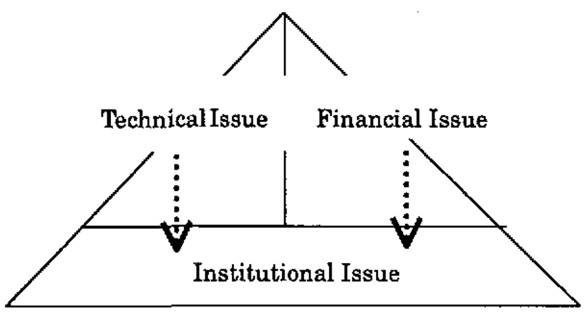
Section 2 Model Plan of Off-grid Rural Electrification

In order to develop a master plan for off-grid rural electrification in northern Vietnam, it is necessary to show concrete ideas as much as possible because there have been very few examples of off-grid electrification so far. Also, we always need to check the feasibility of proposed ideas by asking "Is the system sustainable for a long time?", or "Is the system replicable in other areas?" "Sustainable" and "replicable" are two key words in planning rural development projects in developing countries. There were many cases in the past in which power plants stopped and never resumed operation. Therefore, it is very important to examine the sustainability of proposed plans beforehand. Also, the proposed plans must be easily replicated under different conditions. A rural electrification plan with a custom design that only meets the conditions of a particular site will not work at other sites.

There may be three different viewpoints in developing a sustainable and replicable off-grid system: economics, technology and organization. If one of these factors is inadequate, off-grid systems will eventually fail.

In this section, we will analyze the economic aspect of rural electrification, including the financing plan in Chapter 3, organizational aspects focusing on long-term operation and maintenance in Chapter 4, and key off-grid technologies in Chapters 5,6 and 7.



Three key aspects of rural electrification planning

Chapter 3

Economic Evaluation and Financial Planning

3-1 Economic Comparison of Grid Extension and Off-grid Electrification

The average construction cost of a mid-voltage grid is around $10,000 per kilometer. In the mountainous areas in northern Vietnam, the target areas of this study, grid extension is more difficult and costly because of harsh natural conditions. In addition, the population density is low, which also raises the grid extension cost per household. It is revealed that many off-the-grid communes are located more than 20 kilometers away from the grid. In the future, the grid will be extended and come closer, but some communes will still remain quite far, 10 kilometers for example, from the grid. Assuming a remote commune with one hundred households that is located 10 kilometers away from the grid, a rough economic analysis is conducted as follows.

Rough estimation of cost effectiveness - grid vs. off-grid

Basic assumptions:	Number of households	100 HH
	Electricity demand per household	50W/HH
	Hours of electricity use per day	4 hours
	Electricity tariff	700VND/kWh
	Calculation period	20 years
Case 1-1 10km Grid extension		
	Construction cost	$100,000 ($10,000/km)
	Development cost per HH	$1,000/HH
	Total revenue over 20 years	$6,720 (6.7% of investment)
Case 1-2 10km Grid extension and increased demand (200W/HH)		
	Construction cost	$100,000 ($10,000/km)
	Development cost per HH	$1,000/HH
	Total revenue over 20 years	$26,880 (26.9% of investment)

Case 1-1 shows that over 20 years, tariff revenues can recoup only 6.7% of the grid extension investment. In other words, more than 90% of the investment costs generate no return. The grid extension cost is basically unchanged regardless of user demand. When the demand for electricity is large, therefore, revenue will increase and the return on investment will be improved. For example, Case 1-2 suggests that the demand grows four-fold. However, even in this case, the 20-year total revenue accounts for only a quarter of the investment.

Case-2 5km Grid extension

Construction cost	$50,000	($10,000/km)
Development cost per HH	$500/HH	
Total revenue over 20 years	$6,720	(13.4% of investment)

Case-3 Stand-alone micro-hydro

5kW Micro-hydro plant	$10,000	
Development cost per HH	$100/HH	
Total revenue over 20 years	$6,720	(67.2% of investment)

If the distance from the grid is short as in Case-2, the economic performance will be improved. However, the return on investment is still quite low. Thus, grid extension is not recommended in electrifying remote and small communes because it is difficult to balance the investment and the revenue from electricity usage.

In contrast, an off-grid electricity system is suited to such cases because it is possible to develop a power plant in an appropriate size. Case-3 shows an off-grid project that is based on a 5kW micro-hydro with an investment of $10,000, which is viewed achievable. The expected revenues over the 20 year period will cover more than two thirds of the investment, which is much better than the previous cases of grid extension. Recently, the cost of micro-hydro or solar components is decreasing so that off-grid development can be more cost effective in the future. Off-grid projects will be far more attractive than grid extension in terms of effective use of money. In conclusion, off-grid systems should be given precedence over grid extension in remote areas.

3-2 Demand Estimation

Fair estimation of electricity demand is the necessary first step for designing off-grid projects. It is important to understand that all the households in the target area are not always electrified at the initial stage. Also, it should be noted that electric appliances in households vary depending on household income, and rural villagers will buy appliances on a one-by-one basis over many years. Therefore, the actual electricity demand will not reach the expected level until several years after commissioning. As time passes, more people will apply for electricity supply service and add appliances, so that the total electricity demand will continuously grow. Table 3-2-1 shows a summary of our electricity demand survey in rural Vietnam, which indicates typical household power demand.

Table 3-2-1 Estimation of basic power demand at a typical rural household

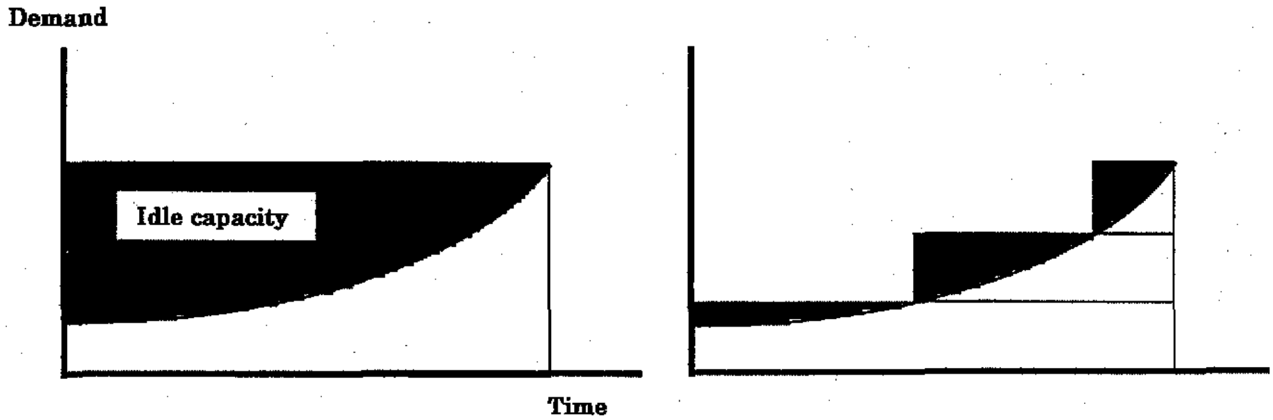
Appliances	Power (W)	Units	Total Power (W)	Possession ratio (%)	Peak-time Coefficient	Basic power demand at peak time (W/household)	Remarks
Light	20	2	40	100	0.8	**32.0**	Fluorescent light (small)
TV	30	1	30	80	0.8	**19.2**	B/W TV
Radio-cassette	10	1	10	40	0.1	**0.4**	
Electric fan	30	1	30	30	0.3	**2.7**	Small (30cm)
Total						**54.3**	

It is understandable that electric appliances to be used vary from one family to another. Also, the electricity consumption pattern is different at each household. The peak of electricity demand in a day occurs in the evening, because many villagers use electricity for lighting, TV, etc. at the same time. In contrast, the daytime demand is relatively small. In high-income communes, it is expected that some households use color TVs or electric water heaters. On the other hand, only lights are used in poor communes. In conclusion, it is recommended to use a basic unit demand of 50W per household (70W at a high-income commune) in planning off-grid rural electrification projects. This figure looks relatively small, but our recommendation is to keep the excess capacity of power system at a minimum to secure financial sustainability.

3-3 Step-by-step Development

It is often found that overestimation of electricity demand and reckless expansion of the supply area in off-grid electrification projects resulted in overcapacity and high investment costs. Its consequence is insufficient revenues to cover the capital and recurring costs, which leads to poor maintenance of the installed off-grid power systems. Eventually, the systems come to a stop and never resume operation.

In order to avoid this miserable situation, it is necessary to build small-size plants in steps to meet the growing demand. The following illustrations explain this idea of "development in steps". Figure 3-3-1(A) indicates that the initial plant capacity is too big and has a big idle capacity for a *long time*. In this case, the bottom line is in the red and the plant often stops operation due to a shortage of maintenance funds. On the other hand, Figure 3-3-1(B) shows a multiple development plan to meet the demand increase and to reduce the idle capacity. In the latter case, the plants will run with a high load factor and the users don't have to bear the costs of excess capacity. In other words, the recommended approach is to develop a series of 5kW plants rather than a single 20kW plant. This is a very important point to achieve the financial sustainability of off-grid electrification systems that need to be managed with villagers' payments. In this regard, we are going to focus on small-size plants, from 1 to 10 kW in particular. Our goal is to develop a model of small-size off-grid rural electrification by using Vietnamese technologies and to reduce costs to an affordable level.



(A) Initial capacity is too large **(B)Capacity is added to meet demand increase (Step-by-step development)**

Figure 3-3-1 Demand growth and plant capacity

In the past, overseas donors preferred relatively large-scale plants in case of rural electrification, because they did not want to change their conventional design. For example, 100kW-class hydro plants were often developed to electrify several villages. They believed bigger systems were more reliable. They paid less attention to the long-term operation and maintenance of the installed off-grid power systems, which the villagers could not deal with properly. Another reason for choosing large-sale plants was that the technical base of Vietnamese manufacturers had not progressed to offer micro-hydro components. To develop unfamiliar small-sized power plants required technological breakthroughs. In this JICA study, we took a different approach as mentioned earlier. Our suggestion is, "the smaller, the more sustainable". Once necessary technologies for small off-grid systems become available in Vietnam, it is expected that such low-cost and small off-grid projects will be booming in remote areas.

3-4 Financial Evaluation

It is important to check the financial sustainability of off-grid projects before implementation, because it is the key to sound management of installed power systems. Unlike grid extension, the recurring costs of off-grid projects are not to be covered by EVN. The financial management will be a responsibility of the commune or village, whose financial capability is extremely weak. The most important point is whether recurring costs can be covered by revenues from users. If the revenues are not enough to cover the operational costs, the power system cannot be maintained properly. There have been many such cases in the past. It is often found that the financial feasibility of off-grid projects was not examined intensively due to an optimistic estimation of revenues and expenses. Conducting a strict financial evaluation is extremely important to achieve long-term sustainability of off-grid projects.

