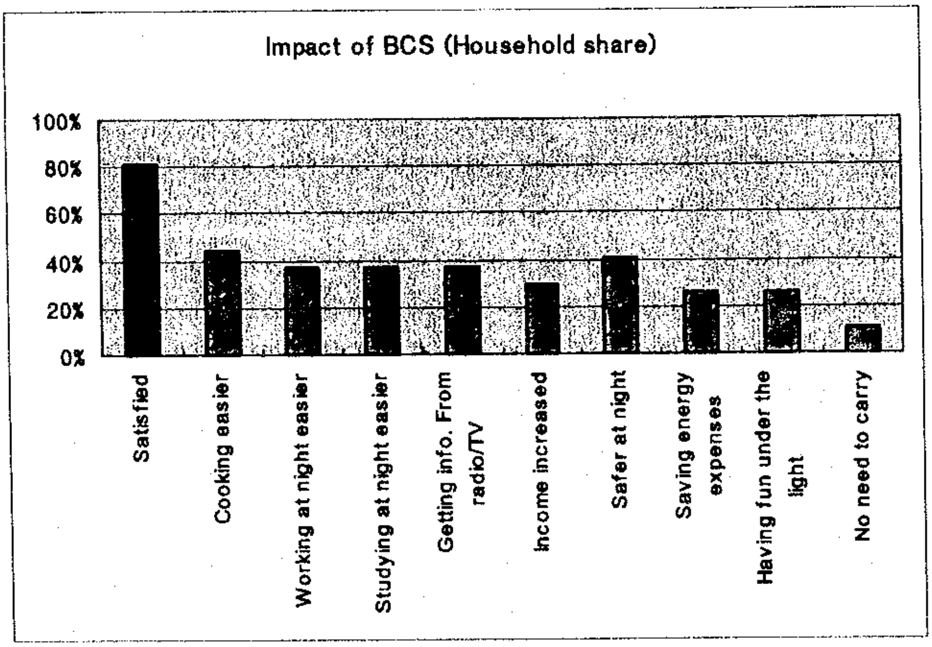


Figure 2-4 Impacts of BCS

3 Participatory Approach

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

3-1 Three Keywords

3-1-1 People's Participation

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

3-1-2 Capacity Building

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

3-1-3 Cost Recovery

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

3-2 Training Program for PV Users

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

3-2-1 Training venue and materials

On-site mass training in a house with a basic 55W SHS is recommended because it will be practical and realistic for the villagers. It will be necessary to bring tools, equipment and training materials. Since AC power supply is not available in the villages, tools and equipment should be portable and DC driven.

If the power from a PV module is necessary, it will require daylight and a place to set up. In those cases, night-time training is impossible. An alternative power source, such as a small generator or battery might be needed when sunshine is uncertain.

3-2-2 Assessing knowledge of trainees

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

3-2-3 Activities of VEC

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

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

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

4 Pilot System

4-1 Basic Design of PV System

4-1-1 Solar Home System (SHS)

(1) Estimated power consumption

It is assumed that one 8W fluorescent lamp and one 24W black/white TV will be used in a typical household.

Table 4-1 Estimated power consumption

Appliance	Peak Watt	Unit	Hours/day	Power consumption
Fluorescent lamp	8 W	1	3.2 h	25.6 Wh
TV	24 W	1	4.0 h	96.0 Wh
Total	32 W	-	-	121.6 Wh

(2) Factor of system loss

Table 4-2 Factor of system loss

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

(3) Days of autonomy

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

(4) System capacity

Based on the above conditions, the minimum capacity required for PV and battery is calculated as 43.2W and 791Wh respectively. The equipment procured for this study was a 55W PV module and a 1,320Wh battery, which is sufficient. When there are days with no sunshine, the battery consumes 10% of its capacity every day. Since the over-discharge protection works when the depth of discharge reaches 50%, four consecutive days without sunshine will be the maximum length tolerable to avoid power supply disruption.

(5) Performance of SHS

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

1) Stability of power supply

Table 4-3 shows the estimated number of days which may cause the restriction of power use. According to this table, a 110W SHS can supply power throughout a year. A 55W

SHS might encounter power supply disruptions in the rainy season.

Table 4-3 Potential of power use restriction

Unit: [day]

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

2) Excess power

System capacity was designed for the minimum amount of insolation, which occurs in August. During the dry season, generated electricity is more than actual consumption. There is a significant amount of untapped electric energy every month. (See Table 4-4)

Table 4-4 Estimated excess power

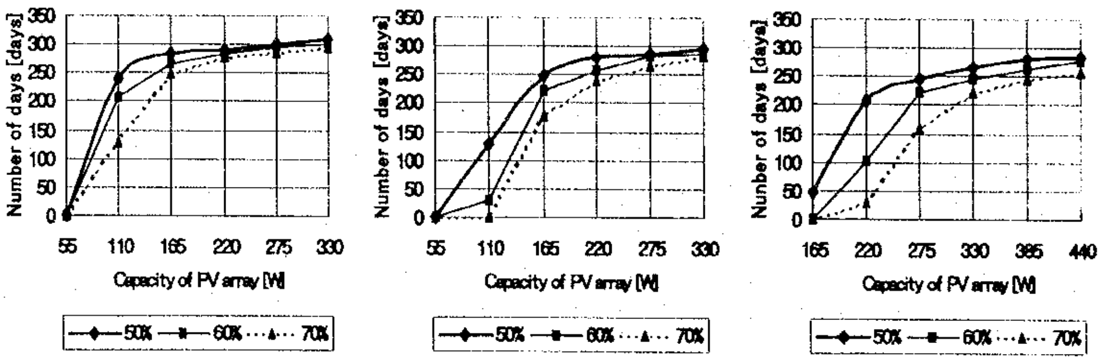
Unit : [Wh]

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

4-1-2 Battery Charging Station (BCS)

(1) System simulation

Based on the sunshine hour data from Vientiane meteorological station, the optimum PV array capacity was calculated for battery capacities of 120(Ah), 70(Ah) and 50(Ah), and for discharges of 50%, 60%, and 70%. Each case is shown in Figure 4-1. This graph shows the number of days that charging full in one day is possible in a year. For example, in case of 50 (Ah), 70 % discharge, 165W of PV array will be able to charge the battery 250 days in a year.



Battery size **50Ah** **70Ah** **120Ah**

Figure 4-1 Number of days possible to charge full

5 Economic Analysis/Financial Management

5-1 Cost Analysis

5-1-1 Forecast of Module Production Cost

Global PV module shipments increased from 46.5MW in 1990 to 201.5MW in 1999. The average production cost of PV modules decreased from $5.5/Wp in 1990 to $4.25/Wp in 1993. After that, average production costs in 1996 and 1997 remained almost flat: $4.15/Wp and $4.25/Wp respectively. However, the minimum production cost has shown a steady decline every year : $4.0/Wp in 1990, $3.5/Wp in 1993, $3.0/Wp in 1996, and $2.75/Wp in 1997.

On the other hand, demand for PV modules in the future will expand due to lower production costs and growing concern over global environmental issues (reduction of CO_2 emissions). The production cost of PV modules in the near future is forecasted by some study reports and research laboratories. In this study, we assumed that the module cost would reach $2.0/Wp in 2005, which lies between the high and low cases. In addition, we assumed that the real market price of a PV module would be $3.0/Wp considering marketing and distribution costs.

