Follow-up Study to the Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam

Final Report

Summary

October 2004

Japan International Cooperation Agency
Economic Development Department

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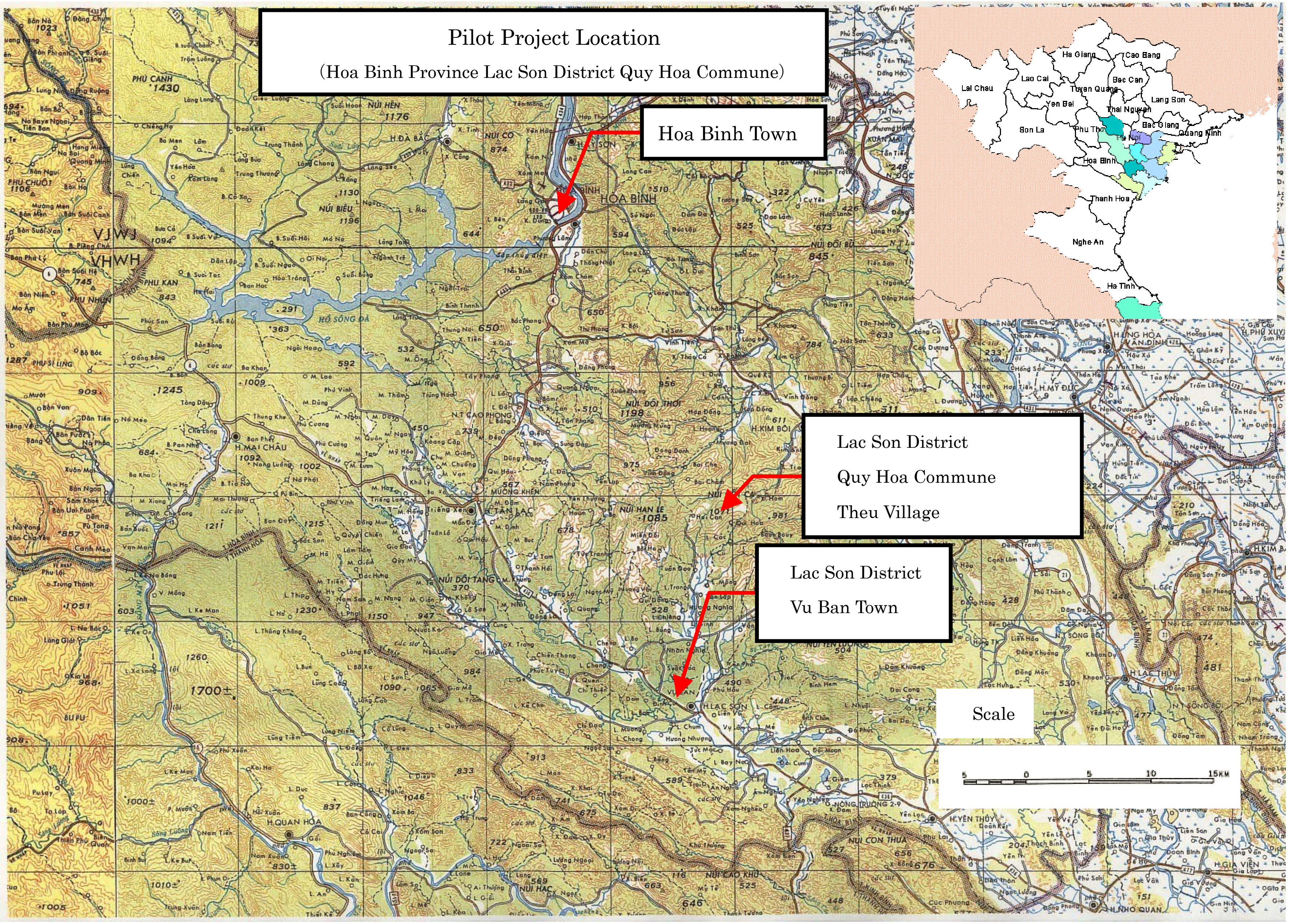

Pilot Project Location
(Hoa Binh Province Lac Son District Quy Hoa Commune)
Hoa Binh Town
Lac Son District
Quy Hoa Commune
Theu Village
Lac Son District
Vu Ban Town
Scale
5 0 5 10 15KM
Ha Giang
Cao Bang
Lao Cai
Lai Chau
Bac Can
Tuyen Quang
Lang Son
Yen Bai
Thai Nguyen
Son La
Phu Tho
Bac Giang
Quang Ninh
Hoa Binh
Thanh Hoa
Nghe An
Ha Tinh

Pilot System Facilities

Intake weir（renovated by villagers）

Headrace（newly built）

Head tank

Powerhouse

Water-turbine and generator

Distribution system

Chapter 1 Background and Study Objectives

1-1 Background and objectives

In the northern mountainous region of Vietnam, the electrification rate is relatively low due to its difficult geographical conditions. Many communes and villages still have no electricity. The Government of Vietnam (GOV) views that rural electrification is an important policy topic, because it is related to the high-priority agenda of poverty reduction and rectifying imbalance between cities and rural areas. The GOV is accelerating the grid extension to remote areas with the assistance from the World Bank. The implementing agency of grid extension is the Electricity of Vietnam (EVN). The goal of EVN is to electrify 90% of villages by the national grid by the year 2010. However, the grid extension is sometimes difficult for the villages located in rugged mountainous terrain or in the outskirts of commune. In such cases, it is necessary to develop off-grid systems. EVN clearly stated that off-grid rural electrification is sometimes unavoidable for outlying villages. In Vietnam, it is stipulated that Provincial People's Committee (PPC), not EVN, is responsible for off-grid electrification. (Prime Minister's decision #22:1999)

Thus, it is assumed that about 10% of villages need off-grid rural electrification. Renewable energy sources such as micro hydropower and solar power are regarded quite feasible in Vietnam. However, there have been few examples of off-grid rural electrification projects so far. We need to understand why off-grid electrification is so slow. First, it can be pointed out that there have not been developed feasible off-grid model plans that can be followed. Those who are in charge of off-grid rural electrification are eager to see appropriate models of off-grid electrification, and to know how to design off-grid systems and how to secure the investment capital.

Given this background, the objectives of this study were to build a micro hydropower (Village Hydro) pilot system in a typical isolated village in northern Vietnam and to demonstrate its sustainability and replicability. Also, OJT technology transfer for the capacity building of province level authorities was pursued during the study. It is our goal that the model plan demonstrated in this pilot project spreads out nationwide and triggers off-grid rural electrification.

＜Goals＞

①Demonstration of the sustainability and replicability of off-grid rural electrification by the concept of Village Hydro from financial, managerial(institutional) and technical viewpoints.

②Capacity building targeting the Department of Industry (DOI) of Provincial People's Committee that is responsible for off-grid rural electrification.

③Preparation of manuals based on the results of this pilot project to create knowledge base for future off-grid projects.

The organizational structure and timetable of this pilot project are shown below.

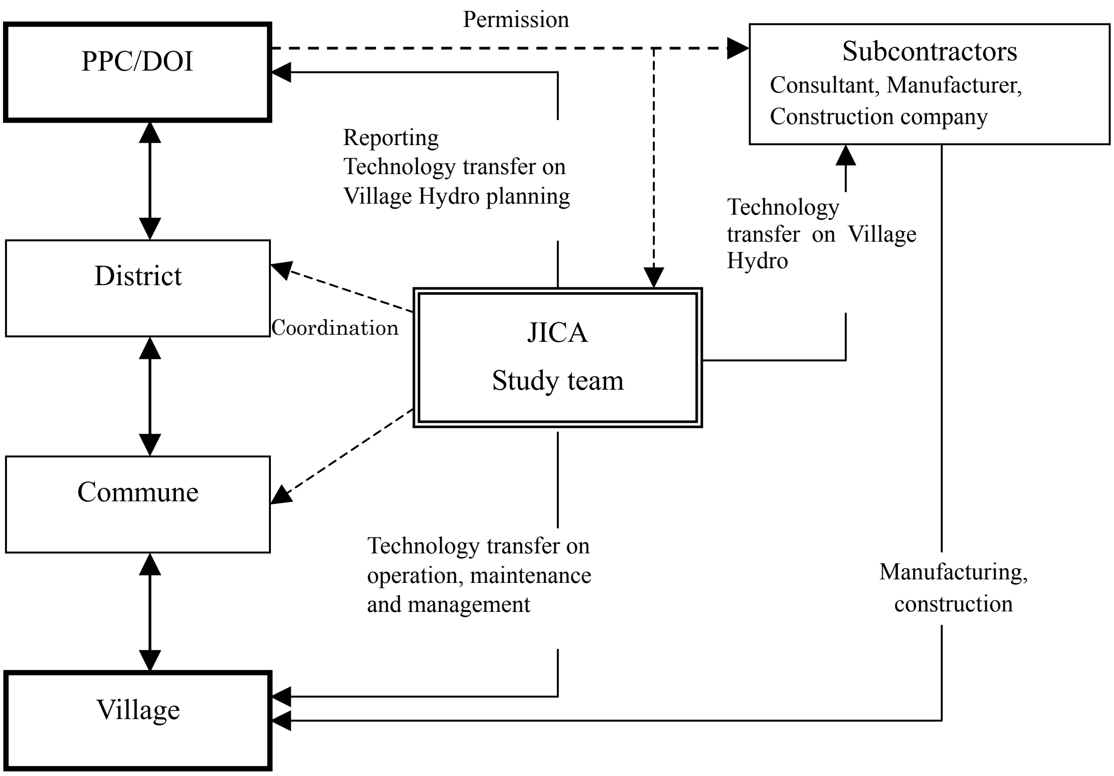


Figure 1-1 Related organizations of the pilot project

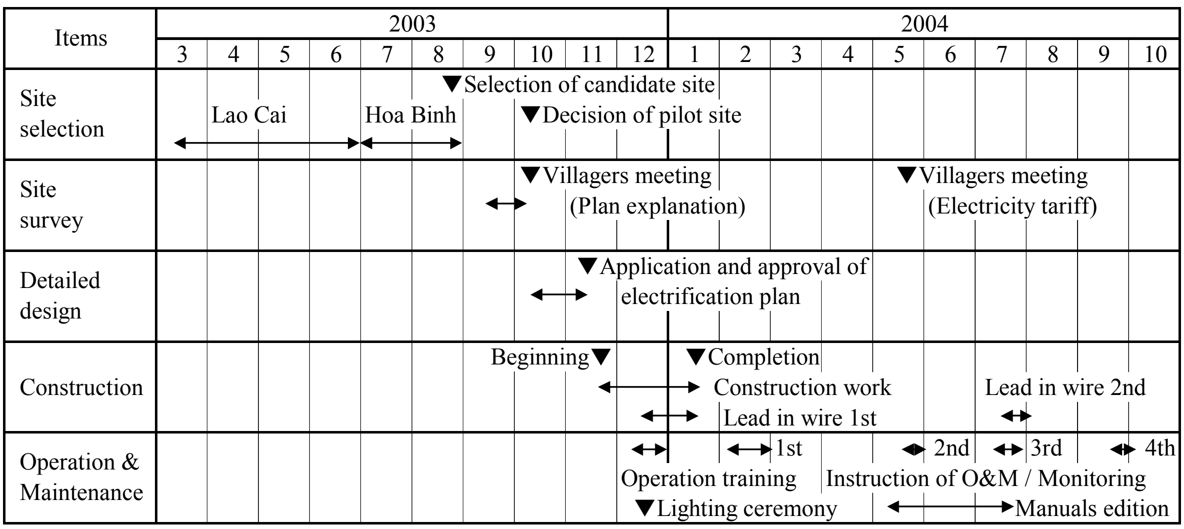


Figure 1-2 Pilot project timetable (actual)

1-2 Pilot Village

1-2-1 Selection criteria

The selection criteria of pilot village are as follows.