3-4-1 Setting tariff

When planning an off-grid project, the biggest concern among rural villagers is the electricity tariff, initial payment and monthly charge. Rural electrification projects will proceed smoothly only when an affordable tariff scheme is adopted taking villagers' income levels into account. The tariff should be set so that the users can pay electricity charges without delay. Revenue shortfall will result in poor system maintenance and system stoppage in the end. Such incidents should be avoided by all means. Based on our previous studies in the Indochina region, it can be said that average rural farmers are ready to pay $1.00 to $1.50 per month for electricity. In addition, it is observed that they can afford around $20 for a pico-hydro generator or car battery as their initial "investment" for electricity supply.

A basic principle for setting the tariff is "100% cost recovery" to avoid reliance on aid or subsidy after commissioning and to secure enough cash flow to cover the repayment and recurring costs. However, the GOV issued a circular in 1999 to set a ceiling on the electricity charge in rural areas at 700VND/kWh. Although this guideline is not necessarily applied to off-grid electrification projects, we need to consider it as a benchmark in setting a tariff for off-grid electricity. Assuming typical household demand for electricity in remote areas is 6kWh per month (50W x 4hours x 30days), the monthly revenue from each user is only 4,200VND, or $0.30. This is far below the cost they are willing to bear. However, given the policy to reduce the financial burden of rural farmers, it would be difficult to charge more. As a result, a substantial amount of subsidy would be unavoidable to offset the revenue shortage, which may be well understood among the government officials concerned.

In general, after getting electricity it is common to see that people work during the nighttime to earn more income. However, this point is not well recognized before the commissioning of the power system. Furthermore, if some productive activities can be developed to utilize unused electricity during the off-peak time (daytime) for generating more income, the commune as a whole will benefit a lot. Therefore, those who are going to draw up off-grid electrification plans are expected to pay attention to productive application of electricity as well.

3-4-2 Cost allocation and financial viability

(1) Micro-hydro

A typical 5kW micro-hydro system with a low-voltage (220V) mini grid is proposed, which can supply electricity to about one hundred households within a 1 to 2 km radius. Also, a battery-charging unit will be attached to gain more income. Our goal is to develop this system for around $10,000, or $2,000/kW. In this case, the development cost per household is only $100. Our study revealed that the goal is challenging but achievable when a standardized design is applied and domestic technology and equipment are used. Based on this figure and other conditions indicated below, the financial feasibility of a 5kW micro-hydro is assessed. (See Tables 3-4-1 and 3-4-2) Due to its limited size, the growing demand for electricity will reach the plant capacity in several years. It is assumed that the plant will be fully loaded in the eighth year.

The cash flow analysis revealed that the micro-hydro system will be financially sustainable as long as a 50% subsidy on the capital cost is given. In other words, if the capital credit is cut half as a result of subsidizing $5,000, the expected revenues from users will be able to cover the repayment of the credit (after subsidy) and O&M costs over the life of plant. This amount of subsidy, 50% of the total investment, is quite ordinary. The GOV or PPC, as creditor, can keep the repayment in a special account (revolving fund) to reinvest in new rural electrification projects. Thus, this approach indicates a workable scenario on the cost allocation and financial management of a village-size micro-hydro scheme.

Table 3-4-1 Summary of financial evaluation—5 kW micro-hydro

Capital investment		$10,000 (150 million VND)	
Subsidy		$5,000 (50% of capital)	
Plant life		20 years	
Electricity demand per household		200Wh/day/HH in year 1 5% increase per year until year 8	
Number of connected households		100 households in year 1 2% increase per year until year 8	
Discount rate		6 %	
Cash out	O&M costs	$20/year	Operation and maintenance cost including lubrication
		$67 (1milliomVND)	Parts replacement cost in year 5 and 15
		$670 (10milliomVND)	Overhaul cost of turbine and generator in year *10* and *20*
	Administrative costs	$20/month	Operator's salary and miscellaneous costs
Cash In	Tariff revenue	700VND/kWh	6kWh/month /HH in year 1 (200Wh×30days=6kWh)
	Charging Revenue	3,000VND/charge	4 users/day×30days 3~4 charge/month/HH
NPV		2.7 million VND	
FIRR		6.45%	

Table 3-4-2 Preliminary Financial Evaluation on Village Hydro (5kW)

Preliminary Financial Evaluation on Village Hydro

Project Name	Sample Village Hydro (5kW)
Capacity	5 kW MHP
Total Investment ($)	10,000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial connected households	100																				
Investment per household ($)	100																				
Investment (VND million)	-150.0																				
Subsidy Ratio(%)	50.0%																				
Subsidy (VND million)	75.0																				
Connected households		100	102	104	106	108	110	113	115	115	115	115	115	115	115	115	115	115	115	115	115
Monthly demand (kWh) per household		6	6.3	6.6	6.9	7.3	7.7	8.0	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Yearly demand (kWh)		7200	7711	8259	8845	9473	10146	10866	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637
Financial Benefits (VND million)																					
Electricity Sales Revenue VND700/kWh		5.0	5.4	5.8	6.2	6.6	7.1	7.6	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Battery Charging Revenue VND3000/charge		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Total benefits		9.4	9.7	10.1	10.5	11.0	11.4	11.9	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Financial Costs (VND million)																					
Operation & Maintenance		0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	10.0	0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	10.0
Operator salary and administration		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Total costs		3.9	3.9	3.9	3.9	4.6	3.9	3.9	3.9	3.9	13.6	3.9	3.9	3.9	3.9	4.6	3.9	3.9	3.9	3.9	13.6
Financial Net cash flow	-75	5.5	5.8	6.2	6.6	6.4	7.5	8.0	8.6	8.6	-1.1	8.6	8.6	8.6	8.6	7.9	8.6	8.6	8.6	8.6	-1.1

FIRR	6.45%
FNPV	2.7

Other assumptions

Calculation period	20 years
Discount rate	6%
Electricity demand per household	200Wh/day
Electricity demand growth	5% per year
Number of connected households	100 (year 1)
Increase of connected households	2% per year
Demand reaching plant capacity	year 8
Maintenance cost	$20 a year for oiling and regular checking $67 every 5 years for parts replacement $670 every 10 years for major overhaul
Operator salary and other administration costs	$20 per month
Number of battery charge users	4 per day

Table 3-4-3 shows a model plan for a 20-year repayment schedule for the $5,000 (75 million VND) credit on the 5kW micro-hydro system. After deducting the administrative and O&M expenses from the revenues, there will be some surplus of cash flow each year. From the surplus, the villagers are supposed to repay the debt. In this case, an interest rate of 6% per annum is assumed. This repayment plan should be arranged and agreed between the creditor and debtor before the commissioning of the plant. Of course, there will be some flexibility to adjust the repayment plan based on actual revenues and expenses. Also, the management organization needs to keep the balance, if any, in a reserve for purchasing spare parts, periodical overhaul and unexpected repair. It is strongly recommended to build up a fairly large amount of reserve within a few years after the commissioning to improve financial sustainability.

Table 3-4-3 Model plan of repayment

(million VND)

Year	1	2	3	4	5	6	7	8	9	10
Net Cash Flow	5.5	5.8	6.2	6.6	6.4	7.5	8.0	8.6	8.6	-1.1
Cumulative Cash Reserve	0.5	0.8	1.5	2.6	3.5	4.0	5.0	6.6	8.1	0
Repayment	**5.0**	**5.5**	**5.5**	**5.5**	**5.5**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**
(Interest)	(4.5)	(4.5)	(4.4)	(4.3)	(4.3)	(4.2)	(4.0)	(3.9)	(3.7)	(3.5)
Debt outstanding	**74.5**	**73.5**	**72.4**	**71.2**	**70.0**	**67.2**	**64.2**	**61.1**	**57.7**	**54.2**
Year	11	12	13	14	15	16	17	18	19	20
Net Cash Flow	8.6	8.6	8.6	8.6	7.9	8.6	8.6	8.6	8.6	-1.1
Cumulative Cash Reserve	1.2	2.3	3.5	4.7	5.1	6.3	7.5	8.6	9.8	1.7
Repayment	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.4**	**7.0**
(Interest)	(3.3)	(3.0)	(2.7)	(2.5)	(2.2)	(1.9)	(1.5)	(1.2)	(0.8)	(0.4)
Debt outstanding	**50.1**	**45.7**	**41.0**	**36.1**	**30.8**	**25.3**	**19.4**	**13.2**	**6.6**	**0**

It is important to reduce repair costs that may soar when unexpected accidents occur. In case of off-grid micro-hydro development, plant operators are often inexperienced and sometimes fail to operate the power systems properly. With such a risk in mind, financial arrangements to cope with unexpected repair should be prepared. One practical idea is to pay a premium to installers or component suppliers to extend the warranty period in order to set out a ceiling on repair cost.

As shown in the above-mentioned analysis, the 5kW micro-hydro system can be financially viable. The GOV and international donors also may want to see if the micro-hydro system is economically and socially beneficial. Potential positive impacts may include improved incomes, reduced kerosene usage, reduced labor for water pumping and enhanced social amenity. By using the figure of "willingness to pay for electricity" 1,820VND/kWh (See Chapter 2) instead of 700VND/kWh the "economic" viability of the micro-hydro development can be assessed. The battery charging fee, 3,000VND per charge is unchanged because it is based on the market price. In this preliminary analysis, shadow price is neglected. Table 3-4-4 shows that EIRR of the proposed 5kW micro-hydro scheme turns out to be 10.2% before subsidy. When we include other economic benefits such as income generation, improved education and so forth, the EIRR will be significantly increased.