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

System Cost in the Future

Table 5-1 Cost structure forecast of 50W-SHS in 2005

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

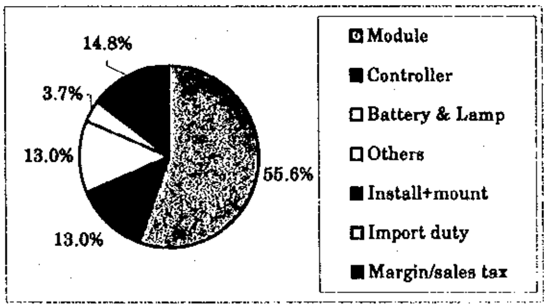
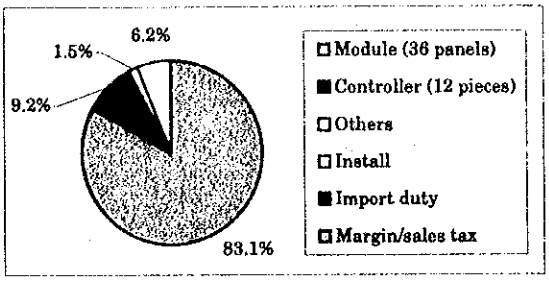


Table 5-2 Cost structure forecast of 1.8kW-BCS in 2005

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



5-1-2 Tariff System

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

(1) Solar Home System (SHS)

Assumption of 50W-SHS

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

Overhead expenses

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

<u>Salary of village committee</u>

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

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

<u>Expenses for MIH local office</u>

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

Fuel expense 5 liters/trip × $0.40/liter × 6 times/year = $12/year

Administrative expenses $2.67/month × 12 months/year = $32/year

<u>Spare Parts Expenses</u>

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

Annual Maintenance Expense

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

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

Replacement of Charge Controller

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

$35/unit × 50 units = $1,750

Based on the above assumptions, the monthly charge was calculated so that the net present value (NPV) of 20 year cash-flow becomes zero with a discount rate of 0.75%. The initial charge is set to be $20. In these calculations, 0.75% soft loans, such as from Japan Bank for International Cooperation, World Bank, and Asian Development Bank are assumed. In this case, the monthly charge is calculated to be $1.62.

Table 5-3 Recommended Tariff of 50W-SHS

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

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

(2) Battery Charging Station (BCS)

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

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

Assumptions for 1.8kW-BCS

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

Overhead Expenses

Salary for Operator

The BCS needs an operator who connects batteries in the morning and charges fees at disconnecting in the afternoon. This is not a full-time job. Therefore, we assumed that his salary is $6.67(50,000kip)/month. ($80/year)

Spare Parts Expenses

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

Annual Maintenance Expense

Like SHS, we assumed that annual maintenance expenses are as follows.

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

Based on the above assumptions, the IRR for a 1.8kW-BCS with a charging fee of $0.27(2,000kip)/charge becomes 11.2%, which indicates it has a good possibility of becoming a commercial venture as long as its owner can secure a low interest loan.

5-2 Comparison between PV Systems and Alternative Systems

5-2-1 Life-cycle cost comparison

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

Table 5-4 Present Value of electrification costs for 20 years (50HH/village)

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

This table shows the costs per household for 20 years at the present value. The figure for a diesel generator becomes $617, and $512 for small-hydro. Among the three options, SHS is the cheapest at $396. This indicates that SHS is the most economical in case of small-scale electrification. In the long run, diesel generation is expensive despite its low initial investment because fuel costs and maintenance costs are quite high. When village scale increases, from 50 to 100 households for instance, the present cost of the diesel generator and small-hydro will decrease. The difference between SHS and small-hydro would become negligible. (See Table 5-5)

Table 5-5 Present Value of electrification costs for 20 years (100HH/village)

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

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

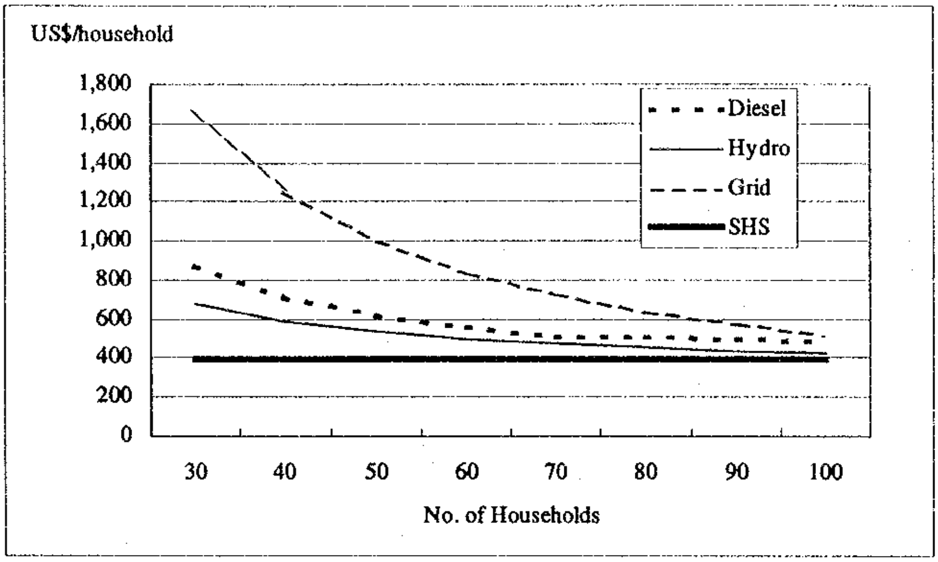


Figure 5-1 Sensitivity analysis of each system (Load : 80W/household)

According to Figure 5-1, when the electricity load per household is as small as 80W and the village scale is 100 households, SHS is economical compared to alternative systems. However, SHS also has a weak point because SHS cannot accommodate AC electric appliances without an inverter. A diesel generator has a higher cost structure than small-hydro. In remote areas, the fuel cost, including the cost of transporting the fuel, is inevitably high. A small-hydro generator can supply AC power and has social benefits of saving fuel and foreign currency, which is much more favorable for Laos.

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

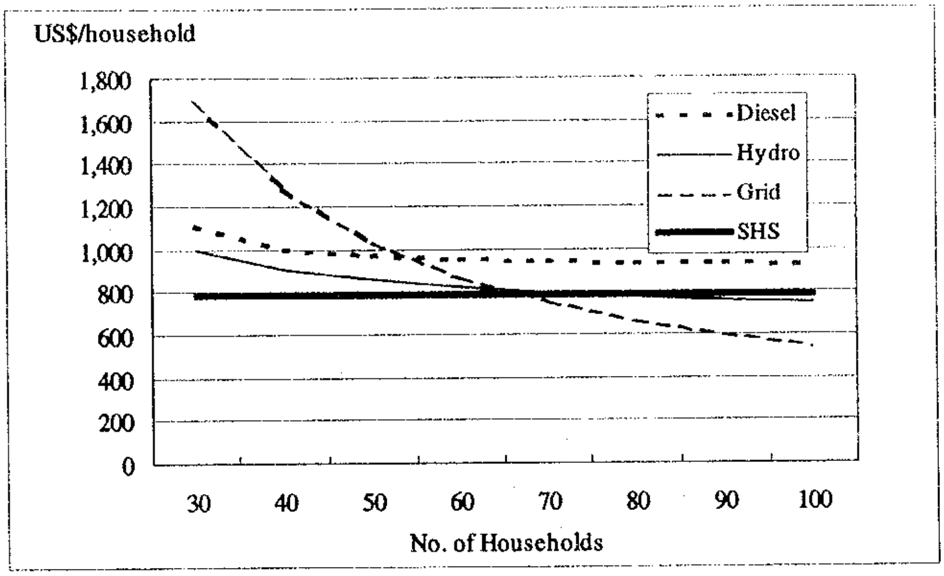


Figure 5-2 Sensitivity Analysis of Each System (Load : 160W/household)

5-2-2 Contract System

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

6 Project Evaluation and System Proposal

6-1 Evaluation of Pilot Project

6-1-1 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 solar system suited for Laos.