① There is an appropriate potential site of micro hydropower.

◆The site is located on the slope of hill

◆The water flow is rich and it is easy to have enough head.

◆Existing irrigation channels and terraced rice fields are well maintained

◆ Possible to secure some water in the dry season.

② Securing enough monitoring period, for at least five years, is possible. (No grid extension plan for the next five years)

③ The villagers can afford electricity tariff, connection charge and electric appliances

④ Villager's proactive participation in the electrification project can be expected, because of their strong unity and eagerness for electrification.

⑤ Dissemination of pilot project information can be facilitated due to easy access to the site.

Since Village Hydro is a small-scale electrification scheme targeting one village, it doesn't have to be demonstrated in commune centers. Accordingly, we searched for an appropriate "village", not a commune, in HoaBinh province, and finally selected Theu village, Quy Hoa commune, LacSon district of HoaBinh province as the pilot village.

1-2-2 Quy Hoa commune

Quy Hoa Commune is located at a distance of two-hour drive from Hoa Binh town and 30-minute drive from Lac Son district center. There are 17 villages with a total population of 5,400 and the center village is Kha. Electrification by the national grid has been in progress in the commune since 2002. Electricity is already supplied to about 50% of households.

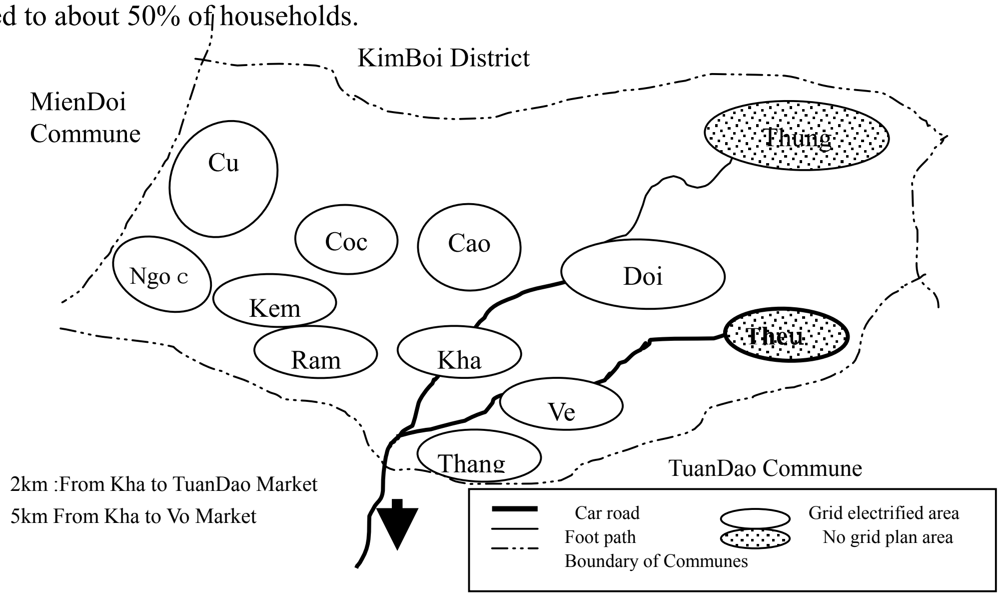


Figure 1-3 Villages in QuyHoa commune

1-2-3 Theu village

Theu is a Muong tribe village, with 78 households and a population of 390, located four kilometers away from the commune center. Although the road to Theu village is not in good condition, 4WD vehicles can reach the center of village. Typical Muong houses are large stilt houses and built along the main road. Theu village is divided into three areas.

Table 1-1 Household and population of Theu

Area	Households	Population
1	31	164
2	25	120
3	22	102
	78	386

＊As of October 2003

Figure 1-4 A typical house in Theu

The villagers cultivate their terraced rice fields, and get two crops in a year. Rice, maize and cassava are their main products. Basically their livelihood is self-sufficient, they get cash income by selling livestock and crops on the local market. According to the village leader, the annual average income was 1.2 million VND per household in 2002.

In October 2003, 54 households were using pico-hydro generators. Their primary electric appliances are electric lights（25W bulbs and 40W fluorescent lights are popular）, black and white TV sets and electric fans. Those un-electrified households that have no pico-hydro generators were using kerosene lamps.

Table 1-2 Electric appliances in Theu

Electric Appliance	Electric Light		TV		Fan	Radio	Cassette-Recorder
	Bulb	Fluorescent	B/W	Color			
Number of owners	53	35	26	4	25	33	15
%	68%	45%	33%	5%	32%	42%	19%

＊ As of October 2003

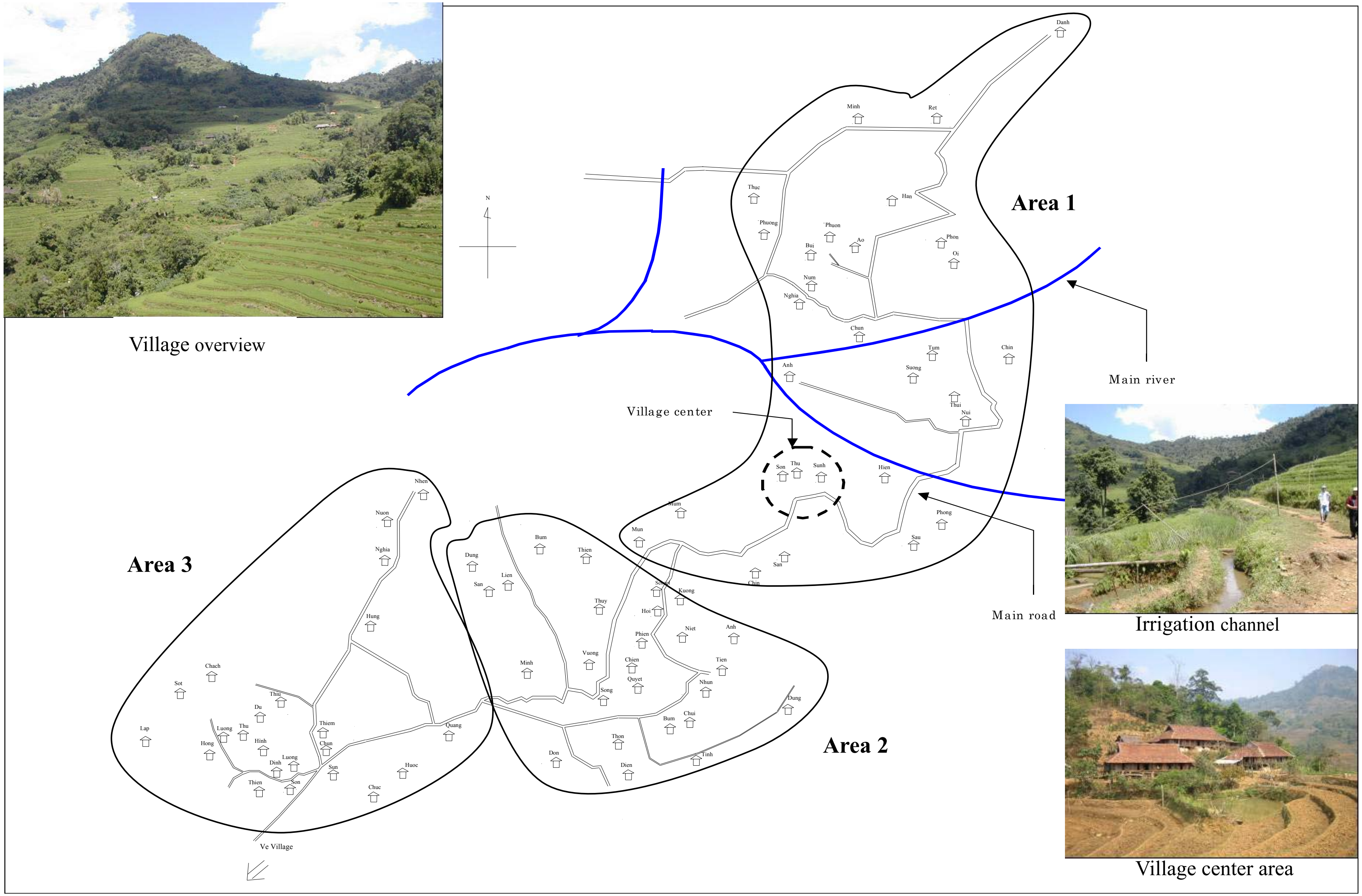
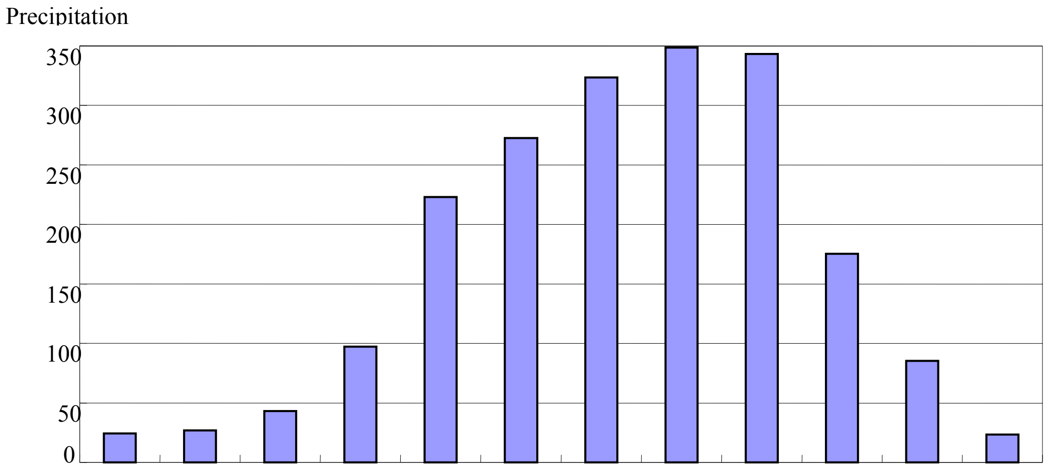


Figure 1-5 House location in Theu

Chapter 2 Design and Construction of the Pilot System

2-1 Outline of Pilot Plant

The monthly precipitation in the LacSon district of HoaBinh province decreases significantly from November to April. (See the figure below) We need to formulate a hydropower development plan based on the decreased water flow in the dry season, because we need to supply electricity all year round.



Season	Dry				Rainy						Dry		Total
Month	1	2	3	4	5	6	7	8	9	10	11	12	
Rainfall	24.5	27.0	43.1	97.1	223.2	272.5	323.6	348.5	343.3	175.4	85.3	23.3	1,986.8
Irrigation	No	Yes								No			

Source: Produced by the study team based on meteorological data provided by IE

Figure 2-1 Monthly average precipitation in LacSon district

We estimated from an interview with elderly people in the village that the water flow in the dry season would be around $0.01m^3/s$. The catchment area of the intake point is approximately 1 km^2. To get the maximum power output in the dry season, we decided to build the powerhouse at the foot of long slope where we have a head of about 60m. Hence, it was expected that the power output (firm output) would be about 3kW in the dry season, which would meet the electricity demand for lighting the whole village. We assumed that each household would use about 40W for lighting. On the other hand, in the rainy season the power output can be increased because of high water flow. Assuming that the electricity demand per household would grow to 100W in the future, the necessary output is about 8 kW. To meet this, we set the maximum water use in the rainy season at $0.03m^3/s$ and developed the pilot hydropower plan based with the maximum power output of about 9 kW.