It is important to note that the electricity tariff in this 5kW micro-hydro project could rise to 1,320VND/kWh if no subsidy is provided. (See Table 3-4-5)

Table 3-4-4 Preliminary Economic Evaluation on Village Hydro (5kW)

Preliminary Economic Evaluation on Village Hydro

Project Name	Sample Village Hydro (5kW)
Capacity	5 kW MHP
Total Investment ($)	10,000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial connected households	100																				
Investment per household ($)	100																				
Investment (VND million)	-150.0																				
Subsidy Ratio(%)	50.0%																				
Subsidy (VND million)	75.0																				
Connected households		100	102	104	106	108	110	113	115	115	115	115	115	115	115	115	115	115	115	115	115
Monthly demand (kWh) per household		6	6.3	6.6	6.9	7.3	7.7	8.0	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Yearly demand (kWh)		7200	7711	8259	8845	9473	10146	10866	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637
Economic Benefits (VND million)																					
Willingness to pay for electricity VND1820/kWh		13.1	14.0	15.0	16.1	17.2	18.5	19.8	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Battery Charging Revenue VND3000/charge		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Total benefits		17.4	18.4	19.4	20.4	21.6	22.8	24.1	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
Economic Costs (VND million)																					
Operation & Maintenance		0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	10.0	0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	10.0
Operator salary and administration		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Total costs		3.9	3.9	3.9	3.9	4.6	3.9	3.9	3.9	3.9	13.6	3.9	3.9	3.9	3.9	4.6	3.9	3.9	3.9	3.9	13.6
Net cash flow (Before subsidy)	-150	13.5	14.5	15.5	16.5	17.0	18.9	20.2	21.6	21.6	11.9	21.6	21.6	21.6	21.6	20.9	21.6	21.6	21.6	21.6	11.9
Net cash flow (After subsidy)	-75	13.5	14.5	15.5	16.5	17.0	18.9	20.2	21.6	21.6	11.9	21.6	21.6	21.6	21.6	20.9	21.6	21.6	21.6	21.6	11.9

EIRR (Before subsidy)	10.19%
ENPV (Before subsidy)	56.2
EIRR (After subsidy)	21.95%
ENPV (After subsidy)	126.9

Other assumptions

Calculation period	20 years
Discount rate	6%
Electricity demand per household	200Wh/day
Electricity demand growth	5% per year
Number of connected households	100 (year 1)
Increase of connected households	2% per year
Demand reaching plant capacity	year 8
Maintenance cost	$20 a year for oiling and regular checking $67 every 5 years for parts replacement $670 every 10 years for major overhaul
Operator salary and other administration costs	$20 per month
Number of battery charge users	4 per day

Table 3-4-5 Preliminary Financial Evaluation on Village Hydro (5kW, no subsidy case)

Preliminary Financial Evaluation on Village Hydro (No subsidy case)

Project Name	Sample Village Hydro (5kW)
Capacity	5 kW MHP
Total Investment ($)	10,000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial connected households	100																				
Investment per household ($)	100																				
Investment (VND million)	-150.0																				
Subsidy Ratio(%)	0%																				
Subsidy (VND million)	0																				
Connected households		100	102	104	106	108	110	113	115	115	115	115	115	115	115	115	115	115	115	115	115
Monthly demand (kWh) per household		6	6.3	6.6	6.9	7.3	7.7	8.0	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Yearly demand (kWh)		7200	7711	8259	8845	9473	10146	10866	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637	11637
Financial Benefits (VND million)																					
Electricity Sales Revenue VND1320/kWh		9.5	10.2	10.9	11.7	12.5	13.4	14.3	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4
Battery Charging Revenue VND3000/charge		4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Total benefits		13.8	14.5	15.2	16.0	16.8	17.7	18.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7	19.7
Financial Costs (VND million)																					
Operation & Maintenance		0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	10.0	0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	10.0
Operator salary and administration		3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Total costs		3.9	3.9	3.9	3.9	4.6	3.9	3.9	3.9	3.9	13.6	3.9	3.9	3.9	3.9	4.6	3.9	3.9	3.9	3.9	13.6
Financial Net cash flow	-150	9.9	10.6	11.3	12.1	12.2	13.8	14.8	15.8	15.8	6.1	15.8	15.8	15.8	15.8	15.1	15.8	15.8	15.8	15.8	6.1

FIRR	6.06%
FNPV	0.7

Other assumptions

Calculation period	20 years
Discount rate	6%
Electricity demand per household	200Wh/day
Electricity demand growth	5% per year
Number of connected households	100 (year 1)
Increase of connected households	2% per year
Demand reaching plant capacity	year 8
Maintenance cost	$20 a year for oiling and regular checking $67 every 5 years for parts replacement $670 every 10 years for major overhaul
Operator salary and other administration costs	$20 per month
Number of battery charge users	4 per day

(2) Solar system

As for solar systems, the assumptions for financial analysis are as follows. (See Table 3-4-6) A typical 1.5kW battery charging system that can serve more than 40 households is proposed. The investment cost will be $7,000, or $4,666/kW, which is much higher than micro-hydro. If a 3kW system is considered to serve 100 households, two sets of 1.5kW system will be installed separately to serve different geographical clusters of customers. A solar system will require a larger capital investment compared with an equivalent micro-hydro. Therefore, a larger subsidy, 2/3 or more, on the capital cost will be needed to achieve financial viability. (See Table 3-4-7) The biggest reason for high initial costs is that the unit price of solar modules, which must be imported, is still high in the global market.

Table 3-4-6 Summary of financial evaluation—1.5 kW PV BCS

Capital investment		$7,000 (105 million VND)	
Subsidy		$4,667 (66.7% of capital)	
Plant life		20 years	
Number of users		40 household in year 1 2% increase per year until year 10	
Charging frequency		40 times/year/HH in year 1 5% increase per year until year 10	
Discount rate		6 %	
Cash Out	O&M costs	$15/year	Parts replacement, etc.
	Administrative costs	$15/month	Operator's salary and miscellaneous costs
Cash In	Charging Revenue	3,000VND/charge	50Ah size battery
NPV		14.9 million VND	
FIRR		10.08%	

Table 3-4-7 Preliminary Financial Evaluation on Village Solar (BCS 1.5kW)

Preliminary Financial Evaluation on Village Solar

Project Name	Sample Village Solar (Battery Charging)
Capacity	1.5kW (10 units of 150W)
Total Investment ($)	7000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Initial Users	40																				
Initial Investment ($)	7000																				
Investment (VND million)	-105																				
Subsidy Ratio	66.7%																				
Subsidy (VND million)	70.0																				
Users		40	40.8	41.6	42.4	43.3	44.2	45.0	45.9	46.9	47.8	47.8	47.8	47.8	47.8	47.8	47.8	47.8	47.8	47.8	47.8
Average charges per user in a year		40	42.0	44.1	46.3	48.6	51.1	53.6	56.3	59.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1
Total charges in a year		1600	1714	1835	1966	2105	2255	2415	2586	2770	2966	2966	2966	2966	2966	2966	2966	2966	2966	2966	2966
Financial Benefits (VND million)																					
Revenue VND3000/charge		4.8	5.1	5.5	5.9	6.3	6.8	7.2	7.8	8.3	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9
Total benefits		4.8	5.1	5.5	5.9	6.3	6.8	7.2	7.8	8.3	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9
Financial Costs (VND million)																					
Operation & Maintenance		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Operator salary and administration		2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Total costs		2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Financial Net cash flow	-35.0	1.9	2.2	2.6	3.0	3.4	3.9	4.3	4.9	5.4	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

FIRR	10.08%
FNPV	14.9

Other assumptions

Calculation period	20 years
Discount rate	6%
Number of initial users	40 (4/unit)
Increase of users	2% per year
Interval of charging	40 times per year/household
Increase of charging demand	5% per year
Demand reaching plant capacity	year 10 (max. 3000 charges/year)
Maintenance cost	$15 per year
Operator salary and other administration costs	$15 per month

3-5 Financing Plan

Securing sufficient funds for promoting off-grid rural electrification is an important task of the GOV. As mentioned earlier, a typical off-grid project requires approximately $10,000, more than half of which needs to be subsidized to buy down the capital cost to an affordable level for the villagers. If these conditions are met, the capital cost after subsidy can be paid back by the users.

In general, the GOV or PPC will have no difficulty in financing such small projects. For example, the GOV has the 135 Program to help more than 2,000 poor communes improve their infrastructures. Its annual budget for each commune ranges from $20,000 to $40,000. By using the 135 Program budget a modest off-grid system can be developed. In addition, the World Bank and the Japan Bank for International Cooperation (JBIC) are separately preparing a special funding scheme for off-grid rural electrification. If these funds become available in the near future, the GOV and PPC will get more flexibility and invest in off-grid projects more aggressively.

3-5-1 The 135 Program

The 135 Program is one of the major government programs for poverty alleviation, targeting ethnic minority communes with special difficulties mostly located in mountainous or border areas (2,325 communes as of 2001). Most of the target communes of this study are eligible for this program. Infrastructure projects such as road improvement, school improvement or irrigation system development, are carried out under this program. Sometimes, repair or upgrading of the existing rural grid was conducted under this program. (See Table 3-5-1)

Table 3-5-1 Infrastructure projects by the 135 Program

Category	1999		2000	
	Total number of projects 2,274	Percentage in total investment	Total number of projects 2,816	Percentage in total investment
Road	631	38.8%	1,039	43.4%
School	642	27.3%	779	25.1%
Irrigation	530	20.0%	548	18.1%
Clean water	307	7.3%	204	5.5%
Electricity	**121**	**5.2%**	**206**	**6.8%**
Clinic	29	0.9%	24	0.6%
Market	14	0.5%	16	0.5%

Source : CEMMA data , May 2001

Although off-grid electrification such as micro hydropower development has been recommended under this program, there have been very few implemented projects so far due to difficulty in drawing up feasible plans. Off-grid electrification is more complicated to design than road construction or irrigation, hindering project implementation. It is strongly recommended that the GOV and PPC take necessary measures including the capacity building of planning divisions to push off-grid electrification projects under the 135 Program.

Reference

Decision No.135 /1998/QD-TTg of July 31,1998

To approve the program on Socio-Economic Development in mountainous deep-lying and remote communes with special difficulties.

Article 1

IV. Tasks of the program

3. To develop the rural infrastructure in line with the production planning and population re-distribution planning, communications systems, drinking water supply systems, and power-supply systems in areas where conditions permit, including mini-hydro-electric power stations.

Article 2

2. Investment and credit policies:

e/ The presidents of the People' s Committees of the provinces covered by this program shall concentrate on directing and mobilizing various local resources for program implementation. Apart from the sources of investment capital for the overall development of the whole region, the State shall also give financial support for performing the following tasks.

-Construction of power supply projects: in areas where conditions permit, the State shall support the investment in building electric transmission lines to the centers of commune clusters according to the planning and the investment capability in each period. In areas where conditions permit the construction of mini-hydro-electric projects, the State shall support the inhabitants part of the expenditures and lend credits for development investment.

3-5-2 Funds from international donors

As mentioned earlier, the World Bank and JBIC are separately considering to set up a fund for off-grid rural electrification. Because poverty reduction and renewable energy development are their priority issues, off-grid rural electrification by renewable energy has been highlighted in their agenda. Therefore, it is very likely that these funds will become available and the GOV can secure more funds for off-grid renewable energy projects in the future.

World Bank	Preparing for a trust fund, "Remote Area Renewable Electricity Facility" (expected to start in 2003), based on the Renewable Energy Action Plan. Money from this fund will be provided to provincial governments as a grant.
JBIC	Studying to include off-grid renewable electrification projects in the existing rural development loan: Rural Infrastructure Development and Living-standard Improvement Project (expected to start in Phase 5 from 2005)

Reference :JBIC sector loan

Rural Infrastructure Development and Living-standard Improvement Project

"In the context of the economic development of Vietnam, assistance to rural agricultural areas, where most of the population lives, is recognized as one of the key issues from the viewpoint of poverty alleviation and equity between urban and rural areas. The objective of this project is to strengthen the agricultural and industrial sectors, to enhance infrastructures in rural areas and, eventually, to improve people's living standards by way of developing such rural infrastructures as road networks, water supply systems and power distribution systems. The proceeds from the loans are for civil works, equipment, and consulting services." (*Extracted from "JBIC ODA Operation in Vietnam, April 2001")

Table 3-5-2 JBIC rural development sector loan

Phase 1	Fiscal 1995	7 billion yen ($53.8 mil.)
Phase 2	Fiscal 1996	4 billion yen ($30.8 mil.)
Phase 3	Fiscal 1998	12 billion yen ($92.3 mil.)