(1) Solar Home System

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 without failure. 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 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.

(2) Battery Charging System

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 this study, a 165(3 x 55)W BCS, which can charge up to 70Ah batteries, is proposed as a basic system. In Paksoun village they are charging their batteries periodically, and those batteries are being charged full. From the above results, it is judged that the capacity of BCS is good. But the capacity of the PV array should be increased where radiation is small.

6-1-2 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. In this pilot project, PV systems require villagers to pay an initial payment and a monthly fee. Their willingness to make those payments is an indication of demand. The explicit demand can be assessed by the fact that many houses already have batteries in non-electrified 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, the potential demand for PV electrification is high because of the high application rate for pilot systems. However, the following points are to be noted for the introduction of PV systems into new villages.

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

(2) Affordability

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) Benefits of PV electrification

People use electricity mainly for lighting, which is useful for a better life, productive work, entertainment and security. 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 remote towns
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 PV electrification is accepted by villagers depends on the easiness of maintenance as well as demand for the system, affordability, and benefits. In this point also, it was confirmed in the pilot project that villagers could easily handle their PV system 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-size 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.

6-1-3 Lessons learned from pilot projects

In the past, there were 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 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 system 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

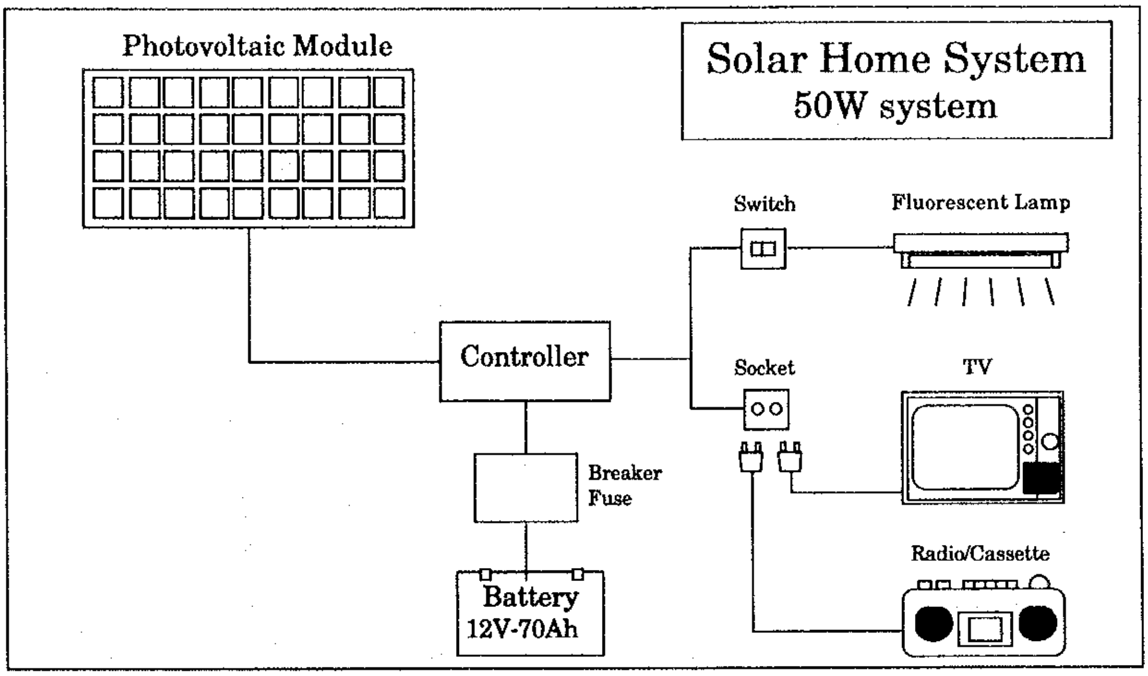
density in the village.

6-2 Proposal of Standard PV System

Based on the results of the pilot project, recommendable PV systems are proposed.

6-2-1 SHS

Considering the electricity demand in rural villages, a 50W SHS is suitable for an average household. For high income families, a larger size SHS, 100W for example, might be considered.



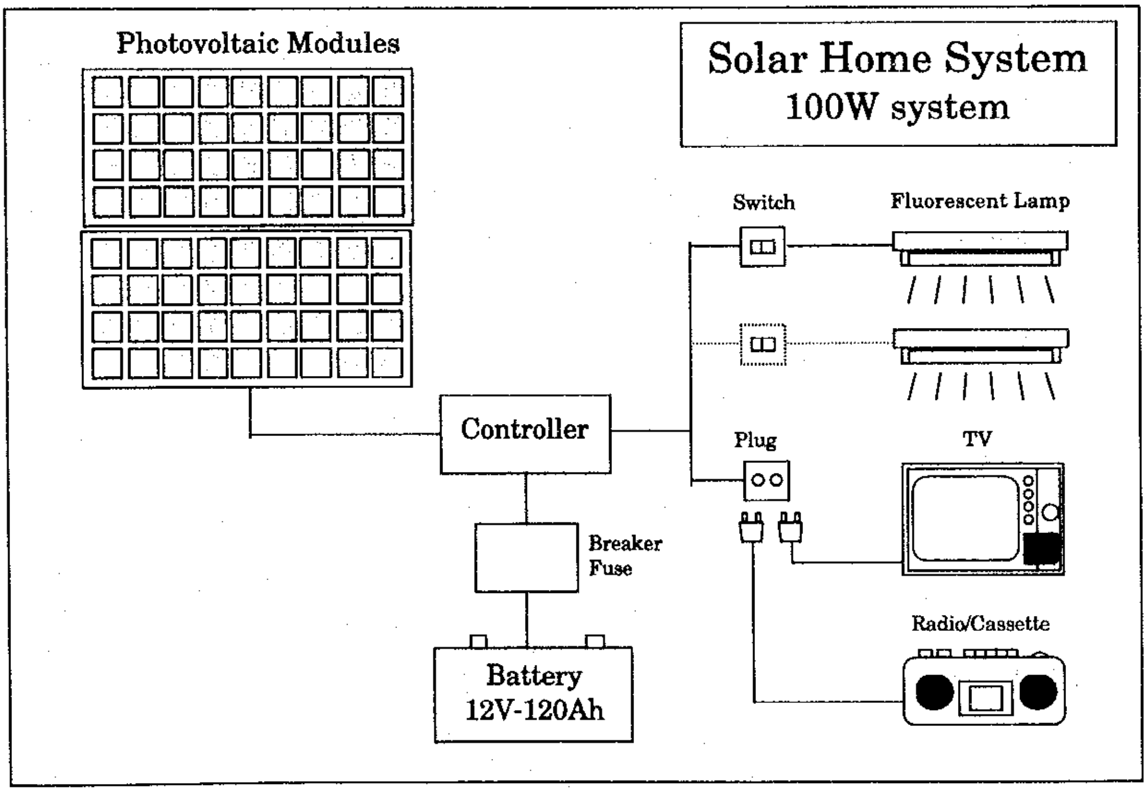


Figure 6-1 Image drawing of basic SHS

As shown in Figure 6-2, with a 50W system villagers can use a 10W FL light for five hours and a 20W B/W TV for three hours.