Table 2-1 Key data of pilot project

Item	Data	Note
(1) Scale of demand	78 households	There is a school and no clinic
(2) Catchment area	1 km^2	
(3) Output (max)	9 kW	
	< 3 kW (Feb-Mar)	In the dry season
(4) Head	60 m	
(5) Water volume	$0.03 m^3/s$	
	$< 0.01 m^3/s$ (Feb-Mar)	Estimated water flow in the dry season

2-2 Civil Works

The most important point to consider in the process of designing the structures for the pilot hydropower system was easy maintenance by the villagers. They will commit themselves to do repairs to keep the power station running. Also, we tried to use existing irrigation facilities as much as possible to reduce the capital cost and to shorten the construction period.

2-2-1 Channels and waterway structures

The villagers renovated the existing weir and intake with stones and mortar to extract more water from the stream. The open no-lining irrigation channels were excavated deeper by the villagers to allow more water flow.

In addition, we decided to extend the irrigation channel by 85 meters, and to build a spillway, silt basin, head tank (forebay tank) and tailrace. These new channels except for the head tank were built with brick masonry, which make these structures strong enough against the water pressure and soil pressure. Mortar surface finish was applied to reduce the roughness of wetted perimeter. The silt basin was installed to settle the suspended sand that might cause expensive damage and rapid wear to the turbine runners.

2-2-2 Head tank, penstock and powerhouse

The head tank was constructed with reinforced concrete to withstand the water pressure and soil pressure. Also, a steel bar screen and steel net were installed before the penstock mouth to catch debris and suspended particles.

We used pressure-resistant PVC pipes as penstock, because these are lightweight and easy to transport, connect and lay. Using steel pipes is not recommended because transporting steel pipes and welding machines into Village Hydro sites is often difficult and costly.

The foundation of the powerhouse was built with reinforced concrete to withstand the weight of the water turbine/generator unit and the vibration of the water turbine. Under the floor, there is a water conduit where the ballast load (dummy load) is installed.

2-3 Electro-Mechanical Equipment

2-3-1 Water turbine and generator

Impulse water turbine is desirable for high head scheme such as this pilot system. A Turgo turbine was designed based on the data of water flow and head, and manufactured by a Vietnamese manufacturer. We decided to buy an inexpensive Vietnamese synchronous generator that is readily available in the market.

2-3-2 Governor

A governor is a device used to properly control the rotation speed of turbine. It works to stabilize the voltage and frequency of power in response to changing external electrical loads. We selected a dummy load governor with electronic control that is common in case of micro hydro scheme. The governor used in the pilot system was manufactured in Vietnam.

2-3-3 Control system and protection

A protection system (relays) was installed to protect the pilot system from over-voltage, over-current and frequency changes.

2-4 Distribution system

Theu village is stretching for more than 2 kilometers along the main road. The powerhouse is located near the village center. The location of houses and distribution lines are shown in Figure 2-2. The low voltage (single phase 220V) distribution system is designed to supply 200V at the end of distribution lines, taking into account the number of households and the length of lines. The Vietnam's technical standards on power distribution facilities were applied. From the viewpoint of cost effectiveness, it was planned to install distribution lines mainly in areas where houses are clustered and to keep the length of lead-in wire to each house less than 100 meters in principle. Also, we installed switches at the Pole No.4 to partially disconnect the distribution lines when the power output is low.

Table 2-2 List of pilot system facilities

1.Civil works		
(1) Weir/Intake	Existing irrigation system	Stone masonry (renovated)
(2) Headrace	Total length: 897 m	
	Existing: 812 m	No-lining irrigation channel (renovated)
	New: l=85 m, w=0.4 m, d=0.3 m	Brick masonry and mortar
(3) Head tank	l=3.45 m, w=0.8 m, d=0.35-0.8 m	Reinforced concrete Water depth=0.2-0.65 m
(4) Penstock	l=165 m, dia.=20 cm	PVC-pipe thickness 9.6 mm and 5.9 mm
(5) Anchor block	l=1.15 m, w=1.5 m, h=0.9 m	Reinforced concrete, 3units
(6) Spillway	l=80 m, w=0.6 m, d=0.4 m	Brick masonry and mortar
(7) Powerhouse Foundation	l=3.5 m, w=3.5 m, h=2.8 m l=3.5 m, w=3.5 m, t=0.2-0.3m	Brick masonry, Fiber-cement board roofing Reinforced concrete
(8)Tailrace	l=65 m, w=0.4 m, d=0.3 m	Brick masonry and mortar
2.Electro-Mechanical system		
(1) Turbine	Turgo-impulse	1 nozzle, 1500 rpm, Direct drive
(2) Generator	Synchronous	Single phase 12 kW, 220 V, 1500 rpm
(3)Control system	Electronic load control	Dummy load capacity =12 kW
3. Grid system		
(1) Transmission	Total length: 2.8 km	Insulated Aluminum cable ($2\times70mm^2$, $2\times50mm^2$, $2\times35\ mm^2$)
(2) Electric pole	Number of poles 71	Concrete pole h=7.5 m

Figure 2-2 Houses and distribution lines

2-5 Technology Transfer to DOI

In the DOI of HoaBinh there are 30 staff members and five of them are responsible for electrification. They have been mainly engaged in electrification projects by the grid, and therefore, they do not have much experience in off-grid rural electrification projects. In order for the DOI to try tackle rural electrification by Village Hydro, the capacity building targeting the DOI staff on the planning, construction, and management of Village Hydro is an urgent issue. It is desirable to carry out the capacity building on an OJT basis. We conducted the following technology transfer in the pilot project and also drafted a design handbook. The DOI recognizes that they need to start site survey and planning of off-grid rural electrification projects. However, the development process of Village Hydro, for which we need to study the nature and people of the site, requires a wide range of knowledge and experience. It is recommended for the DOI to share the experience of Village Hydro development with other organizations.

Table 2-3 Contents of technology transfer to HoaBinh DOI

Stage	Contents
Preliminary survey	Presentation on the basics of off-grid electrification by micro hydropower
Site survey	Presentation on a pilot electrification plan Site visiting for survey and participation in villagers meeting
Planning	Presentation on the functions of facilities Practical training on basic design of facilities Review of pilot system design
Construction and commissioning	Inspection of facilities Presentation on the construction of pilot system

2-6 Organizational structure for construction

As shown in the figure below, the DOI of Provincial People's Committee will play a central role in off-grid rural electrification projects. Projects will be initiated by local communities' requests. Then, the DOI is responsible for electrification planning, as well as authorizing of such projects. As for detailed design, it is realistic that a design company or consultant is hired to carry it out.

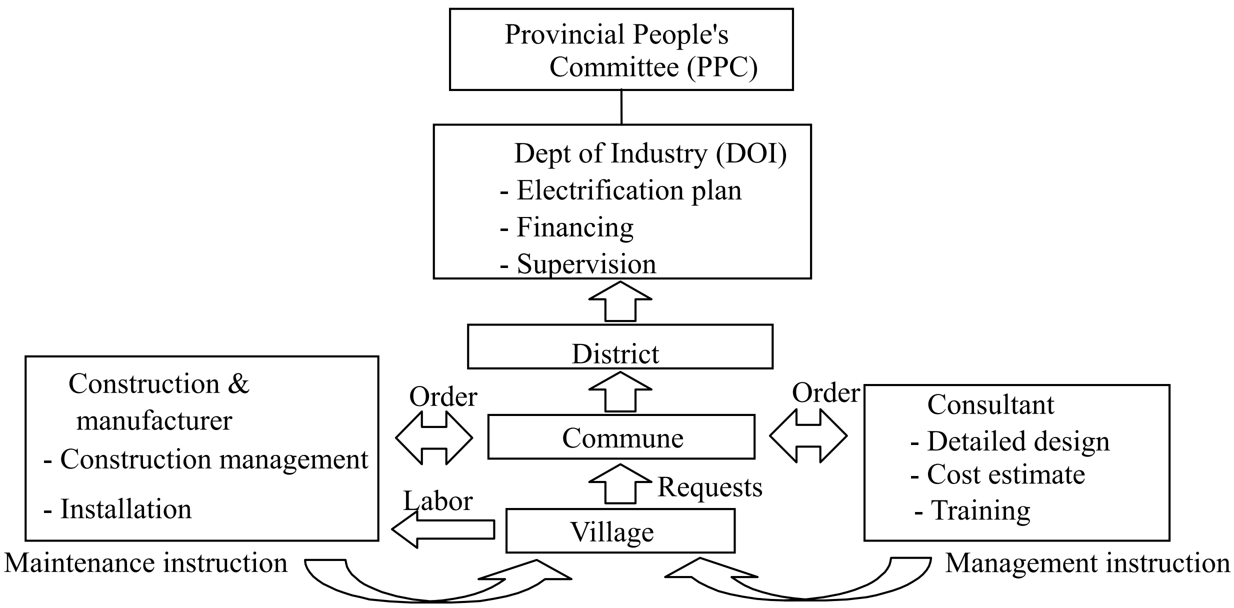
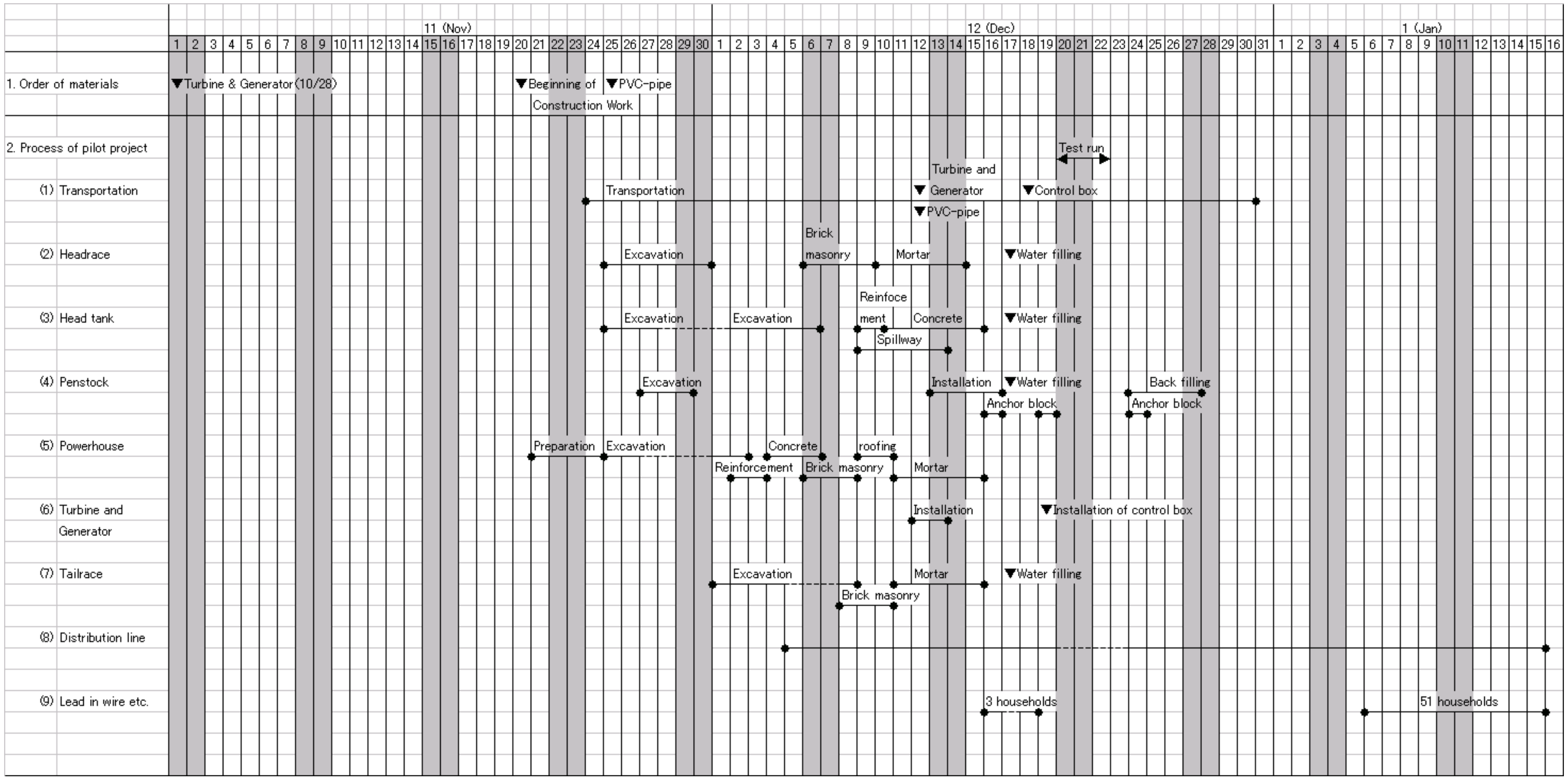


Figure 2-3 Organizations for implementing off-grid rural electrification projects

Based on the above, we set up an organizational structure, in which the DOI of HoaBinh Province is the key organization of overall project management and Theu village is responsible for operation of the pilot system. We hired EDME, a consultant, HoaBinh Construction and Hydro Power Center.