Source : JBIC ODA Operation in Vietnam, April 2001

Off-grid rural electrification requires a large number of small-sized projects. In making financial arrangements for off-grid projects, because of this characteristic, not only the size of available funds but also the required application process should be simple and not time consuming. For instance, JBIC's soft loan for rural development, which is aiming to provide funds to many small-size rural projects, is more suitable than the Japanese grant program that requires a complicated process before project implementation.

The above discussions are related to the implementation stage of off-grid projects. Of course, each project needs a feasibility study and design work beforehand, and the GOV or PPC must secure enough funds for planning as well. The required budget for preliminary survey and planning, however, will not be big because the proposed model plans are standardized so that site-specific work will be limited. This point will be also appreciated, given the difficult financial condition of local governments.

3-6 Micro-finance Scheme

In addition to project financing, micro financing, if available, would help low-income villagers apply for electricity service. For example, the villagers will borrow money to pay the connection fee (service drop charge) or buy pico–hydro generators or batteries. There are many examples of micro financing in Vietnam. However, no government policy has been set out on it. A preliminary study is underway now by an Asian Development Band (ADB) funding to formulate an appropriate framework on micro financing. It is recommended to introduce micro finance for rural electrification in a timely manner using the results of the ADB study.

3-6-1 Outline of micro finance

In general, poor people are isolated from various social services, especially from formal financial services, because of:

○Loan amount being too small
○Inaccessible formal financial services (physically and psychologically)
○Complicated and slow loan application processes
○Having no collateral

For these reasons, rural villagers cannot use formal financial services and, therefore, they have to rely on informal ones such as borrowing from relatives or private money lenders with a high interest rate. This often places poor people in hardship for repaying the debt. To resolve this problem and to assist the poor people to fight against poverty, a small-scale financing targeting the poor which is called "micro-finance" is starting to play an important role. A typical micro-finance scheme is to provide small-scale credit and savings to farmers, entrepreneurs and craftsmen. In rural areas, people need loans to get capital to buy agricultural materials and livestock. Thus, micro-finance targets those people and areas uncovered by conventional financial services by providing income generation opportunities. That is why micro-finance has been drawing attention as a key poverty reduction measure. The general features of a micro-finance scheme can be described as follows:

○Small size loan is acceptable
○Scheme is close to rural people (physically and psychologically)
○Easy loan procedures
○Joint-liability system without collateral (in many cases)

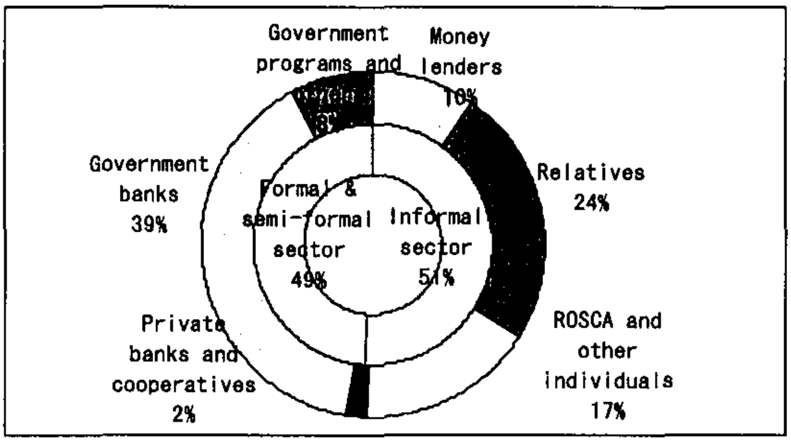
3-6-2 Micro-finance in Vietnam

The Vietnam Bank of Agriculture and Rural Development (VBARD) and the Vietnam Bank for the Poor (VBP) are two large state financial institutions to provide financial services to poor households in rural areas. However, there are still so many people who don't have access to those services. As a result, they depend on informal financing schemes in spite of a high interest rate. To improve this situation, there are rural financing programs supported by the government, NGOs or overseas donors.

Table 3-6-1 Major players in rural finance in Vietnam

	Financial service organization	Average loan amount
Formal	VBARD, VBP, People's Credit Fund (PCF)	3,209,000 VND
Semi-formal	Government program (such as job creation program), Mass-organization or NGO's program	
Informal	Rotating savings and credit associations (ROSCA), Private money lenders	1,752,000 VND

Ref : Vietnam Living Standard Survey, 1997-1998 GSO



Source: Micro finance in Vietnam, 2001 (British Department of International Development)

Figure 3-6-1 Sources of rural household loans

The VBARD, VBP and financial cooperatives are under the supervision of the State Bank and their interest rates are regulated. However, other semi-formal or informal institutions are not controlled by the State Bank, because there are no regulatory measures on micro-finance. For the sound development of small-scale financing to assist the rural poor people, both regulations and promotional measures to facilitate micro-finance will be needed. For promoting rural electrification, a new micro-finance scheme should be considered in line with the overall framework of micro-finance that will be established by the government.

3-6-3 Micro-finance scheme in off-grid rural electrification

Micro-finance has demonstrated its effectiveness in various development projects in many countries. There are some examples of micro-finance schemes in Vietnam for promoting rural electrification.

<u>Reference: Rural electrification project by Vietnam Women's Union (First stage ~1995)</u>

: Supported by Solar Electric Light Fund (SELF) and others

○Project sites : Three provinces : Tien Giang /TraVinh/ Nghe An

○Systems installed : 130 households / 5 Commune centers /2 Local markets

○Technicians for installation : 14 local technicians trained in the country

○Cost : User's responsibility (Revolving Loan Fund—operated by VWU)

—System cost : $ 300/ One unit of Solar Home System

—Repayment period : 3 years

—Repayment interval : Monthly or Bi-monthly

—Repayment rate on time : 95%

Source: International Energy Agency (IEA)-Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), Technical brochure No.28, 1996

With electricity from a pico-hydro, battery or solar system, rural villagers will be able to increase their incomes, for example, by working under lighting to do handicraft work. As a result, to pay back the debt of micro finance will become easier. This is clearly what should happen in social development work.

(1) Feasibility of micro-finance program

Financial feasibility of a model micro-finance scheme for rural electrification is examined with a cash-flow analysis.

1) Assumptions

In designing a micro-finance scheme, customers, implementing institutions and services to be provided should be carefully examined. It is unrealistic to ask rural villagers to put up collateral, so measures against repayment failure should be carefully designed. In this analysis, it is assumed that people purchase pico-hydro generators, which are available for $20 per unit, by borrowing $15 from the micro-finance scheme with a loan term of 24 months and an interest rate of 12% per annum. The proposed interest rate, 2% per month, falls between the average rate of the formal financial sector, which is 1.26% per month, and that of the informal financial sector, which is 3.95%[8] per month. Although the interest payment declines over time, in the analysis an average interest payment of $0.15 per month is used. To cope with default risk, a loan attrition rate of 3% per year is taken into account. Also, administration costs of $24 per month—$20 for salary of a full-time officer and $4 for miscellaneous costs—is assumed.

2) Financial feasibility

In evaluating this scheme, the minimum requirement is full cost recovery to secure long-term financial sustainability. To generate an income of $24 every month, it is necessary to have average outstanding loans of $1,200 at least. On top of this, it is necessary to cover the default loss of 3% of loans outstanding per year, which requires additional loans of $200. In total, the minimum required amount of loans is $1,400. This can be achieved when more than 190 clients are acquired constantly.

3) Affordability of monthly payment

The target users of the micro-finance scheme are lower income people, so it is important to check whether the average repayment of $0.78 per month is affordable or not. It has been observed that people in un-electrified areas pay about $1.0 for kerosene every month, which suggests that the micro finance scheme is viable.

[8] Source: Vietnam Living Standard Survey, 1997-1998 and Micro finance in Vietnam, 2001

Chapter 4

Institutional Development

4-1 Stakeholders in Off-grid Electrification

4-1-1 Implementing organizations and operating organizations

There are two important aspects in planning rural electrification projects. One is a technical issue and the other is a financial issue. On the technical side, expected problems with operation, maintenance and repair need to be dealt with properly. On the financial side, making necessary financial arrangements for construction and securing enough revenues from users for O&M expenses and capital repayment are equally important. These tasks must be performed smoothly and efficiently through a well-managed organizational framework.

Two kinds of organizations need to be studied: one is the organization to implement rural electrification projects, and the other is the organization to operate and manage the installed systems. Both organizations are expected to undertake a series of tasks efficiently to achieve the goal of sustainable rural electrification. It is challenging to develop an appropriate organizational structure that fits the conditions of off-grid rural electrification.

Table 4-1-1 Organizations and their roles in off-grid rural electrification

Type of electrification	Project Planning & Implementation Body	Operating Body	Support Mechanism
Village Hydro (1-10kW class including battery charging) **Village Solar** (Battery charging system with electricity supply at public facilities)	**Province /Department of Industry** responsible for project planning and implementation, making financial arrangements (provision of subsidy from state/provincial budget)	**Community Electricity Unit** responsible for daily operation and maintenance, tariff collection and accounting	**PC local offices/ independent off-grid service providers** for technical support & spare parts supply (back-stopping) Micro-financing to help users
Pico-hydro / Solar Home System	Individuals		Market price Micro-financing to help users

4-1-2 Roles of government

Instead of EVN, the MOI and provincial governments (PPCs) are expected to play a key role in promoting off-grid rural electrification. These organizations not only form the framework of off-grid electrification but also actually implement off-grid projects. The private sector is not going to undertake off-grid projects at the early stage of rural electrification because promoting off-grid projects on a commercial basis is unrealistic. In the long run, of course, they will be more involved. But at the moment, the state government and provincial governments must lead off-grid rural electrification by arranging financing mechanisms, setting rules and guidelines, and, more importantly, by directing individual off-grid electricity system development.

4-1-3 Operation by villagers

After completion, off-grid systems are to be handed over to village organizations. The proposed model plans in this study expect that basic operation and maintenance of installed off-grid systems are to be undertaken by the selected villagers. It should be avoided that rural power systems are abandoned due to poor technical knowledge on their operation, which has often happened in remote areas. We need to secure easy maintenance, which is the key to long-term sustainability. It would be also necessary that local operators gain enough expertise in operation and maintenance through a series of technical and management training courses. In reality, however, they may sometimes have to call outside technicians to fix serious problems. Hence, it is also necessary to establish a workable support mechanism involving outside entities.