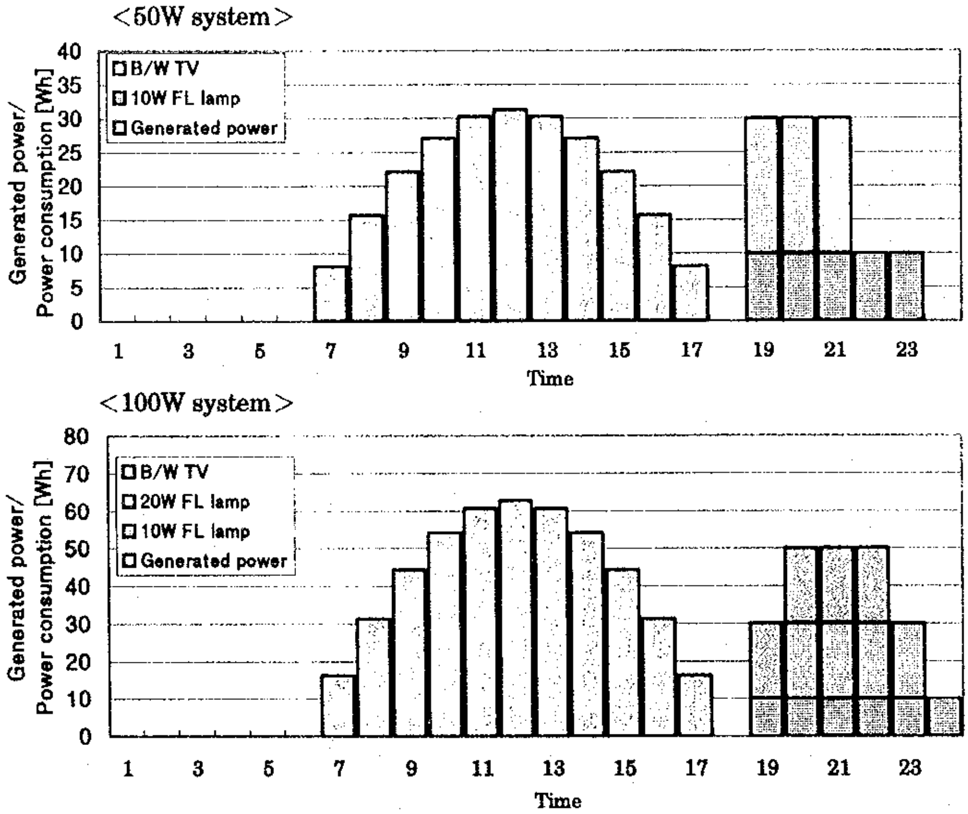


Figure 6-2 Example of operation pattern of basic SHS

6-2-2 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 less than 80Ah. The basic system of BCS 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. A changeover switch is used when charging a battery whose capacity is from 80 to 150Ah.

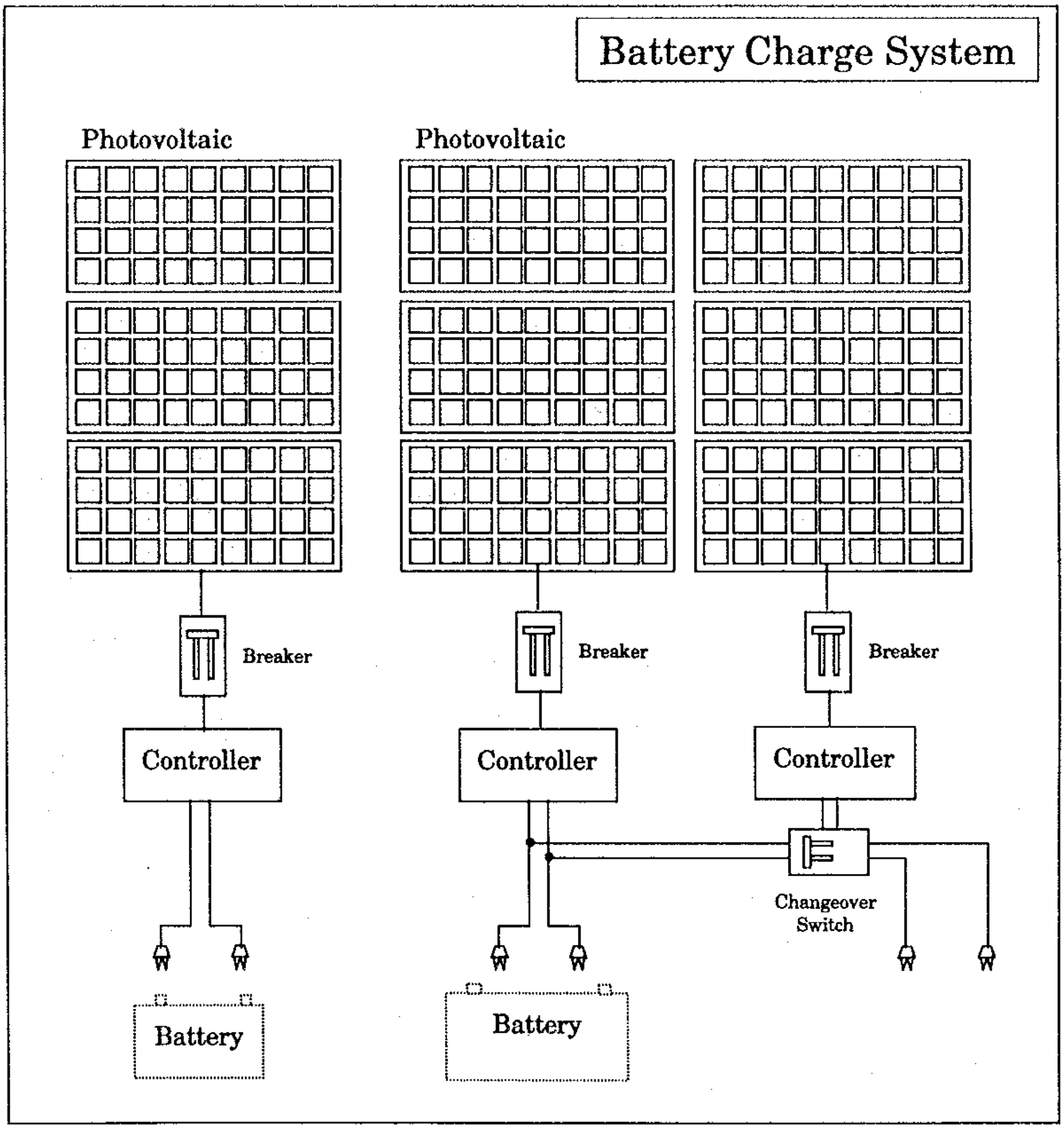


Figure 6-3 Image drawing of BCS

6-2-3 Preparation of technical manual

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

6-2-4 Village Electrification Committee

The results of the pilot project show villagers are familiar with batteries, which are widely used even in remote villages. Today's PV systems are designed to be maintenance-free. The villagers, therefore, do not have a big problem to handle PV systems. However all the villagers do not necessarily have enough knowledge to deal with troubles. In order to help them and to assure the sustainability of PV systems, establishing a Village Electrification Committee (VEC) at each village is recommended. The pilot project has verified that VEC works effectively in helping the villagers properly operate PV systems. Its mission can be summarized as follows:

- Periodical inspection and maintenance of PV system
- Trouble shooting(repair service)／Keeping records and reporting
- Fee collection

In addition, the VEC is expected to do more work, including storing and selling spare parts and moving PV systems in case of relocation, etc. The VEC typically consists of a leader, a cashier and a technician, and undertakes various tasks. Because it is viewed as an organization for life improvement and village development. It is desirable that one of the village leaders join VEC, or give advice as a supervisor regarding its management.