Table 2-4 Pilot system construction schedule (Actual)



2-7 Construction Cost

The table below shows the construction cost of the pilot system. The power generation facility accounts for 44% (civil work structure 26%, electrical and mechanical facility 18%) and the distribution facility accounts for 56%.

Table 2-5 Breakdown of construction cost

	Mai-Theu Village Hydro		Note
1. General Information			
(1) Output Capacity	9kW		
(2) Gross Head	60m		
(3) Design Flow	0.03m3/s		
(4) Length of Distribution Lin	2.8km		
2. Estimated Demand			
(1) No.of Households	78 Households		
(2) Unit Demand	100W/HH		
3. Construction Cost	Specifications	Cost	
		(US$)	
(1) Generation Cost		8,909	
a. Civil Works		5,339	26%
- Weir	Renovated by villagers	(0)	
- Intake	Renovated by villagers	(0)	
- Headrace	Existing: Renovated by villagers	(441)	
	New: Brick masonry with mortar		
- Head Tank	Reinforced concrete	(1,042)	
- Penstock	PVC pipe buried: φ200mm	(2,860)	
	L=180 m		
	3 anchor blocks		
- Power House	Basement by reinforced concrete	(657)	
	Walls by brick masonry with mortar		
	Fiber cement roofing		
- Tailrace	Brick masonry with mortar	(339)	
b. Electric Mechanical		3,570	18%
	Turgo turbine, synchronous generator	(3,430)	
	Dummy load controller		
	CV-cable	(140)	
(2) Electric Grid Cost	Single phase 220V	11,433	56%
- Cables	Al-PVC 35,50,70mm2, total L=2.8km	(2,570)	
- Poles and construction	71 poles H-7.5m B,Ctype	(8,340)	
- Others		(523)	
Total Cost		20,342	100%
Profit Margin		1,118	
VAT		1,073	
Project Cost		22,533	

Chapter 3 Operation Management of the Pilot System

There are two aspects, financial side and technical side, in the tasks that the villagers must to do to manage the pilot system. And the timeframe of these tasks is varied, ranging from daily operation to ten-year maintenance. These are the tasks that the villagers have never experienced. They cannot do them immediately, and therefore, they need to learn by going though sufficient training. This is the most important point that leads Village Hydro to a success. The following figure illustrates the tasks to be carried out.

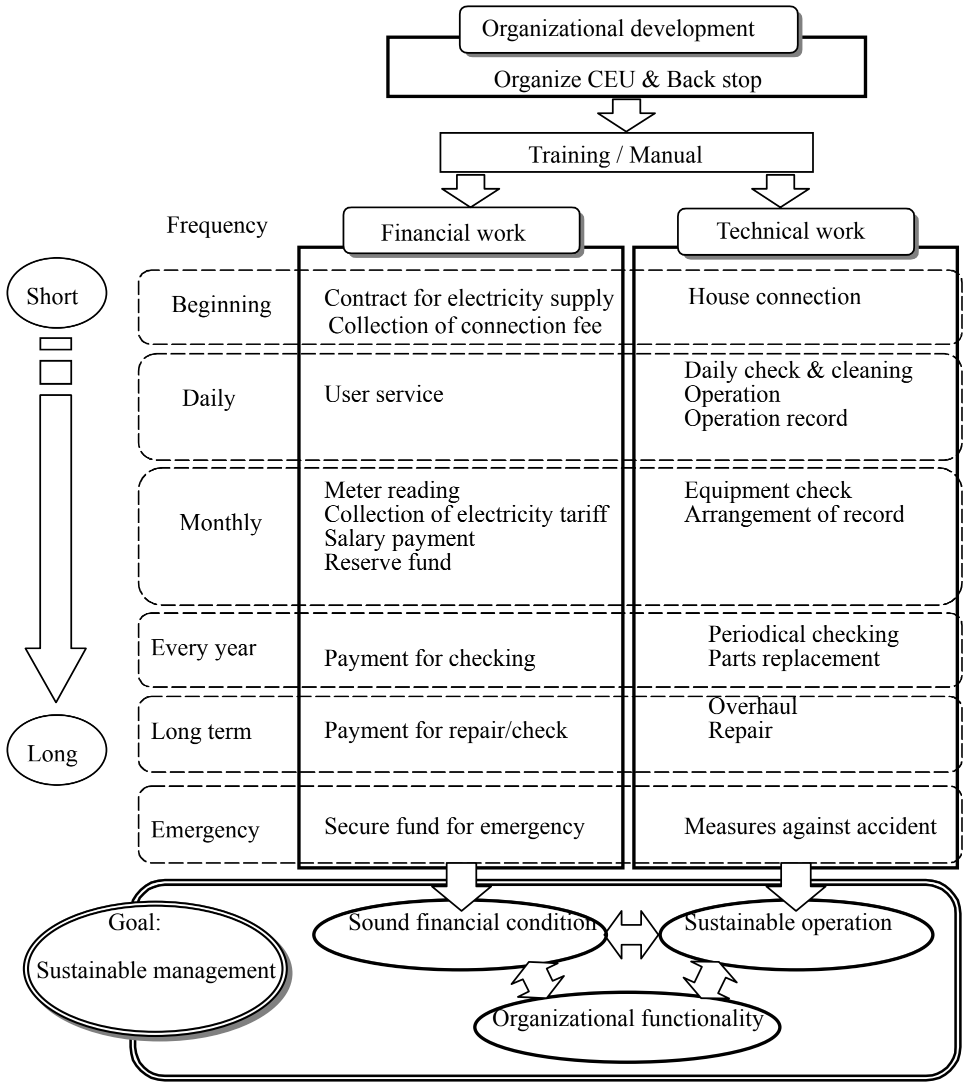


Figure 3-1 Operation and management plan

3-1 Organizational framework and back-stop

In off-grid rural electrification, the power systems require to be operated independently by the local people. For the smooth operation and management, it is important to make a consensus among the villagers beforehand. As a result of villagers meeting at Theu village, in order to do operation and maintenance of Village Hydro system including tariff collection and money management, they agreed to establish a special organization in the village for management of Village Hydro. Soon after the meeting, the Community Electricity Unit (CEU) was established. Its structure and responsibilities are as follows.

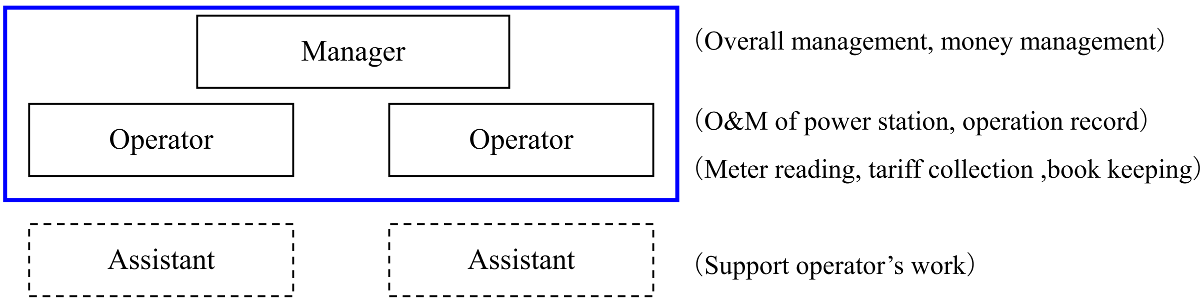


Figure 3-2 CEU members and their responsibility

The trained CEU members conduct daily operation and maintenance work, money collection and other management work. However, they need technical support from outside experts in the case of unexpected troubles. In this pilot project, following backstop system was developed.

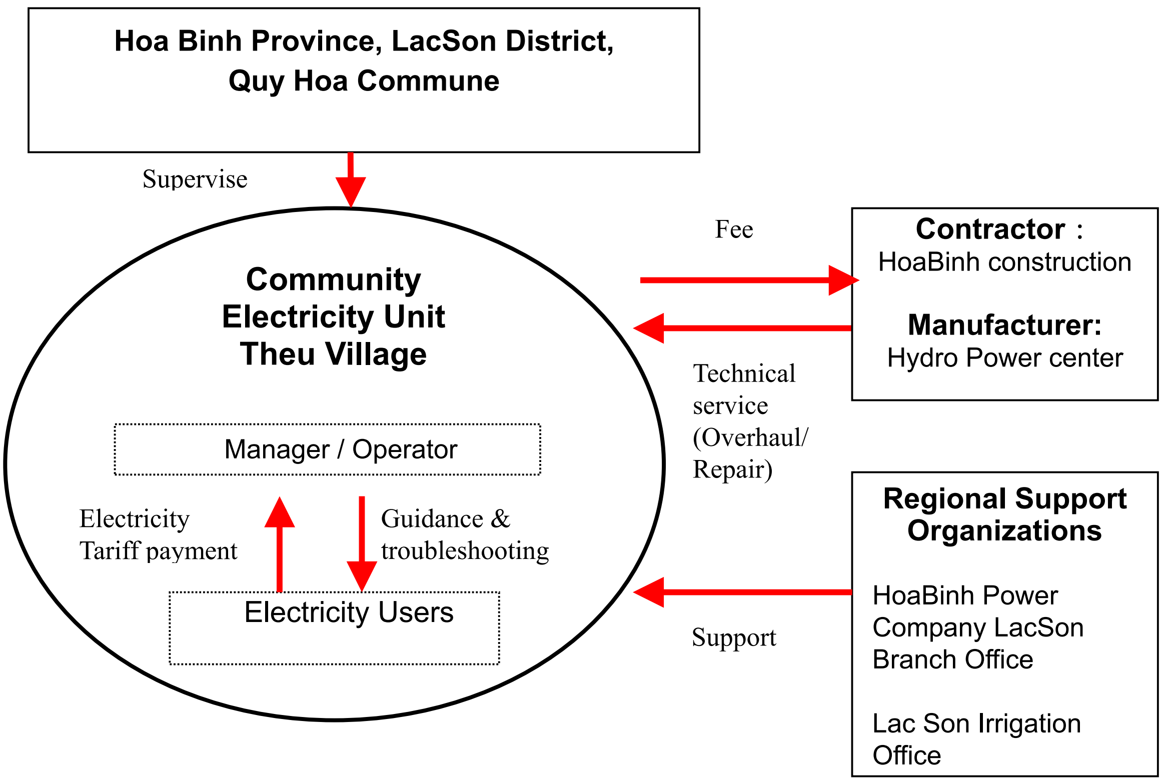


Figure 3-3 External backstop system

3-2 Operation and spare parts

The basic operation of Village Hydro, start-and-stop of generator for example, is simple, but we need to keep in mind that inappropriate operation often causes serious damage to the system. Although the current operators received enough training from the study team, we need to prepare some materials for new members to make them learn the operation and maintenance of Village Hydro. Therefore, we created an Operation & Maintenance Manual that covered basic technique and precautions to operate the pilot system properly. This manual will be referred to every time the operators run into troubles and also be used when new members join the management group.