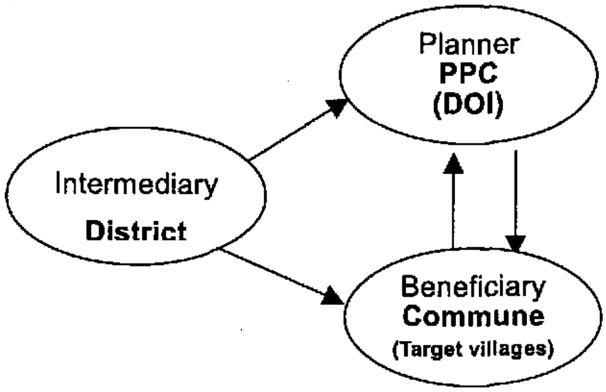
4-2 Organizational Development for Off-grid Rural Electrification

In general, rural electrification is not financially attractive because of its high initial investment and low monthly income. In addition, the GOV has set a ceiling for the unit electricity price in remote villages very low at 700VND/kWh, which makes off-grid projects more difficult. Also, off-grid development sites are usually very far away from district centers and difficult to reach by car. Given all these difficulties, it will be difficult to expect that private entities play a leading role in off-grid projects in the near future. Realistically, off-grid electrification, therefore, must be promoted by the public sector until the market environment matures enough for the entry of private entities.

4-2-1 Province and central government

It is clear that the Department of Industry (DOI) of PPC, not EVN, is primarily responsible for off-grid rural electrification. However, very few off-grid plants have ever been built under DOI's initiative. At this moment, provincial engineers are inexperienced in off-grid electricity so that training them is important and urgent. They will be able to gain sufficient knowledge and skills to play a key role in the future if a well-organized training program combined with some pilot projects is implemented.

It is strongly recommended that PPC delegate operation and management of off-grid systems to the villagers after commissioning. By assigning such tasks to them, PPC can concentrate on their primary role of planning and developing off-grid rural electrification projects.



Stakeholder	Position	Function
Provincial People's Committee (PPC)/ Department of Industry (DOI)	Planner	*Off-grid planning *Site survey *Feasibility study (F/S) *Explanation of the project to villagers *Recommendation & support on set-up of CEU *Basic design
District People's Committee (DPC)	Intermediary	*Offering data and information of target area to PPC *Explanation for better understanding of the project
Commune People's Committee (CPC)	Beneficiary	*Understanding & agreement of electrification method, restrictions, tariff etc *Set-up of CEU

Figure 4-2-1 Organizations at planning stage

The MOI is responsible for coordinating the activities of their provincial departments (DOIs), and has been active in developing off-grid rural electrification policies and promotional mechanisms. For example, the MOI has been working with the World Bank to develop a financing scheme for off-grid electricity, which contributes to accelerating off-grid rural electrification nationwide. On the other hand, provincial governments (PPCs) are functioning under the Ministry of Planning and Investment (MPI). There might be some twisted control mechanisms in the relationship among these authorities in promoting off-grid rural electrification. In any case, consolidated efforts of the MOI and MPI will be particularly important.

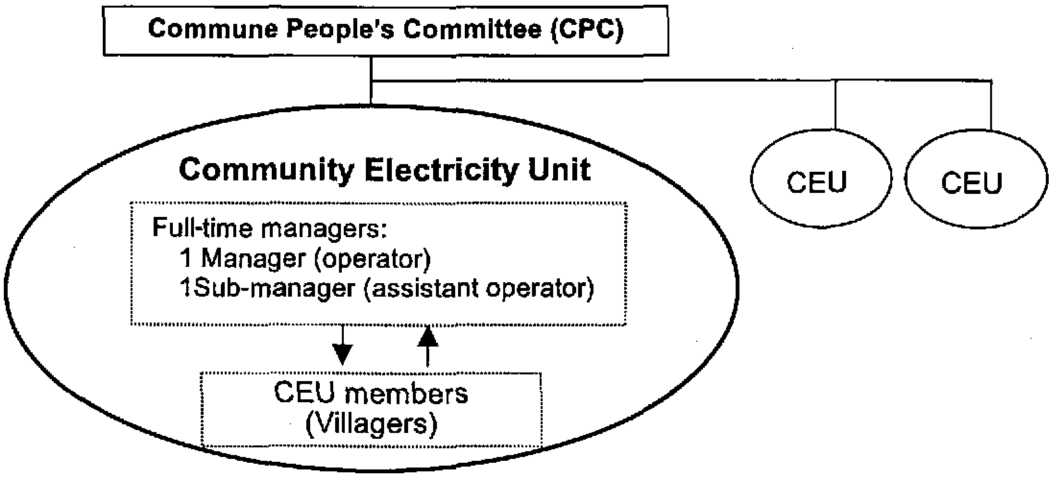
4-2-2 District

District Office is expected to act as intermediary. They will help PPC engineers find appropriate sites and hold discussions with the villagers, etc. to promote off-grid projects. Also, they will give consultation to the villagers to help them gain understanding on the proposed electrification plans and to ensure good management of the installed systems after commissioning.

4-2-3 Village organization

The most important point for the long-term success of off-grid rural electrification is community involvement. Project planners and villagers should be fully involved throughout the project cycle: planning, design, construction, commissioning and operation. Without community support, off-grid projects will easily fail.

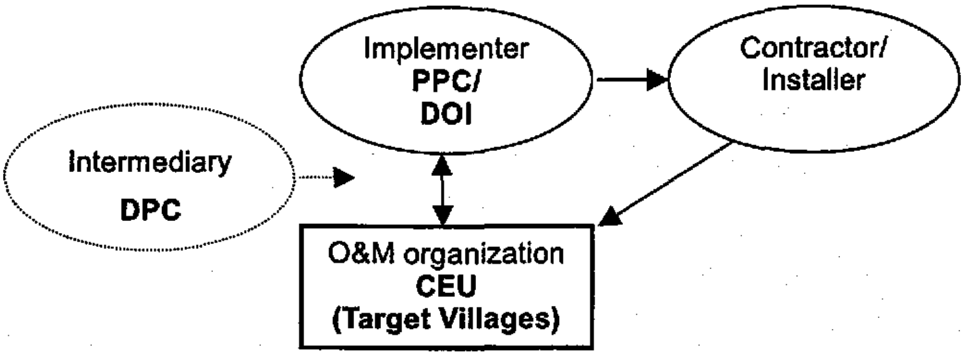
User maintenance is the key to sustainable off-grid electrification. Off-grid projects require more work by the villagers than grid extension. It is recommended to organize a small group, a Community Electricity Unit (CEU), in the village that is supposed to undertake daily operation, fee collection, bookkeeping, scheduled maintenance, and minor repairs. A CEU can be defined as an autonomous group that is dedicated to the operation and management of an off-grid power system. Its mission is to keep the system in good condition both physically and financially and to provide good electricity supply to users. The legal status of the CEU can be a "cooperative" or informal user group. Even in the case of grid extension, it is common in Vietnam to establish a village organization to collect tariffs from the users. Thus, rural villagers are familiar with such an organizational structure and its functions, which is an advantage in rural Vietnam to promote off-grid rural electrification.



Stakeholder		Position	Function
CPC		Supervisor	*Supervising & advising management of CEU
CEU	Managers	Operator	*O&M of power system *Minor troubleshooting *Financial management, and tariff collection *Reporting to CPC
	Members (Villagers)	Electricity User	①Mini-grid users *Installation of electric meter & in-house wiring *Tariff payment ②BCS users *Purchase & maintenance of batteries *Payment of charging fee

Figure 4-2-2 Village organizations for off-grid project

Before establishing a CEU, it is recommended to hold a villagers' meeting or Project Cycle Management (PCM) workshop to openly discuss the responsibilities of CEU and to build a consensus among the stakeholders. Selected CEU members have to go through a well-organized training program on technical and financial management. With appropriate training, the CEU core members will learn how to do fee collection, bookkeeping, scheduled maintenance and so on. Ideally, there should be two operators at least to share the work and responsibilities and to back up each other. In principle, modest compensation for such work should be given to the core members to keep their commitment high. Collected money should be managed under a proper accounting method for allocating funds to administration, repayment and reserve for future maintenance.



Stakeholder	Position	Function
PPC /DOI	Implementer	* Hiring Contractor *Supervising installation * O&M training *Management training
DPC	Intermediary	* Coordinating work
CEU	O&M organization	*Training participation *Contract (with each electricity user on electricity supply / with PPC on capital repayment)
Contractor /Installer	Installation& OJT	*Plant installation * O&M OJT

Figure 4-2-3 Primary organizations at construction stage

4-2-4 Backstopping

Since remote villagers have no knowledge about electricity before the commissioning of off-grid system, it is hard to imagine that the system can be operated for a long time without any technical assistance from outside experts. The villagers have to rely on outside technicians who will be able to provide special technical services in case of unpredicted problems. Securing such technical backstop is important for securing stable operation of off-grid systems. It has been confirmed that EVN and regional power companies (PCs) are willing to support off-grid projects technically. It is, therefore, recommended to set up an appropriate support scheme involving EVN, PCs or other entities to secure technical assistance to CEU. In particular, PC local offices will be very important as a source of technical expertise in remote areas. Of course, the PC will be paid for such technical services.

Technical problems will occur mostly in hydropower systems because solar systems are basically maintenance-free. In off-grid projects based on micro-hydro, electro-mechanical components as well as civil works need to be checked and serviced regularly to secure long-term reliability. Of course, component manufacturers and contractors will provide such services under warranty obligation after a few years from commissioning. However, in the long run, developing local workshops in remote areas that can provide such checking and repair services will be strategically important. When many off-grid projects are implemented, running a repair workshop on off-grid electrical components will become a good business.

4-2-5 Contract System

Although an off-grid system provides power supply to a small number of households, it is strongly recommended to prepare a contract form for the electricity supply. To avoid future problems caused by misunderstanding or ignorance, it is important to clearly define the responsibilities of the CEU and each user before project implementation. For this, it is recommended to show the terms and conditions of the electricity supply contract at the planning stage. Each user is requested to sign the contract. It is also important to confirm the number of applicants who agree to sign the contract before the construction starts. Without this process, troubles such as non-payment may often happen. Getting confirmation in writing to reaffirm the responsibility of users to pay the tariff regularly was found extremely effective in our previous off-grid projects.

4-2-6 Training

Intensive training targeting CEU members focusing on overall management, as well as the technical operation and maintenance of installed off-grid systems, is indispensable to achieve the long-term sustainability of off-grid projects. The training should start during the construction period and continue after commissioning. To refresh their memories and improve their skills, follow-up training should be given at least during the first two years.