If VEC can not provide these services, technical staff from outside villages have to visit the villages frequently, which obviously increases the cost of PV electrification. It is a decisive factor for successful PV electrification in remote areas that the villagers can resolve various issues, such as trouble-shooting and collecting money, with the help of VEC.

6-3 Capacity Building

Although the counterpart (C/P) gained some experiences in installation, monitoring, and mobilizing villagers, while working with the JICA team at the initial stage of PV installation, they didn't have an opportunity to manage PV electrification projects under their own initiative. There was a concern that they might not be able to undertake future projects due to lack of experience. Considering their need for more practical experience, JICA decided to carry out an additional PV project to beef up the counterpart's capability from September to November, 2000.

The counterpart independently did a series of jobs, from system design to monitoring, and successfully completed the introduction of PV systems into three new villages. Although they need to improve material management and to continue to support the VEC, etc., they recognize those issues and are trying to resolve problems on a one-by-one basis. Thus, it can be concluded that the C/P have reached the level where they can undertake PV electrification projects on their own. This additional PV project undoubtedly contributed to the capacity building of the counterparts. In the case of PV projects executed in the whole country, it is not desirable that engineers of the central government are always involved in installation or technical training. Therefore a technology transfer to engineers of the local offices should be planned at an early stage through executing some model projects in which the C/P engineers work with local engineers.

7 Master Plan

7-1 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.

7-1-1 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. 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 pay, and also operate and maintain their PV systems.

(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 initial charge and $1.50 as 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 associated costs are very small. The dominant cost component is the initial investment. A 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-based rural electrification 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 an 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 service charge every month. Furthermore, for the service charge 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 the 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 service charge 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.

(2) Technology

As for technology, the basic specifications of SHS are fixed. In rural areas of Laos, 50W class SHS combined with controller and regular size (70Ah) lead-acid battery is recommended. There is 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 experiences 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 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 developing countries, restructuring of the electric power sector is in progress to achieve a sound financial structure. Under these circumstances, it is becoming more and more difficult for power companies to promote rural electrification on their own initiative. In Laos, 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 7-1)

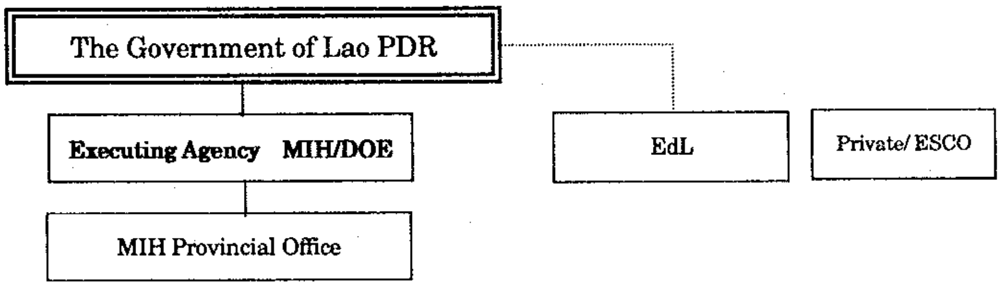


Figure 7-1 Organizational framework on rural electrification

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 in 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 Energy Service Companies (ESCO), will be dominant in providing PV based electricity supply in remote areas.

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 VEC was able to handle many issues after some guidance and training to ensure sustainable operation of the solar system. The reason for the success of 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 organizations will be indispensable.

7-1-2 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, 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 recommended 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 on 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 these factors.

Solar power is suitable for a village where the demand for electricity will remain less than 100W 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-hydro power 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, it is always important to secure a sufficient maintenance mechanism for the installed electricity supply system. Diesel generators and hydro power 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 install solar systems in remote villages where technicians are not easily available.

7-2 Strategy for Solar-based Rural Electrification

In the pilot project, it was revealed that solar systems were well received by local Lao people. The next step is to promote the penetration of solar systems into rural Laos based on a well-defined strategy. In the following section, a strategy for solar-based rural electrification is presented.

7-2-1 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 these 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

7-2-2 Tariff and Promotion Body

With these measures and the anticipated production cost reduction of solar panels, 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. 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 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. The effort for organizational strengthening should be continued by implementing a series of rural electrification projects. In order to improve MIH's capacity to manage rural electrification projects, an additional project was implemented in late 2000.

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 projects. Rather, provincial governments are strongly encouraged to take the initiative in project implementation. Therefore, they must quickly develop the capability of undertaking rural electrification projects. 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.

7-2-3 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

It is possible to collect service charges including some capital costs from users even in the case of rural electrification funded by grant. In this case, surplus revenue will be accumulated over time. In the pilot project, PV system users are supposed to pay the initial charge and monthly charge, which are calculated from model plant costs. A total of 40 million kip (about $5,000) has been accumulated already, and two million kip will 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.

7-3 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. A commercial project is hard to imagine, although it 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

Table 7-1 shows the target figure up to the year 2010. According to this table, about 80,000 households will have been electrified by solar systems in 2010. Assuming $300 plus 50% overhead per unit, a rough idea about the total financial requirement over the next ten years is $36 million.

Table 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.

7-4 Implementation Plan

7-4-1 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.

7-4-2 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 systems 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.

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). The first two or three projects in each province will be conducted by MIH/DOE, which has expertise in solar-based rural electrification. The provincial authorities will learn the process of project management by working with MIH/DOE. After that, the provincial authorities will take over and carry out the remaining projects. As for financing, the Lao government has difficulty in setting aside funds in the national budget for this plan. Rather, they are required to secure funds from overseas aid organizations. 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 the previous chapter, it can be said that the project cost per household in this stage is around $400 including 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 internal 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 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. 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.

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 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".

7-4-3 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 them tax exemptions 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 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 2000 new customers will be acquired. In the 1st stage as a whole, there about 5000 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 acquire 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 7-2 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 7-3 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.