Early detection of irregularities and abnormalities, and quick response to fix them are the key to long-term stable operation of Village Hydro. Therefore, we set up rules about inspection and regular maintenance, and prepared checklists and reporting forms. The Operation & Maintenance Manual states the procedure that should be followed when the operators check the system conditions periodically and keep records. The operators were trained until they could undertake the tasks smoothly.

There are some parts in the electro-mechanical equipment that must be replaced periodically due to normal wear. We picked out some parts that had limited life, and set up the interval and method of parts replacement. These parts are all made in Vietnam, and can be purchased in the market in Hanoi. We gave some parts to the operators as spares because it is difficult to find in the local markets near Theu village.

3-3 Electricity Supply Contract

It is strongly recommended for the CEU and customers to sign electricity supply contract, which defines the rights and duties of both users and suppliers, to avoid future problems caused from misunderstandings or ignorance. It is recommended to make consensus on the terms and conditions of the contract through villagers meeting or others at the planning stage.

Electricity users have to pay a connection fee, depending on the necessary cable length. Lump sum payment is standard in Vietnam, however, we allowed the users to pay by installments with a monthly 1% interest on the balance, six months at the longest, so that many people could pay connection fee.

In addition, there are provisions mentioning the possibility of revising the original tariff system shown in the contract, and also the possibility of forcing power usage restriction.

3-4 Collection of electricity tariff

3-4-1 Tariff of off-grid electricity

A basic principle for setting the tariff is “100% cost recovery” to secure enough cash flow to cover the repayment and recurring costs. However, in case of off-grid rural electrification in remote areas, it is difficult to pay back the construction cost due to hard economic conditions. Since the operation and maintenance of Village Hydro is to be done by the villagers, we only consider securing enough revenue to cover operating expenses. Although there is a government guideline of electricity tariff to set at 700VND/kWh in rural areas, in the case of off-grid rural electrification, we can set a different tariff. We need to carefully design the new tariff system of off-grid power supply to stabilize the cash inflow throughout a year regardless of the fluctuation of power output in the dry season and rainy season.

3-4-2 Willingness to pay for electricity

At the beginning of the pilot project, an interview survey was done about the willingness to pay for electricity. It turned out that they were willing to pay, on average, 9,200VND per month at that time. Based on the current kerosene price, 5,000VND per litter, they can save around 10,000VND per month because an average family uses 1.5 to 2 litters in one month. The villagers in Theu village well recognize, after long discussions, that they need to pay for electricity to cover the operation costs including CEU salary and long-term maintenance cost. After starting to use Village Hydro electricity, they have been satisfied with the quality and convenience of electricity supply. Accordingly, their willingness to pay, if surveyed now, would go up to 10,000VND per month or a little more.

3-4-3 Allocation of income

For a successful long-term operation of Village Hydro for 5 to 10 years, it is required to secure money for long-term maintenance as well as daily operation. Electricity tariff revenue, largely depending on the water flow, varies significantly in a year. The CEU needs to pay attention to this issue.

The table below shows the estimated income and expenses of Theu pilot system. It is apparently difficult to balance the income and expense even in the rainy season, when the income is large, as long as the standard rate, 700VND/kWh, is applied. It is necessary to revise the tariff system.

Table 3-1 Trial calculation of CEU money management for a month（700VND/kWh）

	Dry season	Rainy season
Expense Long term O&M reserve	60,000VND	60,000VND
Salary for CEU staff	150,000VND	200,000VND
Administration	10,000VND	10,000VND
（Total expenses）	**220,000VND**	**270,000VND**
Income (Tariff revenue)	(108kWh) **75,600VND**	(270kWh) **189000VND**
Balance	**▲144,400VND**	**▲81,000VND**

* Assuming 54 households

3-5 Training Plan

Training, both technical and managerial, given to the CEU members consisted of the following.

Table 3-2 Contents of training

Timing	Technical contents	Management contents
Before commissioning	-Operation of water turbine and generator -Operation record -Maintenance of facilities -Lead-in wiring	-Contract for electrification -Collection and record of connection fee -Maintenance of user record
After commissioning	-Method of facility inspection -Ways to cope with the shortage of water flow -Maintenance of channels in the rainy season -Failure diagnosis, parts replacement	-Collection of electricity tariff and record -Management of income -Financial forecast and revision of electricity tariff -Treatment of troubles

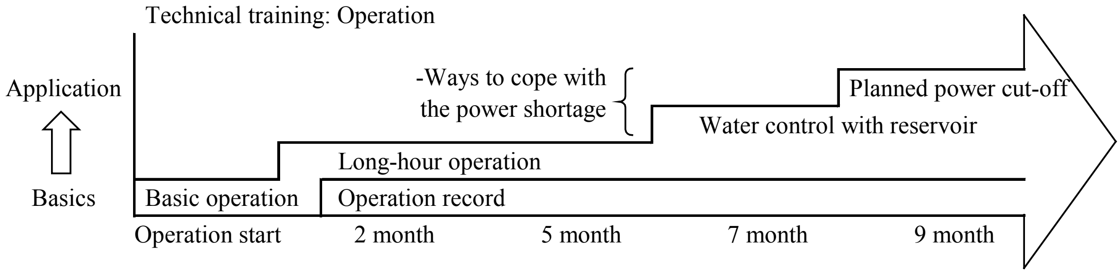


Figure 3-4 Accumulation of the know-how about operation

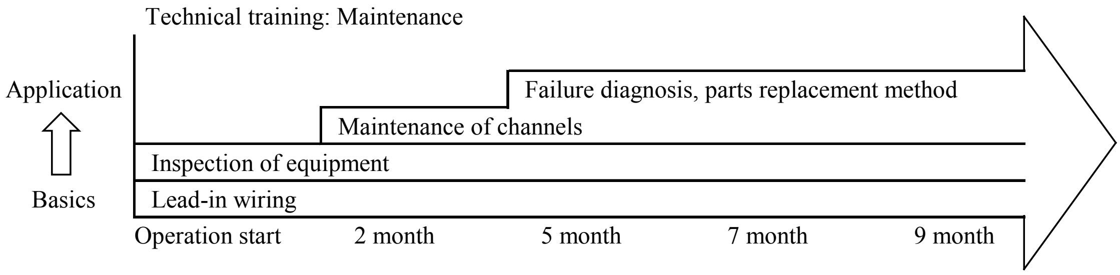


Figure 3-5 Accumulation of the know-how about maintenance

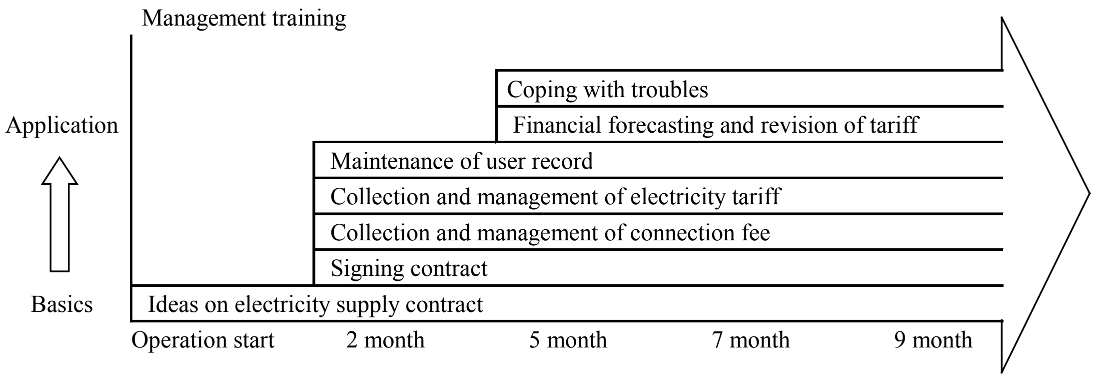


Figure 3-6 Accumulation of the know-how about management

Chapter 4 Monitoring Results and Evaluation

4-1 Seasonal Operation

In order to cope with the low water flow in the dry season, we proposed and implemented some countermeasures. In order to increase the power output during the peak hours in the dry season, we decided to use an existing storage pond (with an area of about 130m^2) as a small reservoir (with an effective depth of 0.5 m) for power generation, and installed a 100-mm diameter steel pipe with a sluic valve underground. Such storage ponds are common in the terraced rice field areas in the mountainous area. This idea can be used as a measure to cope with drought in mountainous area.

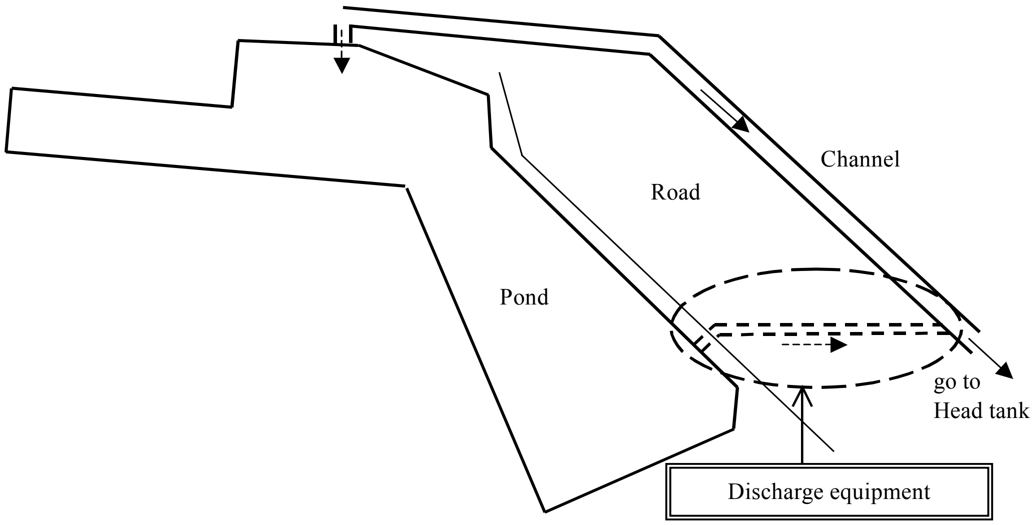


Figure 4-1 Storage pond as reservoir

In addition, switches were installed at the #4 pole to cut power supply when voluntary restriction of electricity usage does not work well. Theu village is divided into two areas and each area may be blacked out in turn in the dry season.