4-3 Capacity Building

The proposed model plans in this study are to be used for planning and implementing actual projects by PPC engineers, who are assigned to promote off-grid projects. However, most of them are inexperienced. Since the GOV is going to accelerate off-grid rural electrification based on our model plans, their first task is to develop the capacity of PPC engineers before developing the legal framework or financing mechanism. Otherwise, nobody is going to play a leading role in off-grid projects. In this regard, it is strongly recommended to undertake some pilot projects soon in each province so that PPC engineers can learn about off-grid projects on an OJT basis. This effort will not only help them gain experience but also contribute to quality improvement and cost reduction of domestic off-grid system components.

The following diagram summarizes the organizational framework discussed in this chapter.

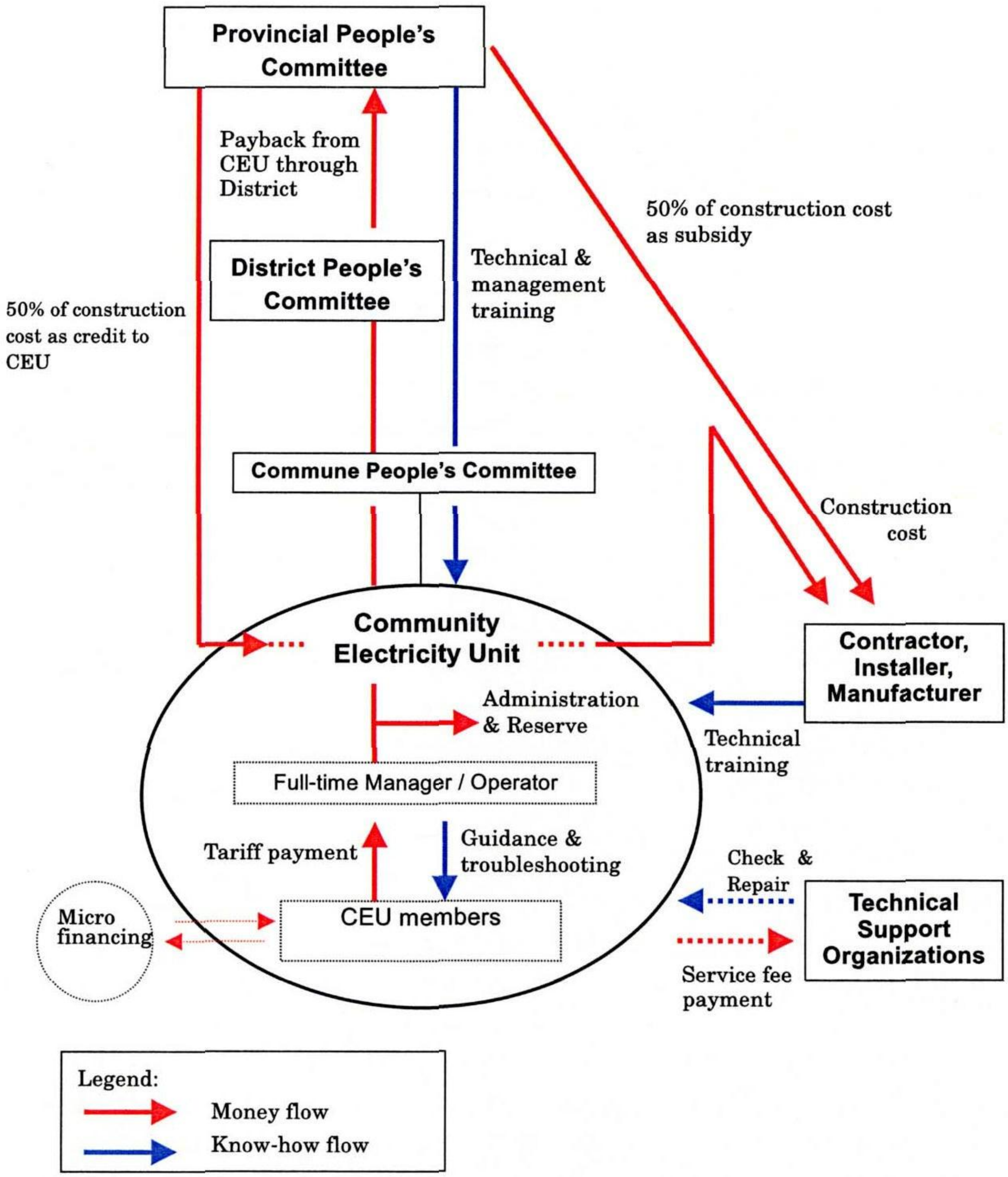


Figure 4-3-1 A typical flow of money and know-how in off-grid (micro-hydro) project

Chapter 5

Village Hydro—Rural Electrification by micro hydropower

The term "Village Hydro" can be defined as small water-driven systems suitable for power supply in rural communities not connected to the national grid. The capacity of Village Hydro systems is typically within the range of 200 watts to 20kW. Systems larger than this are usually too expensive to operate and manage in a rural community, and the demand for power rarely justifies larger systems. As discussed in Chapter 3, in order to promote financially sound rural electrification, avoiding excess plant capacity is important. Developing a series of small-scale micro-hydro plants, Village Hydro, fits in with this strategy. We worked to develop a low-cost but robust Village Hydro design focusing on Vietnamese technologies. Our goal is to achieve "easy to finance, easy to build and easy to operate" models.

5-1 Basic Concepts

The technical features of Village Hydro developed in the JICA study are as follows:

① Standardized design based on domestic technologies
② Using domestically available equipment and materials
③ Enabling its operation and maintenance by local people
④ Lightweight components to be hand-carried

The standardization effort is the key to lowering costs and improving the quality of equipment. Spare parts supply and repair service will become easier and less expensive. Based on these standardized models, PPC engineers will be able to draw up off-grid plans on their own without relying on experienced consultants. Also, the standardized design facilitates subsequent replication of similar power systems at other sites. In addition, using domestic technology is important. This ensures that suitable repair and replacement skills are accessible to the users of the plant.

A Village Hydro serves a relatively small area, because extending the distribution lines beyond the limit—usually less than two kilometers—is very expensive. The villagers living outside of the service area are expected to use batteries. Battery charging equipment is readily available in the market. They are expected to come to use the battery chargers installed at the powerhouse regularly. This is a practical idea to increase the number of electrified households with a small additional investment. Revenues from battery charging cannot be ignored. At the planning stage, therefore, it is necessary to estimate the demand for battery charging as well.

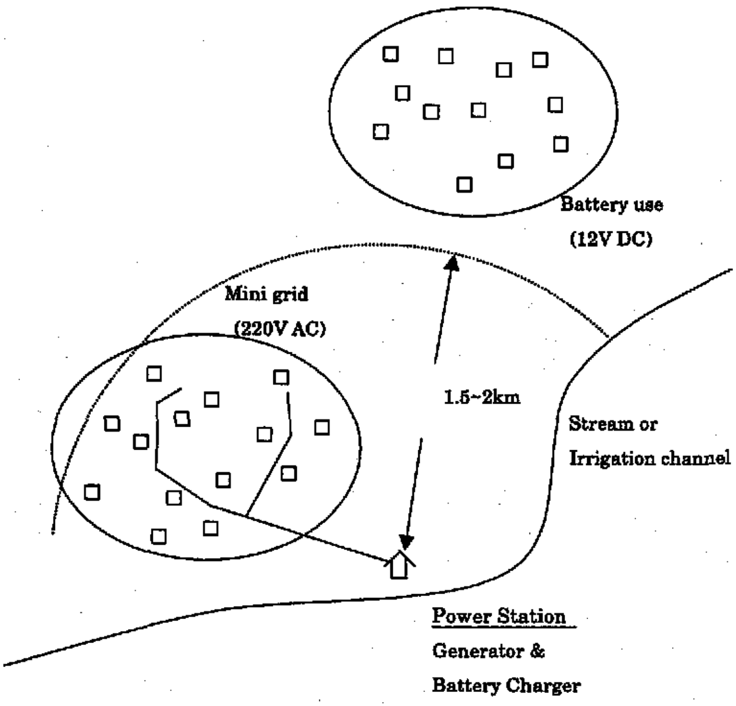


Figure 5-1-1 Concept drawing of rural electrification by Village Hydro

5-2 Technology

5-2-1 Generation system

(1) Village Hydro -1 (Run-of–river type)

This is a typical run-of-river type design, which comprises a weir, intake, channel, head tank, penstock, turbine and generator, and powerhouse. (See Figure 5-2-1) Even in remote communes, it is not so difficult to find an existing irrigation channel that can be renovated to incorporate a Village Hydro. We proposed standard packages of turbine and generator that would be selected based on the data of discharge and water head at the site. This effort will encourage inexperienced developers and villagers who are willing to implement off-grid projects, because they can skip the complicated technical design of turbines and generators. They only need to place an order for a suitable package. Building a penstock is another potential problem. We recommend to use PVC pipes instead of steel pipes. PVC pipes are lightweight, inexpensive and strong enough.

One of the key features in Village Hydro is the use of induction motors as generators by connecting a set of appropriate capacitors, which is not widely known in Vietnam. This technology, contributing to cost reduction, is now proven and has become an important element in village-scale micro-hydro in developing countries.