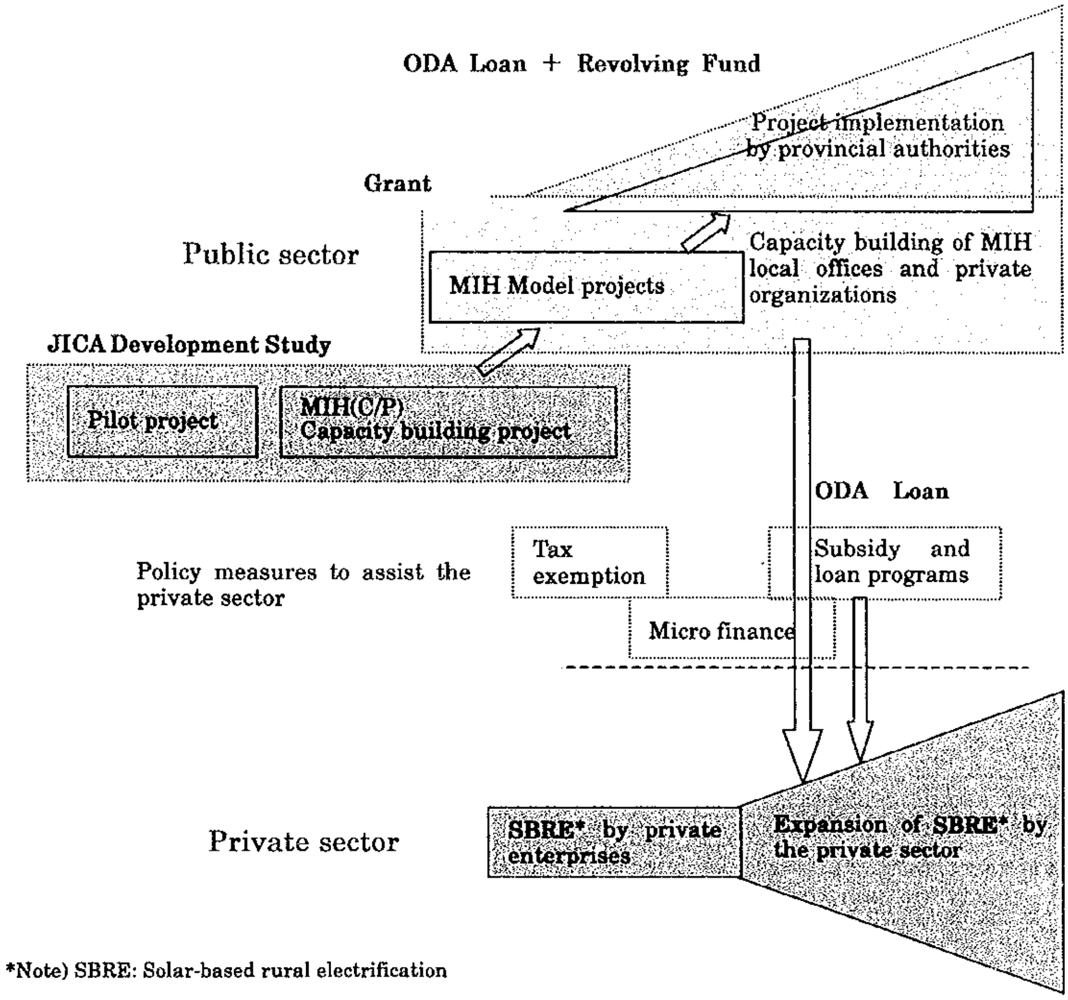


Figure 7-2 Strategy for solar-based rural electrification

8 Small-hydropower Development

8-1 Small-hydro for rural electrification

There have been many examples of small- or mini-hydro developments for rural electrification in the world. There are several types of mini-hydro plants suitable for village electrification, ranging from 20kW to 100kW, whose design has been almost standardized. A much smaller size of system, called micro-hydro, is also developed based on the same technology. In this study only a pre-feasibility study was conducted on a couple of potential small-hydro sites. The following evaluation, therefore, is not based on actual demonstration.

The economic feasibility of hydropower depends largely on natural conditions such as topography or water discharge. As a characteristic of hydropower, the initial investment is quite large and, therefore, requires a long time for cost recovery. This problem makes small-hydro development difficult to realize on a commercial basis. In case of hydro power, people can use AC power and many electrical appliances so that they benefit much more compared with a solar system. In theory, the average fee of hydro power should be higher than that of solar power to reflect the advantage of hydro. However, it was made clear in this study that villagers in the remote areas of Laos can only pay about $2.00 every month for electricity. This is a very tough condition for small-hydro development so that potential sites must be investigated with such economic conditions in mind.

Small-hydro development requires skilled contractors who undertake the construction work of main structures such as the weir, channel and power house. Also electrical/mechanical equipment such as the turbine, generator and controller requires custom design. Even after commissioning, special knowledge and skill are necessary for the maintenance of hydro equipment. As operators, educated experts are required, which is a tough condition for rural villages. There are many examples where poor maintenance caused fatal damage to the equipment of village hydropower. Providing intensive training to develop local experts is one of the most important tasks in the case of small-hydro development.

8-2 Small-Hydropower Potential

It is estimated that the hydro potential in Laos is as large as 13,000MW. Given such a large hydro potential, it is not difficult to find many 20kW-class attractive hydro sites near the foot of mountains. This size of hydropower is appropriate for electrifying one village. But if the site is too far from the village, it is not economically viable. Also, if the site is located in an area where the grid is to be extended, its development should be avoided. In conclusion, truly attractive sites will be limited and careful consideration for development is required.

Examination of comparative data of annual precipitation in Laos is necessary to understand the situation of hydrology in Vientiane and Borikhamxay Provinces. According to those data, the central area, represented by the Vientiane municipality, has relatively high precipitation (annual average: 1,684mm in Vientiane, 1,386mm in Luangphrabang, 1,451mm in Savannakhet). In particular, Vangvieng(annual average: 3,225mm) and Kengkouan(annual average: 1,944mm) of the central area have relatively high precipitation.

8-3 Case Study

8-3-1 Zoning

The target zone for micro-hydropower development in the target area of Vientiane and Borikhamxay Provinces will be selected based on EdL's electrification plan, as well as other criteria. Basic zoning criteria in this study are:

- **the area where grid extension will not be realized in the coming decade;**
- **the area with comparably easy accessibility;**
- **the area located at more than 8 km distance from the existing or planned grid;**

Based on the result from the cost estimation for the case study, transmission system construction in Laos would cost approximately $10,000-/km. Therefore, in general, grid extension would be more economical in areas where the distance from the grid terminal is less than 8km.

Note *) : Average unit construction cost is estimated at approximately $5,000-/kW, including survey & design works and the transformer/transmission system. When the minimum size of utilities in the planned area is 100 households with unit demand of 150W/household, the required minimum installed capacity would be 15kW and the project cost would be about $80,000-. This is almost equal to the cost of extending the grid for 8 km.

and

- **the direct distance between the location of the powerhouse and the nearest accessible road should be within 2km**

When the direct distance between the powerhouse and the nearest accessible road is more than 2km, it would require a significant amount of extra cost for a temporary road and transmission line.

1) Electrified and to-be-electrified Area

The necessary information was provided by EdL and/or Local MIH Offices (DIHs). It was foreseen that the planned area is limited to a location in the vicinity of grid transmission lines along the major national roads.

2) Target Area for M/H Development (Zoning)

Target areas for M/H development was selected on topo-maps of 1:100,000 under the above conditions.

8-3-2 Basic Plan

Among the selected candidate sites in the two targeted provinces, one study site for each province was selected with accessibility mainly in mind. Then, basic design work followed. The outline of selected study sites is as follows;

1) Vientiane Province

The selected stream of Houay Sing is located at a distance of approximately three hours drive in a 4WD vehicle from Vientiane Municipality. In the wet season the site is inaccessible due to poor road conditions. Ban Nalao, the planned recipient community, is located very close to the candidate site and had 82 households (1998). The planned facility comprises a 15kW(minimum 10kW) generation system and a low-voltage distribution line of approximately 780m between the power plant and the community.

2) Borikhamxay Province

Ban Tonsan and neighboring Ban Kammouan, located near the river Nam Phouan, were selected as the candidate locations. The area is located at a distance of about five hours drive by 4WD vehicle from Vientiane Municipality. The area is also the source of the river Nam Theun. The number of recipients in the two villages is 147 households (1998). The planned facility comprises a 20kW (minimum 10kW) generation system, due to flow conditions, and a low voltage distribution line of approximately 3.7km connecting the power plant and the two recipient communities.