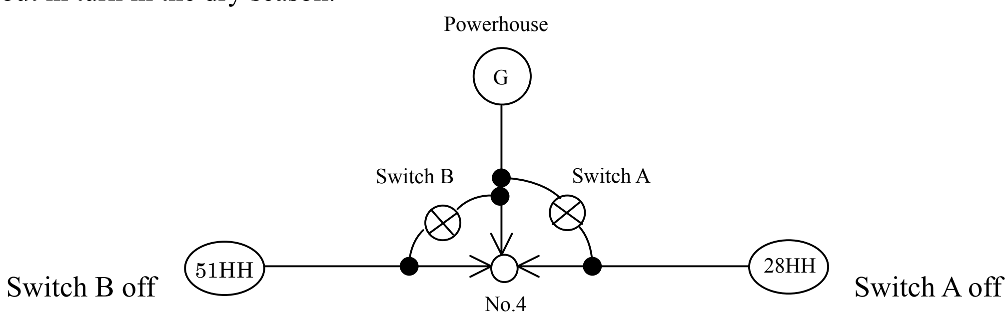


Figure 4-2 Idea of planned blackout

4-2 Operating Performance

We measured a daily load curve to confirm power consumption and voltage stability. We also conducted the test measurements for the final confirmation of normal operation, such as start / stop, dummy load control, output adjustment and load rejection.

-- There are two peaks in a day: at 19:30 Peak-A and 6:00 Peak-B. Villagers use lights at both of these peak times.

-- Dummy load system works well to control voltage and frequency when load is unstable. The Transit stabilities are kept well. Even if rapid load fluctuation such as 1 kW ON/OFF, voltage fluctuation is only less than 15V.

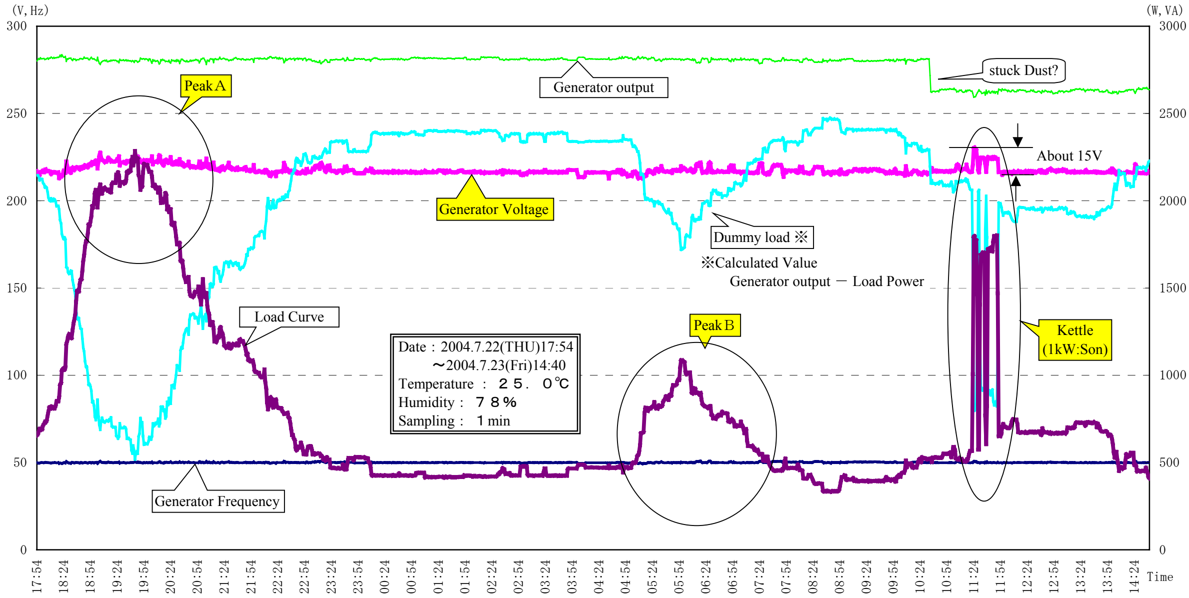


Figure 4-3 Daily load curve and generation (July 2004)

4-3 Demand Analysis and Forecast

It was assumed that the electricity unit demand at the time of pilot system completion was around 40W per household because many families had pico-hydro generators, lights and appliances.

Table 4-1 Electricity demand per household in Theu (Current)

Electric appliances	Power consumption (W)	Units	Total capacity (W)	Rate of ownership (%)	Peak-time-use Coefficient (%)	Unit peak demand (W/HH)
Incandescent bulb	25	2	50	68	50	**17.0**
Fluorescent light	40	1	40	45	80	**14.4**
Black and white television	30	1	30	33	70	**6.9**
Color television	60	1	60	5	70	**2.1**
Cassette recorder	10	1	10	20	10	**0.2**
Electric fan	50	1	50	32	10	**1.6**
Total						**42.2**

After the pilot system was completed, many households wish to buy lamps and TVs. Theu is a village of the Muong tribe, who generally has large houses. Therefore, fluorescent lamps, brighter incandescent lamps, will be widely used. In addition to 30 households that already have TVs, 22 more households wish to buy TVs. Lamps and TVs will account for a large part of future electricity demand. Table 4-2 shows a demand forecast for a few years ahead. In order to meet an increase in electricity demand due to an increase in electric appliances owned by the villagers, we recommend to use a unit electricity demand of 70 to 100 W per household in the design of Village Hydro.

Table 4-2 Electricity demand per household in Theu (Future)

Electric appliances	Power consumption (W)	Units	Total capacity (W)	Rate of ownership (%)	Peak-time-use Coefficient (%)	Unit peak demand (W/HH)
Incandescent bulb	25	1	25	80	50	**10.0**
Fluorescent light	20	2	40	70	80	**22.4**
Black and white television	30	1	30	60	70	**12.6**
Color television	60	1	60	20	70	**8.4**
Cassette recorder	10	1	10	40	10	**0.4**
Electric fan	50	1	50	60	10	**3.0**
Total						**56.8**

4-4 Tariff Collection and Financial Management

4-4-1 Setting of new electricity tariff

The pilot system started operation in January 2004 when the power output was very small due to the low water flow. It was clear that the original tariff of 700VND/kWh was insufficient to cover operators' salaries and other expenses. At a villagers' meeting, this issue was raised and it was agreed that the electricity tariff system be increased. There may be many different ways to increase the income, introduction of fixed base rate or increase of kWh rate. However, taking the majority opinions into consideration, we adopted the basic idea of "the more you consume, the more you pay". We considered the seasonal variations of electricity consumption pattern and revised the tariff as shown in Table 4-3 to secure enough revenue even in the dry season. As a result, high rates are applied to low consumption customers, and now it is possible to balance the expenses against the income.

Table 4-3 New electricity tariff （VND）

kWh	700VND/kWh (A)	**Increased tariff (B)**	Increase rate (B)÷(A) = (C)
5	3,500	**5,800**	166%
4	2,800	**5,100**	182%
3	2,100	**4,400**	210%
2	1,400	**3,200**	229%
1	700	**2,000**	286%

*700VND will be added to each kWh after5kWh.

Table 4-4 Income and expenses for a month based on the new tariff

	Dry season	Rainy season
Expense Long term O&M cost	60,000VND	60,000VND
Salary	150,000VND	200,000VND
Administration	10,000VND	10,000VND
(Total expense)	**220,000VND**	**270,000VND**
Income (Tariff revenue)	(108kWh) **172,800VND**	(270kWh) **313,200VND**
Balance	**▲47,200VND**	**43,200VND**

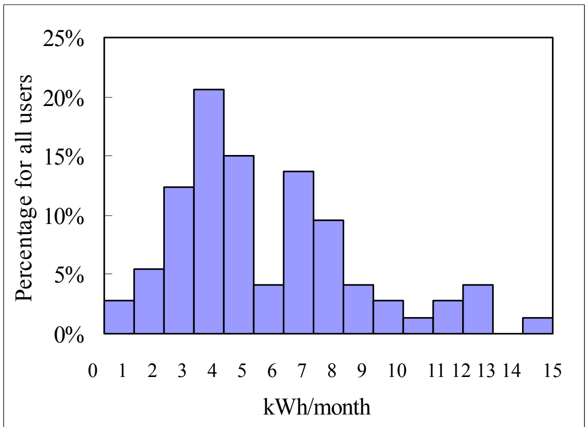
*Assuming 54 households

4-4-2 Electricity consumption and villagers payment

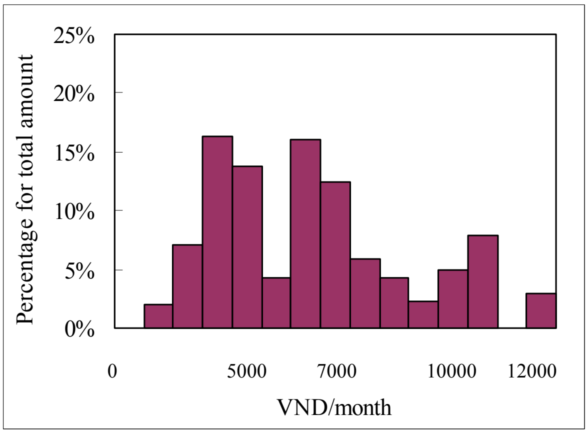
According the electricity consumption data of September 2004, most users fall in the range of 3 to 4kWh per month and about 40% of households used less than 4kWh per month. These households mainly use electricity for lighting.

○Total electricity consumption：359kWh
○Average electricity consumption /HH：4.9kWh

○Total electricity charges：406,100VND
○Average electricity charge/HH：5,560VND



(1) Electricity consumption

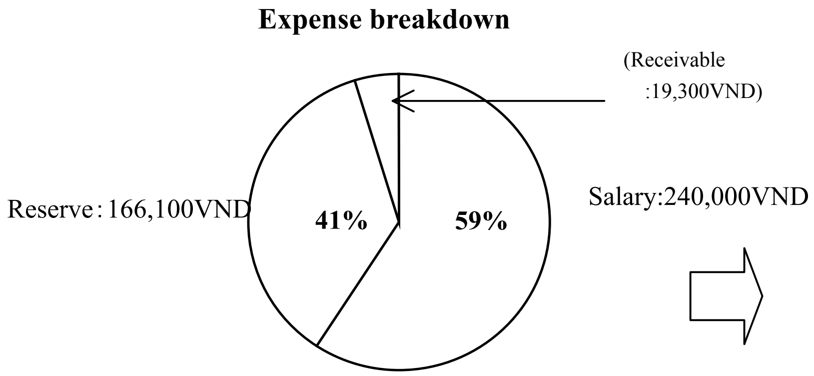


(2) Villagers payment

Figure 4-4 Electricity usage in Theu village (September 2004)

There was no complaint on the new electricity tariff and most users paid their bills on time. On-time payment rate was 95%. In addition, villager's willingness to pay for electricity is estimated to be around 10,000VND per month, based on a household interview survey and price comparison with kerosene cost. Accordingly, it can be said the villagers accepted that new electricity tariff.

4-4-3 Financial management by CEU



Salary breakdown

（240,000VND）

Manager	20,000
Operator1	60,000
Operator2	60,000
Operator3	60,000
Assistant	40,000

Figure 4-5 CEU expenses（September 2004）

The CEU salary accounts for 60% of total expense. And the balance was kept as a reserve for long-term maintenance. It is recommended to keep at least 50,000VND as a reserve every month. However, when there is a surplus, it should be also kept as a reserve to make up the shortages that may occur in the dry season.

4-5 Villager’s Satisfaction

After the commissioning of pilot system, we had a series of monitoring surveys on the electricity usage pattern, affordability of Village Hydro electricity, etc. We selected 10 sample households in the village with different income levels (high income-4 households, medium income-3 households and low income-3 households). The household survey was conducted based on interviews and questionnaires.