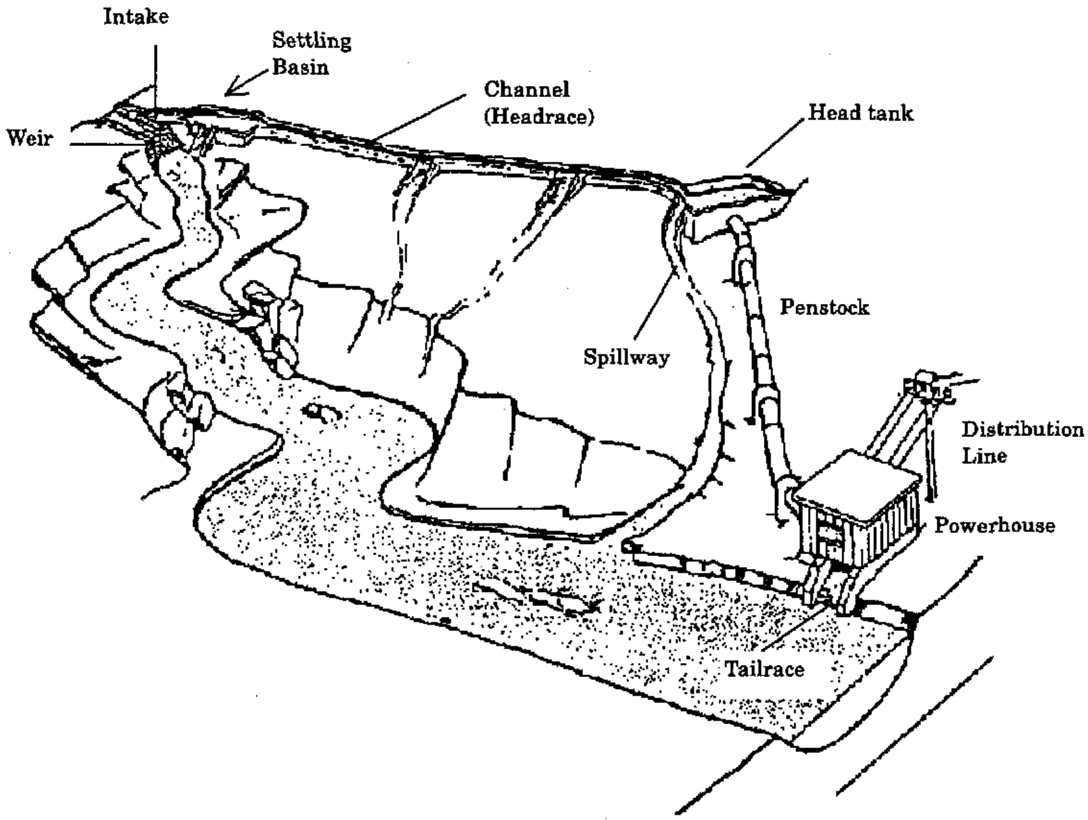
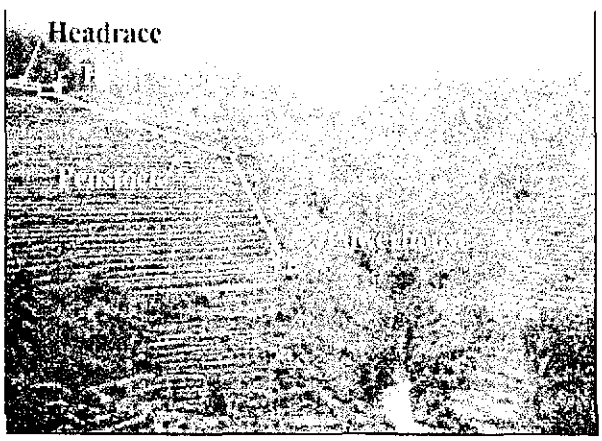


Figure 5-2-1 Run-of-river micro-hydro



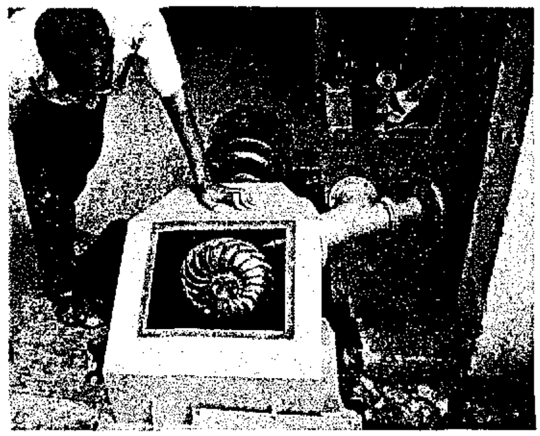


Figure 5-2-2 Site plan

Figure 5-2-3 Packaged turbine and generator

1) Specifications

Table 5-2-1 Basic specifications of Village Hydro-1

Item	Specifications	Remarks
1.Basic factors		
(1)System	Run-of-river type	
(2)Output	Up to 20kW	Village-scale
(3)Water head	Maximum 50m	Maximum head is determined by tolerable internal pressure of PVC pipe.
(4)Water volume	Maximum 0.20 m^3/s	Maximum water volume is determined by maximum available diameter of PVC pipe.
(5)Supply area	Maximum 2 km radius	Length of distribution line is determined by tolerable voltage drop
2.Civil Work		
(1)Weir	Stone masonry concrete	Combined with irrigation system
(2)Intake	Stone masonry concrete	Combined with irrigation system
(3)Settling basin	Reinforced concrete	Can be omitted when silt in water is little
(4)Headrace	Excavation	Combined with irrigation system
(5)Head tank	Reinforced concrete	Combined with irrigation system
(6)Penstock	PVC pipe	Lightweight, low cost and maintenance-free
(7)Powerhouse	Brick	Conventional method
(8)Tailrace	Excavation	
3.Electrical facilities		
(1)Water turbine	One-box type	Pelton, Turgo, Propeller or Cross-flow
(2)Generator		Induction motor with capacitor excitation
(3)Voltage controller		Electronic controller with dummy-load
4.Distribution facilities		
(1)Voltage	220 V	
(2)Connection	Single Phase	
(3)Supply voltage	220V – 198V	
(4)Frequency	50Hz± 5%	

It is assumed that an existing irrigation channel is renovated to incorporate a Village Hydro. All the materials mentioned above are available in Vietnam. In principle, necessary goods including PVC pipes and distribution cables should be procured at the regional center. However, the turbine, generator and voltage controller, which require technical expertise and know-how, are to be manufactured and tested at experienced factories and sent to the site. Civil work will be done by using local labor under the supervision of a contractor.

(2) Village Hydro-2 (Pico-plus generator)

Pico-plus generator is designed for low-head sites to generate an output of up to 2kW. To offset the low water head, a Pico-plus requires a relatively large volume of water flow that is often difficult to secure in the dry season. It uses the same technology as a

100W class propeller turbine and generator (pico-hydro generator) that is available in the local market. A common form of pico-plus generator is the permanent magnet type, although a small induction motor can be used as a generator as well. It needs special structures to guide the water to the turbine (i.e. flume), but the penstock and valves are eliminated.

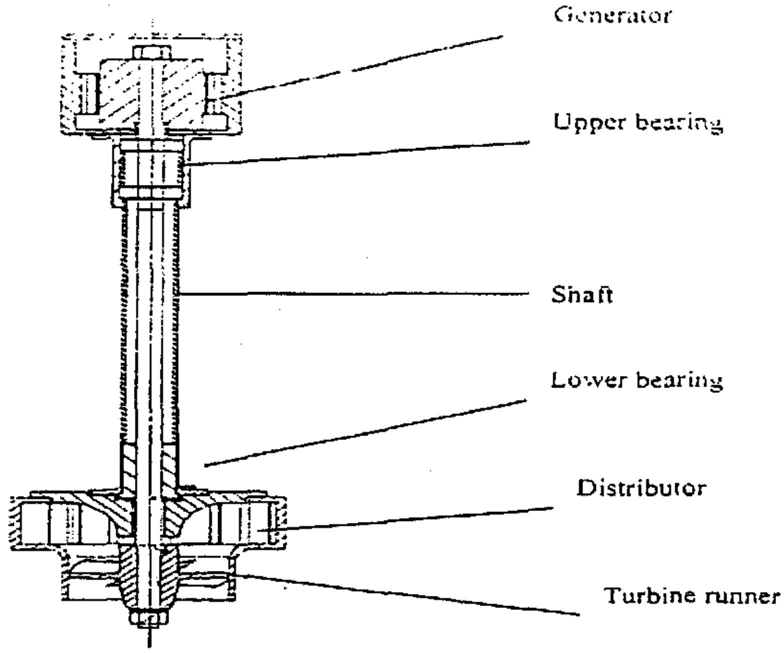


Figure 5-2-4 Pico-plus generator unit

1) Installation

The components of a pico-plus system are easy to transport and install, since the total weight ranges from 20 kg to 80 kg. The civil works for a pico-plus unit are usually designed to allow operation for most of the year, even in the months of high river flow. This is in contrast to pico-hydro units which often are removed from the river during the months of high flow. The pico-plus propeller system requires a small headrace and a draft-tube to ensure enough head (usually between 1.0 and 2.5m).