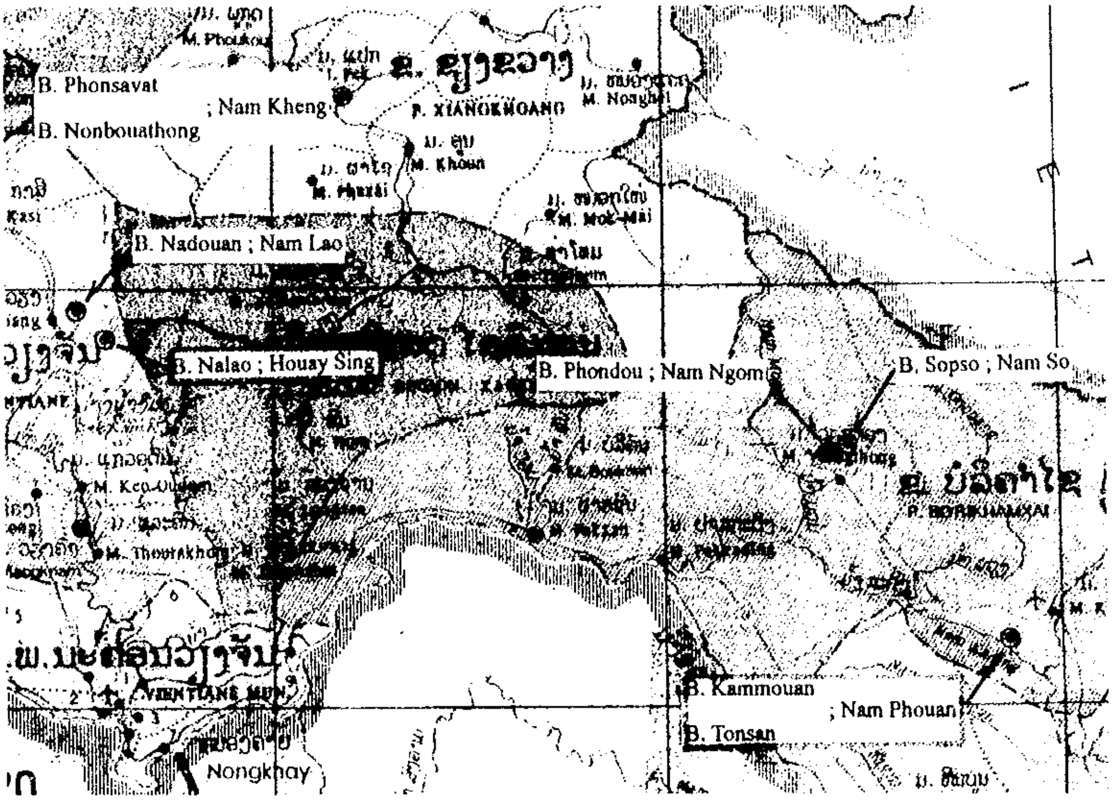


Figure 8-1 Location of pilot mini-hydro sites

8-3-3 Basic Design

Basic design works for the two study sites were undertaken and the outcome will be the basis for the cost estimation. The design took into consideration the use of local materials and skills as much as possible, as well as the need for easy maintenance facilities. (Drawings are attached in the main report)

8-3-3 Cost Estimation

Based on the basic design, the total direct costs were calculated by multiplying each work item with its unit cost and adding the figures together. Project costs were derived by calculating overhead costs, which were assumed not to exceed 10% of the direct costs. Unit costs for materials and work items were based on actual prices in Laos (researched by EdL) or domestic market prices in Japan when unavailable in Laos.

1) Houay Sing Project(Vientiane Province) ; installed capacity- 15kW

•Civil Works	: $37,900-
•Equipment Installation	: $23,000-
•Low voltage distribution line (780m)	: $4,800-
•Additional Works	: $5,900-
•Cost for Direct Works(Subtotal)	: $71,600-
•Overhead(within 10% of subtotal)	: $7,100-
Grand Total	: $78,700-
•Unit Project Cost per kW	: **$5,250 /kW**

2) Nam Phouan Projcet(Borikhamxay Province) ; installed capacity- 20kW

•Civil Works	: $34,700-
•Equipment Installation	: $23,000-
•Low voltage distribution line (3.7km)	: $26,100-
•Additional Works	: $9,500-
•Cost for Direct Works(Subtotal)	: $93,300-
•Overhead(within 10% of subtotal)	: $9,200-
Grand Total	: $102,500-
•Unit Project Cost per kW	: **$5,130 /kW**

(1) Evaluation of Unit Project Cost

Analyzing the outcome from the above-mentioned study projects, the following findings could be introduced:

In the case of installed capacity of around 20kW, the costs for civil works and power generating equipment are almost the same or constant regardless of site conditions, and the major controlling factor of project cost would be the transmission/ distribution line. When looking at the derived Unit Project Costs per installed capacity, installation for a 20kW (or approx. 20kW) system with a 2km distribution line would cost approximately $5,000/kW. Of that, $3,700/kW is to be spent on civil works and equipment. The $5,000/kW figure exceeds by about 65% the targeted unit cost of $3,000/kW. Also, considering the current situation for material supply in Laos, one can observe that most domestically utilized industrial products are imported from abroad. Moreover, the design of maintenance-free projects might lead to rather expensive civil structures.

8-4 Ten-year development plan (Master Plan)

It is difficult to formulate a long-term small-hydro development plan taking into account site conditions, because potential hydro sites have not been fully investigated so far. Therefore, only a conceptual frame work is discussed in this section.

8-4-1 Demand forecast

An average-size village is assumed to have one hundred households. The villagers will use only fluorescent lamps, not incandescent lamps, and TV/radios. Electricity demand during the daytime is small because only rice mills, irrigation pumps and a few lamps at a limited number of public facilities will be used. With these assumptions, the maximum demand is estimated 14.9kW in the evening. Thus, the unit demand per household becomes 150W, which is relatively large. This figure, which is inflated to take into account projections for future demand growth, will be used for planning purpose.

8-4-2 Basic principle

The following conditions were considered to make a ten year plan.

① Target Year

The ten-year period starting with the year 2001 is divided into two phases: Phase-1 for planning and designing and Phase-2 for construction and installation.

② Target Community and Plant Size

An average size rural village with approximately one hundred households is assumed and a 15 kW size mini-hydro power plant, which corresponds to the village size, is studied.

8-4-3 Capital Requirements

An estimation of required total investment for the ten year period is made as follows.

(1) Candidate Districts

The candidate districts for the Master Plan were screened based on the before-mentioned criteria, such as size of each community, the status of electrification and future electrification plan and potential of mini-hydro, etc. Information on potential mini-hydro sites was reviewed referring to 1:100,000 topo-maps. The selected candidate districts are as follows:

① Vientiane Province
- -Vanvieng District
- -Kasi District

② Borikahmxay Province
- -Khamkeut District
- -Vianthong District

(2) Candidate Villages

The location of potential mini-hydro sites in the vicinity of target villages is checked using topo-maps (1:100,000) and interview data from DIH. As a result, in the four target districts, 16 villages were selected for further investigation. It is recommended that MIH/DOE concentrate their efforts on a limited number of projects, because they have limited knowledge and experience in mini-hydro development. Starting one or two projects every year is reasonable. For estimating the capital requirements for the ten-year period, we selected 10 projects covering 11 villages, as primary development project sites. (See Table 8-1)