Table 4-5 Monitoring timing and topics

	First monitoring	Second monitoring	Third monitoring
Timing (after commissioning)	After 1 month	After 4 months	After 6 months
Month/year	February 2004	May 2004	July 2004
Weather	Dry season	Transition time (Dry→Rain)	Rainy season
Survey topics	Electric appliances and using hours, activities under the lighting, comments on usage restriction, connection fee payment, etc	Electric appliances and using hours, comments on efficient light, usage restriction, extra payment, etc.	Electric appliances and using hours, new purchase of electric appliances, comments on new tariff, satisfaction and complaint, etc.

Thanks to the power supply in the evening time, the sample households have meals, do domestic work, feed animals and study under lighting. Thus, they enjoy the advantages of having electricity even short supply hours in the dry season.

Based on the raised electricity tariff, the average payment per household is 4,400VND per month. The sample households all pay the bills on time and agree that the new tariff system is acceptable. They pay for electricity much less than they would pay for kerosene. They used to buy 1.5 to 2 litters of kerosene and pay 7,500 to 10,000VND.

All of the sample households are satisfied with the electricity supply from the pilot system and willing to continue buying electricity. Their main reason for their willingness to continue is “stable power supply”. Compared with pico-hydro, it is obvious that the pilot system supplies better quality electricity to the users. For example, its power supply is more stable at night, stronger to give brighter lights and make a TV and fan usable. For these advantages, they accept the new electricity tariff and restriction of electricity usage.

4-6 Economic Evaluation

The plant factor of off-grid power stations is low because most village people use electricity only in the evening and early morning. In addition, raising electricity tariff in the case of off-grid rural electrification is difficult because villagers’ income in remote areas is low. For these reasons, economic evaluation, in terms of return on investment, of off-grid projects usually turns out to be negative. For example, in the pilot system in Theu village, the revenue and the expenses are balancing and there is no surplus or profit. This is not a good investment. Assuming the revised electricity tariff and 90% subsidy given to the construction cost, the Financial Internal Rate of Return (FIRR) was analyzed for the Theu pilot project based on a cash flow for 10 years. The FIRR is mere 1.7%, which means commercial investors will not be attracted. (See Table4-6)

Table 4-6 Economic evaluation result—FIRR - Subsidy rate 90％

Capital investment		$22,500 (348 million VND)	
Subsidy		90%	
Plant life		10 years	
Electricity demand per household		160Wh/day/HH in year 1 <Rainy reason 6months> 70Wh/day/HH in year 1 <Dry reason 6months> 5% increase per year	
Number of connected households		70 households in year 1 5% increase per year	
Cash out	Long term maintenance cost	$130 (2 million VND)	System check (all parts) cost in year 5
		$260 (4milliomVND)	Repair of turbine runner in year 7 to 9
	Administrative costs	$16/month<Rainy reason> (0.25 million VND) $10/month<Dry reason> (0.16 million VND)	Operator's salary and miscellaneous costs
Cash In	Tariff revenue	Based on the new tariff system in Theu	4.8kWh/month/HH in year 1 <Rainy reason> (160Wh×30day) 2.1kWh/month/HH in year 1 <Dry reason> (70Wh×30days)
FIRR		1.7%	

On the other hand, it is possible to consider various social benefits of electrification, such as longer working hours at home, in the economic evaluation of off-grid projects. These benefits can be valued higher than the amount paid for electricity. In other words, it is better to evaluate how much the people's life is improved against the total investment capital. When the Government of Vietnam plans to implement off-grid micro hydropower projects without donor assistance, it will be better to take into account all the social benefits enjoyed by the villagers in the economic assessment. The Economic Internal Rate of Return (EIRR) is calculated in such a way to give a better picture on the return on investment in case of social development projects.

For example, in case of the Theu pilot project, such positive social impacts may include increased efficiency in domestic work, longer study hours at night and so on. Although this part should be analyzed more in detail, it may be possible to conservatively evaluate people's social and economic benefits as 20,000VND/month in the rainy season and 10,000VND/month in the dry season respectively. Table 4-7 shows the result of EIRR evaluation using these figures. According to this, the EIRR is more than 30%, which supports the viability of off-grid rural electrification projects.

Table 4-7 Economic evaluation result—EIRR - Subsidy rate 90％

Capital investment		$22,500 (348 million VND)	
Subsidy		90%	
Plant life		10 years	
Electricity demand per household		160Wh/day/HH in year 1 <Rainy reason 6months> 70Wh/day/HH in year 1 <Dry reason 6months> 5% increase per year	
Number of connected households		70 households in year 1 5% increase per year	
Cash out	Long term maintenance cost	$130（2 million VND）	System check (all parts) cost in year 5
		$260（4milliomVND）	Repair of turbine runner in year 7 to 9
	Administrative costs	$16/month<Rainy reason> (0.25 million VND) $10/month<Dry reason> (0.16 million VND)	Operator's salary and miscellaneous costs
Cash In	Benefits		20,000VND/month/HH <Rainy reason> 10,000VND /month/HH <Dry reason>
EIRR		30.2%	

4-7 Source of investment capital

4-7-1 The 135program

The Program on the Socio-economic Development in Mountainous, Deep-lying and Remote Communes with Special Difficulties（Decision No.135/QD-TTg of 1998） is called "the 135 Program". This program, providing grants to social development projects in remote communes, is an important government program for poverty alleviation. Infrastructure development projects such as road improvement, or building schools and irrigation systems have been carried out under this program to increase the agricultural production and to improve the living standard in rural areas. Though project implementation is administered by the provincial authorities, each entitled commune has the right to propose projects and to make a request. The annual budget allocated to each commune is 500 million VND, or about $32,000. Micro hydropower development is included in the list of project categories allowed under the 135 program. Therefore, application for the 135 program fund should be considered first when planning a Village Hydro development.

4-7-2 RARE

The World Bank (WB) in cooperation with the MOI has established a special fund to accelerate rural electrification by renewable energy. This is called "Rural Area Renewable Energy Facility （RARE）", which was proposed in the preceding project formation study; Renewable Energy Action Plan（REAP）. The WB and MOI are going to develop approximately 20 off-grid electrification pilot projects with the RARE funds. In principle, it is possible to use the RARE fund for a Village Hydro development as long as the requesting village formally applies for the fund. However, the RARE fund is not a grant but a subsidy up to 80% of construction costs.

Chapter 5 Overall Evaluation and Recommendations

In this study, the main objective was to demonstrate the sustainability of off-grid micro hydropower (Village Hydro) by installing a pilot plant in a typical remote village in the northern mountainous region of Vietnam. One important thing was to check whether or not appropriate technologies were used in the generation system and the total investment was within the targeted amount. Another issue was to confirm that the villagers mastered the operation and maintenance of the generation system. Also, we gave training to off-grid system planners working for provincial governments and prepared Village Hydro manuals in order to accelerate Village Hydro development under their initiative. In particular, we would like to emphasize that we successfully developed good management practices such as contracting, tariff setting and collection, and cash flow management through dialogue with the villagers, which were all viewed difficult to implement in remote areas. This is a remarkable achievement and can be applied in many rural development projects in Vietnam.

In this chapter, the outputs of the Village Hydro pilot project were summarized and the necessary measures for promoting Village Hydro development were discussed. Provincial People's Committee (PPC) is supposed to play a key role in promoting off-grid rural electrification. It is strongly expected that the following discussions make clear the underlying problems and give the right direction to the state government as well as provincial authorities.

5-1 Overall Evaluation of Pilot Project

The construction work of Village Hydro pilot plant in Theu Village started in late November 2003 and proceeded without delay thanks to good weather and the cooperation of villagers. In late December, the pilot system was completed except for the grid and started test operation. The total investment was $23,000, which was in the target range. The unit construction cost of $2,000 per kW is difficult to achieve in Japan due to complicated design requirements, but is quite normal in developing countries. This is attributed to the design policy of using Vietnamese materials and generation system (turbine, generator and controller) and using the exiting irrigation system as a part of the generation system.

The pilot plant is functioning well as designed. Its voltage (220V) and frequency (50Hz) are stable. This is owing to the good performance of the dummy-load control system, which is the first commercial unit produced in Vietnam and has been working without any problems. The turbine and generator are also made in Vietnam and performing well. The fact that we installed the pilot Village

Hydro plant, following the design concept of Village Hydro, with 100% Vietnamese technology, and cleared the cost target and achieved stable operation suggests the good potential of dissemination, suggests high potential of spreading this technology in northern Vietnam.

Of course, we experienced some problems during this project such as power shortage due to limited water flow in the dry season. This problem almost always happens in case of off-grid hydropower development. How to resolve this issue, choosing maximum water flow and output, would be an important matter in improving the utilization factor of power station and return on investment. In the pilot project, we installed an underground pipe to connect a pond to the water channel in order to use the pond as a small reservoir. This idea may be applied in other cases as well.

Many people commented that the long-term management was more difficult than plant construction in case of Village Hydro. We, therefore, organized village peoples' meetings to make a consensus on collaboration with our team and establishing an autonomous management group before the start of construction, which was a first step toward management system development. When the pilot plant began test operation, we started a serious of training exercises to make operators master necessary skills. This pilot plant is equipped with an automatic control system that makes the operators easy to learn how to run the power system. They only need to adjust the water pipe valves. Even the village operators who do not have appropriate educational background can quickly master necessary skills.

The management team consists one manager, two operators and two assistants. They are required to do operation, contracting, house connection, fee collection, bookkeeping and money management. They have no background for these jobs and need long time to learn. In this study, intensive training was conducted from time to time during the six-month monitoring period. In particular, electricity tariff was an important topic, because the government has regulated the tariff to be less than 700 VND per kWh in remote areas. However, in off-grid systems it is allowed to set a different tariff. In this project we raised the tariff based on the estimated revenue and expenses, which shows a good example for follow-on projects. The most important point is to operate the power station without operational subsidy. Therefore, it was necessary to reduce the salary of operators and to raise the tariff in order to balance the cash flow. Another important issue was preparation for unexpected failure of the plant. We asked the management team to put some money as reserve for repair every month. Also, an emergency fund would be a good idea to cope with this problem. Thus, the lessons learned in this pilot study must be taken into account in many ways when follow-on projects are to be undertaken. In short, this project achieved a good management system that can be used as a good example for future. Our invaluable experience was accumulated in the manuals and also the counterparts gained a lot of knowledge.

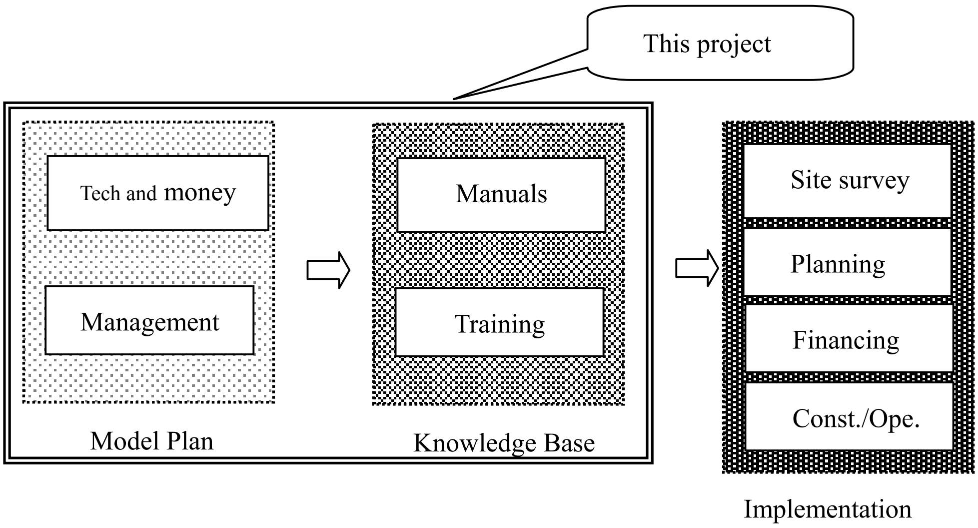


Figure 5-1 Accumulation of pilot project know-how

5-2 Toward the Goal of Village Electrification

From now on, the Vietnamese counterpart must develop many sites under their initiative using the output of this study. The table below summarizes the required tasks.

Table 5-1 Necessary activities for future project implementation

Item	Organization, related issues
Site survey	Work to evaluate water flow, head, distance from demand center, geography. Commune provides site data. DOI or consultant undertakes site survey for more information.
Planning	DPI or consultant is responsible for planning using the manuals. Necessary cost would be less than $1,000. The 135 program must be taken into account.
Financing	It is the easiest way to apply for the 135 funds. Also, the funds from Rural Area Renewable Energy Facility can be used (maximum 80% subsidy). However, the procedure is rather complicated.
Construction	Local contractor can do the construction work. Appropriate machinery and equipment can be procured in the local market.
Training	It is essential to build a good management system. The manuals give good reference. Support from local authorities helps.

The basic workflow is shown below. First, the request for development is conveyed from the commune to DOI. Then, DOI conducts site survey and draws up a basic plan. If the plan is approved for implementation, the DOI secures necessary funds and make arrangements for construction and management. This is a typical workflow.

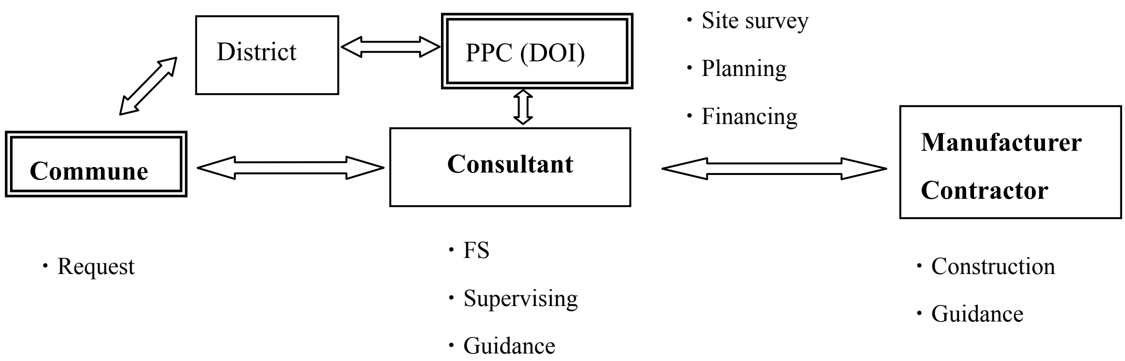
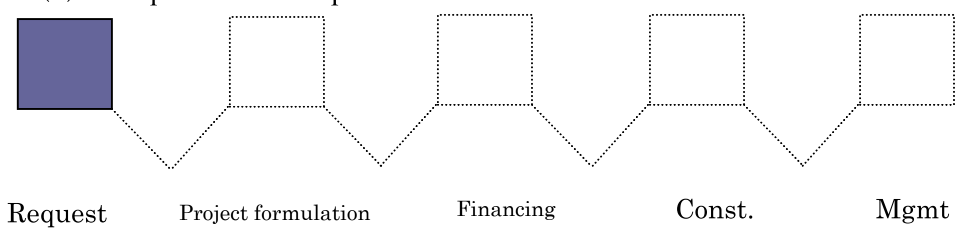


Figure 5-2 Typical workflow of Village Hydro project implementation

More detailed analyses on problems and resolutions are presented below.

5-2-1 Issues and countermeasures of project implementation

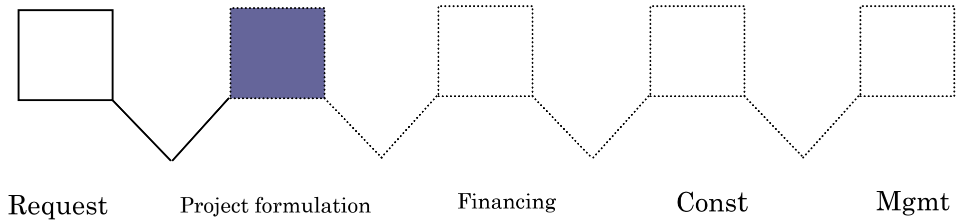
(1) Request for development



Request for Development Priority B
JICA outputs Video creation on Village Hydro for gaining awareness
It is required to do more for receiving publicity on off-grid micro hydro.

So far, only few unelectrified villages formally requested off-grid development although they have strong needs for electricity. Therefore, it is necessary to generate awareness among village people on off-grid electrification methods such as Village Hydro. To receive more publicity would be an important first step.

(2) Project formulation



Project formulation Priority A

JICA outputs Basic design, tech transfer to PPCDOI, Manuals

It is most important to conduct training targeting PPCDPOI staff in northern VN.

There are few organizations in Vietnam that can develop project plans of Village Hydro at present. It is, therefore, required that the DOI evaluates the hydropower potential of candidate sites and formulates basic plans. The DOI must have professional knowledge to do this. It is important to note that without appropriate project formulation it is impossible to mobilize related organizations toward development. Compared with grid extension, which can be done easily based on manuals, Village Hydro development requires more complicated site-specific work.

Table 5-2 Comparison of grid extension and Village Hydro development

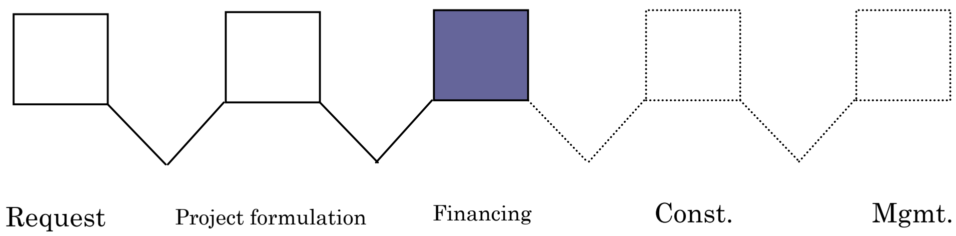
	Grid extension	Village Hydro development
Responsible Organization	EVN or Power Company is responsible from the planning stage.	EVN or Power Company is not responsible. PPC should play a key role.
Commune	Grid extension is well known and easily agreed.	If grid extension is desired, Village Hydro might be opposed.
Technical complexity	Standardized and easy for planning	Professional knowledge is necessary for planning
Experts Consultants	Many experts/organizations that have know-how on grid extension.	Few experts/organizations that have know-how on Village Hydro

It is, therefore, extremely important to develop the capacity of DOI to conduct these tasks by giving appropriate training on micro hydropower design. However, there have been no such efforts ever. Village Hydro project implementation will be halted due to lack of knowledge and experience of DOI.

The first priority issue for the GOV, therefore, is capacity building of DOI, if the GOV is seriously want to implement many Village Hydro projects. For this purpose, the manuals developed in this study can be used as materials for training.

There may be another idea to employ outside consultants for project formulation. However, their assignment period may be limited and collecting information widely from unelectrified villages would be difficult. They will come up with very few project ideas. On the other hand, the DOI can persistently undertake site survey and project formulation. It is recommended to develop the DOI and use them in Village Hydro development.

(3) Financial planning



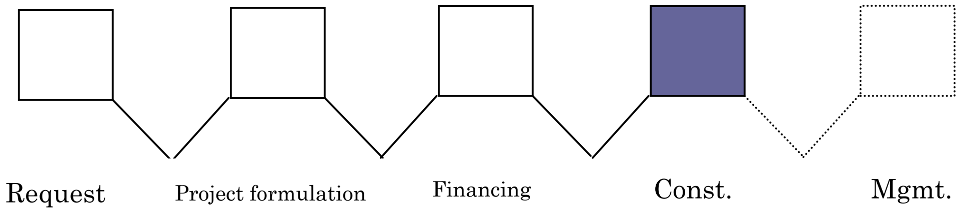
Financial planning Priority B

JICA outputs Assessment of available financing programs such "the 135 program" and MOI's Rural Area Renewable Energy Facility (RARE)

More projects under the 135 program and improvement of RARE

In Vietnam, there are financing programs suitable for Village Hydro development already. The 135 program of GOV that is designed for infrastructure development in remote communes, and the Rural Area Renewable Energy Facility that is funded by the World Bank and now managed by the Ministry of Industry. In particular, the 135 Program has been playing a key role for the development of road or irrigation facilities for many years. Village Hydro is a small-scale rural development project and fit the objective and conditions of the 135 Program. Therefore, it is recommended to develop many examples of Village Hydro by using the 135 Program. These efforts help spread the financing idea of Village Hydro. On the other hand, the RARE program is not used because local people's awareness is limited and it requires applicants to go through more complicated procedure. It is recommended to modify the rules and regulations of RARE so that villagers can use RARE more easily.

(4) Construction



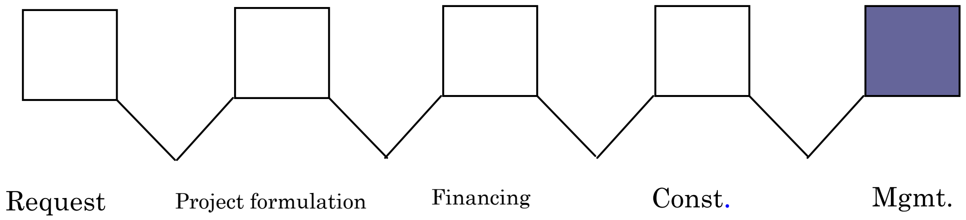
Construction Priority B

JICA outputs Detail design, domestic manufacturer, and local contractor

Improvement of technical capacity of domestic companies

It is ideal that Village Hydro is constructed with domestic technology. Using domestic technology is good for long-term maintenance. Detail planning of construction work is to be done by consultants or local contractors. From our experience, we can say that experienced contractors can do these tasks correctly. The DOI examines the plan and give approval. Also, the DOI, on behalf of local community, is supposed to supervise the construction work until completion.

(5) Management



Management Priority A

JICA outputs Establishment of village org. practical training, manuals

It is important to set guidelines for village organization and tariff system

It is one of the most important tasks to establish an autonomous management organization after the completion of Village Hydro. Intensive training targeting villagers is essential to achieving a good management system. The GOV is recommended to set guidelines regarding management system including tariff system and money management. It is also expected that the DOI continues to monitor Village Hydro sites and give appropriate suggestions and guidance to avoid operational problems. Furthermore, developing a backstop system to help villagers is needed.

5-2-2 Summary

Necessary action plans to be conducted by the GOV and PPCDOI for the dissemination of Village Hydro are summarized below.

Priority A	１． Intensive training of PPCDOI of northern mountainous region ２． Guideline development for autonomous management including organization and tariff system
Priority B	１． Generating publicity in remote areas by building more pilot plant ２． Financing demonstration with the 135 program , improvement of RARE scheme ３． Improvement of technical capacity of domestic companies

Thus, we can point out many different problems in the process of Village Hydro development, and their priorities vary. First, the development of Village Hydro must be triggered by villagers. They must be committed to developing and managing a small hydropower station for a long period by themselves. There are good financing programs already in Vietnam and also capable consultants and manufacturers. Necessary conditions are almost there. It is quite feasible to start developing many Village Hydro projects by combining these favorable conditions. The key remaining tasks are stimulating and facilitating project planning and village people management.