Table 8-1 Selected communities for S/H Master Plan

Province	District	Community	No. HH	Notes
Vientiane	Vangvieng	Keokouang	119	
		Nalao	82	Case study
		Nakhoun	88	
		Phonsavang	86	
		Phonxou	94	
		Sub Total	469	
	Kasi	Phato	106	
		Phonthieng	87	
		Viengsamay	106	
		Sub Total	299	
		Provincial Total	768	
Borikhamxay	Kamkeut	Khammouane	105	Neighboring to Tonsan
		Tonsan	42	Case study
		Sub Total	147	
	Viangthong	Phondou	117	
		Sub Total	117	
		Provincial Total	264	

Note : Number of households is based on EdL information as of February 1998

(3) Cost Estimation

The investment cost of each project was estimated based on the previous case study. The cost for survey and design work of each project in Phase-1 is assumed to be $20,000. The total investment required for the ten-year period turned out to be around $930,000. (See Table 8-2)

- Unit demand — 150W/household
- Survey and Design cost — $20,000 (Preparation $500, Planning $3,000, Survey $1,500, Design $15,000)
- Unit construction cost
  - Civil and power facilities — $3,700 / kW
  - Distribution Line — $8,000 / km

Table 8-2 Cost estimation for S/H Master Plan

Province District	Community	Households	Plant Capacity (kW)	Distribution (km)	Cost	Notes
Vientiane						
Vangvieng	Keokouang	119	17.9	2.0	$102,300-	
	Nalao	82	12.3	0.6	$70,400-	
	Nakhoun	88	13.2	2.0	$84,900-	
	Phonsavang	86	12.9	2.0	$83,800-	
	Phonxou	94	14.1	2.0	$88,200-	
	Sub Total	469	70.4	8.6	$429,600-	
Kasi	Phato	106	15.9	2.0	$94,900-	
	Phonthieng	87	13.1	2.0	$84,500-	
	Viengxamay	106	15.9	2.0	$94,900-	
	Sub Total	299	44.9	6.0	$274,300-	
	Vientiane Total	**768**	**115.3**	**14.6**	**$703,900-**	
Borikhamxay						
Kamkeut	Khammouane	105	15.8			With Tonsan
	Tonsan	42	6.3	3.0	$125,800-	
	Sub Total	147	22.1	3.0	$125,800-	
Viangthong	Phondou	117	17.6	2.0	$101,200-	
	Sub Total	117	17.6	2.0	$101,200-	
	Borikhamxay Total	**264**	**39.7**	**5.0**	**$227,000-**	
	Two provinces Total	**1132**	**155**	**19.6**	**$930,900-**	

Note : Number of households is as of 1998 (EdL data)
Case study data of Nalao and Khammouane/ Tonsan are not used here.

8-4-4 Prioritization

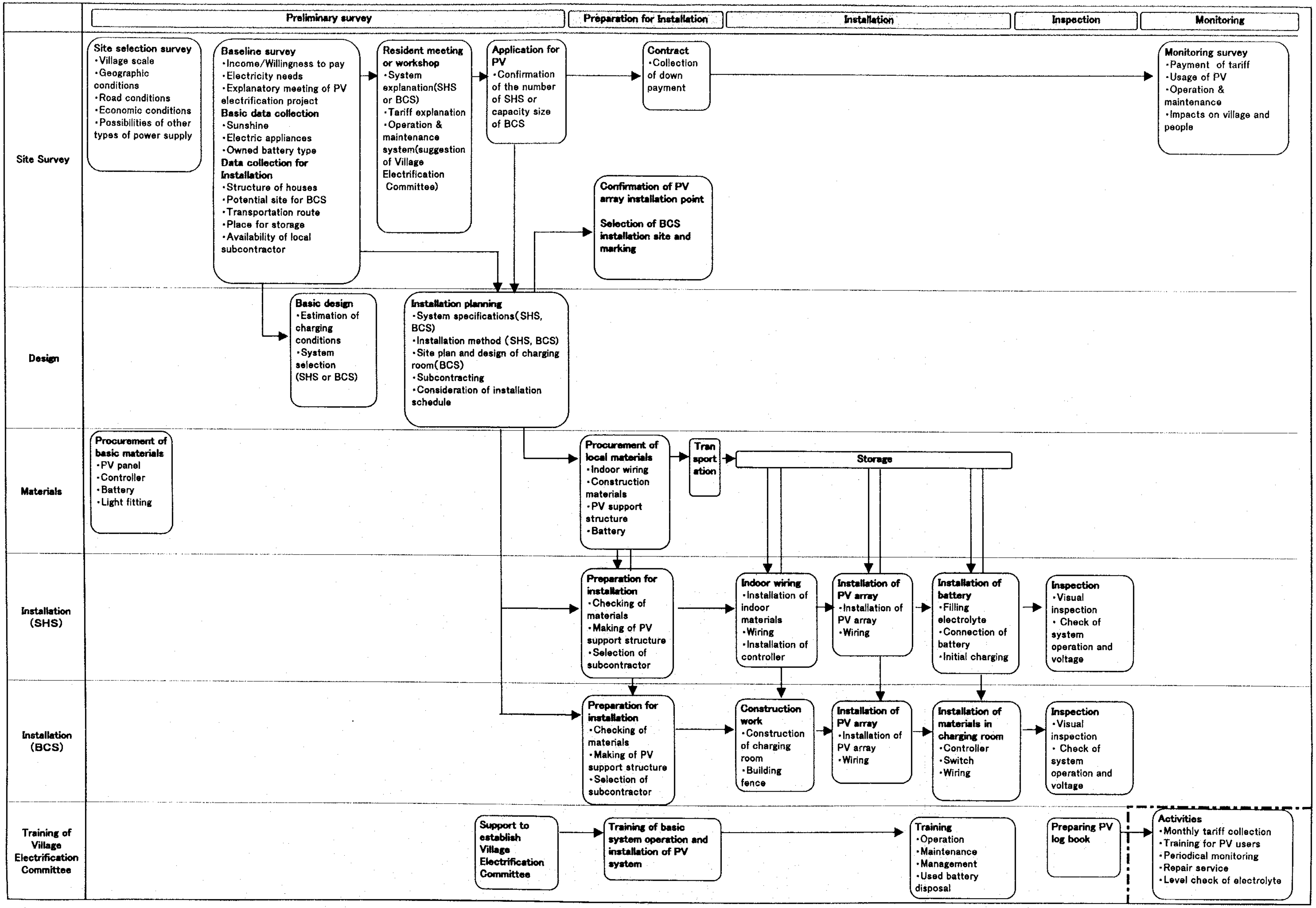
During Phase-1, detailed survey will be carried out on each site, and priority projects are to be decided based on set criteria such as economic feasibility, and urgency, etc. In Phase-2, the projects will be implemented based on the order of priority.

8-4-5 Investment Plan

Based on the total capital requirement of $930,000—$200,000 for planning and $730,000 for construction—the annual budget for the whole period can be estimated at $90,000 to $100,000. Thus, the necessity of securing approximately $100,000 annually to develop mini-hydro plants for rural electrification in the two provinces must be recognized.

Grants from foreign aid organizations are the most likely source of capital for mini-hydro development as well as for solar system development. However, the Lao government needs to provide funds for the survey stage, which may not be covered by grants. In this case, it would be possible to use the funds to be created by collecting fees from solar system users, because solar and mini-hydro development has the common goal of promoting rural electrification. With such measures, the rural mini-hydro development can be accelerated. At the same time, it is important to train local technicians so that they can provide inspection and maintenance services of mini-hydro facilities, because good maintenance is the key to success in the case of rural mini-hydro development. Developing a separate training program is indispensable.

Flow Chart of Rural Electrification by Solar System



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