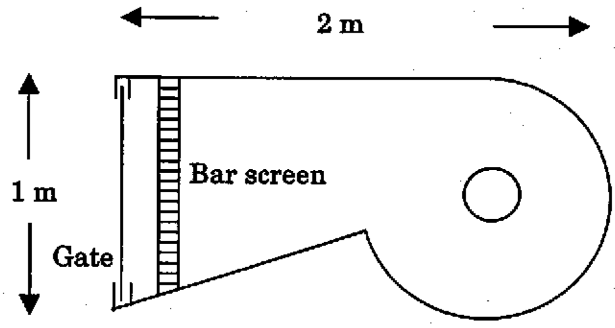


Figure 5-2-5 Basic design of a flume

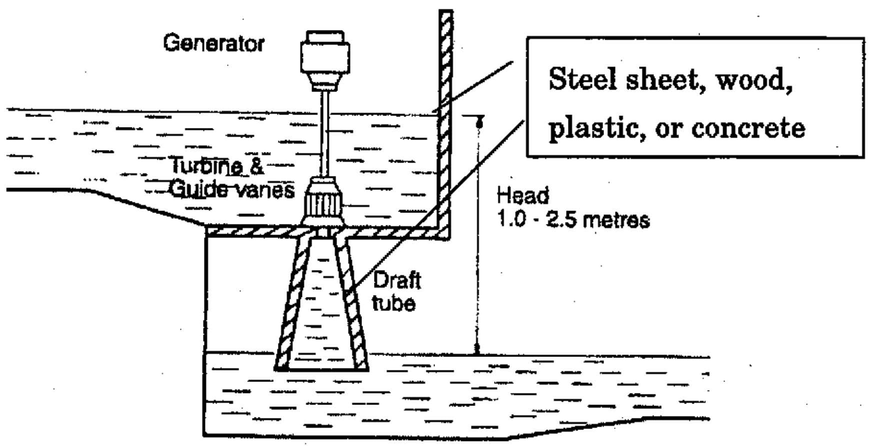


Figure 5-2-6 Installation method of Pico-plus generator

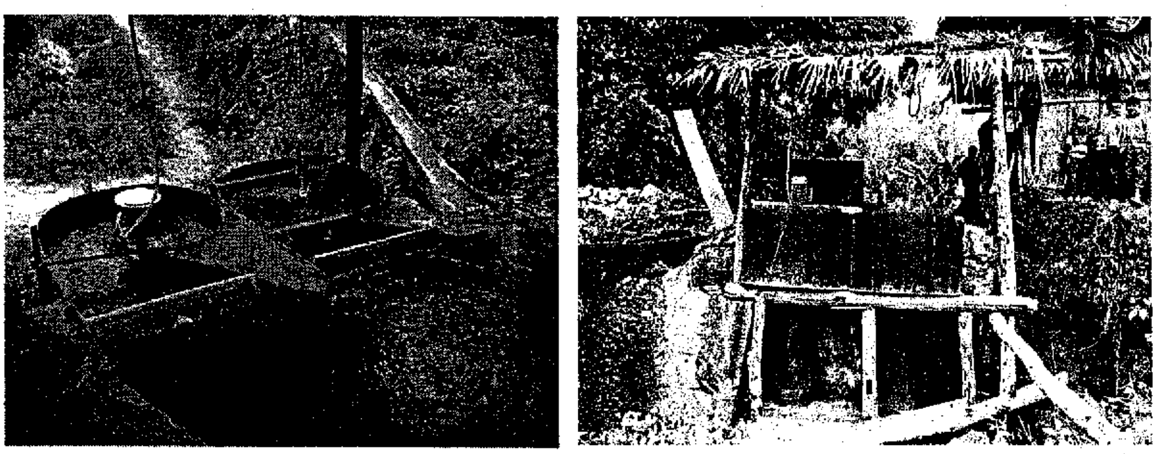
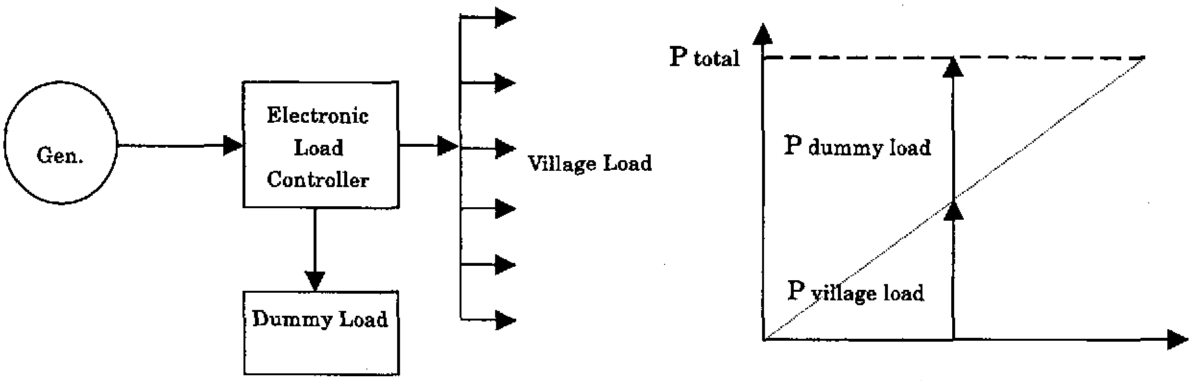


Figure 5-2-7 Testing two units of Pico-plus (1kW each)

5-2-2 Control system

In both models the generation systems are equipped with an electronic voltage controller to stabilize the voltage at 220V. The generated voltage is controlled by maintaining a near constant load on the turbine, as illustrated below. The controller compensates for variations in the village load by automatically changing the amount of power dissipated in a resistive load (dummy load), in order to keep the total load constant. This improves the safety and operability of installed power systems. A prototype of the voltage controller has been engineered and is now being tested at a workshop in Hanoi.



(1) Outline (2) Power Allocation

Figure 5-2-8 Principle of dummy load controller

5-2-3 Protection

All electrical equipment in the powerhouse should be connected to an earth point. And the earth point is connected to an earth rod, which can be purchased in the local market. There are two types of safety switches installed in the powerhouse: one is an earth leakage circuit breaker (ELCB) and the other is a miniature circuit breaker (MCB). The ELCB protects people from electric shock, and it protects the whole installation from some wiring and connection faults. The MCB also protects the circuits from damage, and people from shocks. It disconnects the generator if the current drawn by the circuit exceeds the rating of the MCB. This could be due to overload, or a short circuit caused by mishandling or a defective wire. The MCB is manually switched off when the line downstream of the controller needs to be serviced.

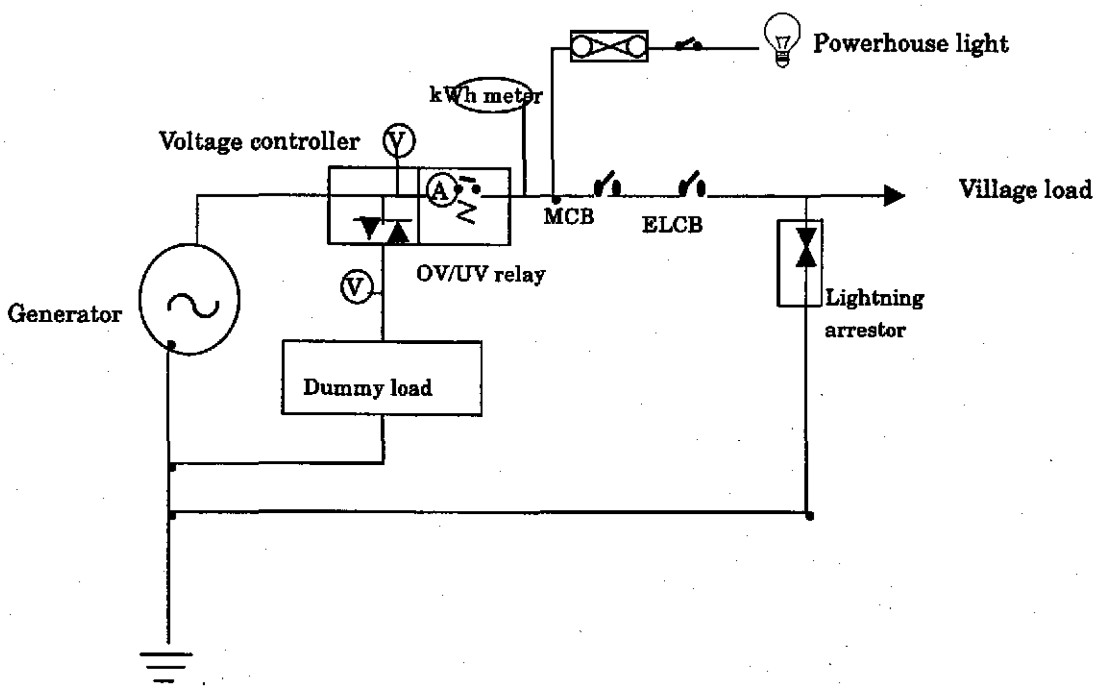


Figure 5-2-9 System Diagram of Village Hydro

5-2-4 Distribution system

Since houses are dispersed in remote areas, the distribution system accounts for a significant part of the capital investment. The voltage level of the Village Hydro distribution system is 220V, because the high-voltage distribution system that was often used in the past cannot be justified from the viewpoints of economy and maintenance. The total service area of a distribution system is determined by the voltage available at the end of distribution line. By using larger-size cables, it is possible to expand the service area, however the system cost will rise. One practical idea is to generate at a higher voltage (maximum 250V). Under normal conditions, when the system is loaded, voltages at end-users will drop to 220V. This will save on distribution line cost.

5-3 Cost estimation

Table 5-3-1 shows a cost estimation of a typical 5kW run-of-river Village Hydro.

Table 5-3-1 Cost estimation of village hydro-1 (5kW class)

	Village Hydro Model Plan	Notes
1 . General Information		Use an existing irrigation channel
(1)Output Capacity	5kW	
(2)Gross Head	20m	
(3)Design Water Flow	0.05m3/s	
2 . Electricity Demand		
(1)Households	100 Households	
(2)Design Unit Demand	50W/HH	
(3)Length of Distribution Line	0.8km	
3 . Project Cost	Cost (US$)	
(1)Generation	6,036	
a. Civil Works	3,151	Channel renovation PVC pipe for penstock
b. Electro-Mechanical	2,885	One-box generation unit Battery charging
(2)Distribution	3,987	220V
Total Cost	10,023	
Profit Margin	551	5.5% of Total Cost
VAT	528	5.0%
Total Project Cost	**11,102**	

Note: See Appendix for more details.

Table 5-3-2 shows a cost estimation of a typical 1kW—two units of 500W—pico-plus system. This will be able to serve about 20 households. Thus, the development cost will be around $1,800 per kW or $90 per household, which is very attractive compared with conventional micro-hydro development ideas.

Table 5-3-2 Cost estimation of Village Hydro-2 (1kW Pico-plus)

Item	$	Unit	$ total	Remark
Civil work	150		150	Intake and Powerhouse
Generator unit	250	2	500	Including controller
Flume Draft tube	150	2	300	Steel or FRP Including transportation and installation
Distribution line	0.35/m	1,600m	560	
Sundry items			100	
Total Cost			**1,610**	
Profit margin			**89**	5.5% of total cost
VAT			**85**	5%
Total Project Cost			**1,784**	

5-4 Expansion of Village Hydro

Village Hydro should be designed to be able to incorporate its expansion afterwards to meet demand increase. If more water is available at an existing Village Hydro and another penstock and turbine/generator unit can be added, the power output can be easily increased. Since the Village Hydro design is standardized, it is relatively easy to replicate it at other sites. Modifying existing civil works such as the intake, silt basin, headrace, and head tank might be necessary to cope with the increased water volume. These facilities can be originally built with an adequate margin if future expansion is foreseen adding only a fraction of the capital cost.

5-5 Operation and Maintenance

5-5-1 Daily operation

As a daily routine, when the turbine is stopped, the operator in the village should check the water way: that is, the intake, channel, spillway, trash racks, penstock (or flume), turbine and the exit area. These areas should be cleaned and freed of debris. All sand, stones, vegetation, etc, that may have collected must be removed. He should also inspect the electrical items to check that no external damage has happened since the last operation or while the machine was stopped.

If the operator is satisfied that the above is in good order, he can open the valve or gate to let the water enter the turbine. As water enters the turbine it will begin to rotate and as more water fills the entry area, the turbine will speed up and generate volts. When there is sufficient speed the voltage will reach the preset value of 220 volts and the power generated by the turbine will be diverted into the dummy load. After allowing the turbine to run for a few minutes to stabilize the water flow, it is now possible to connect the village load on to the generator. Once this is done it is possible to keep the turbine running without an attendant for a long period of time (overnight). To stop the turbine it is necessary to switch off all the village loads, and then stop the water to the turbine, finally stopping the water flowing into the channel.

During rainy days it may be necessary to visit the powerhouse every 3 hours or so to clean the trash rack if this is likely to get blocked.

5-5-2 Regular maintenance

Daily checking and preventive maintenance by the CEU will be the main part of Village Hydro management. Also, the Village Hydro installation requires regular maintenance to be carried out on a weekly or monthly basis. Serviced or repaired items should be recorded on the power station control ledger for future reference.

(1) Water way

Blockage of the water way or leakage in the water way should be carefully checked regularly. If the water flow is blocked because silt is deposited, or vegetation has grown, remove the deposits or cut back the vegetation.

After heavy rain, a special inspection should be carried out. If any damage is found in the water way, repair it with conventional technologies.

(2) Electro-mechanical equipment

Regularly check wiring and connections, and tighten loose connections. There are three major mechanical checkpoints on electric equipment as follows.

① Irregular values in indicators
② Temperature increase
③ Unusual vibration or noise

If any irregularities are found, check the electro-mechanical equipment carefully. Try cleaning or lubrication. When the problems still persist, call local technicians. When the turbine or controller is found broken, call the manufacturer for repair. In case of trouble with the induction generator, which is a standard motor, local technicians may know how to repair it.

The turbine, which often gets worn quickly, is recommended to go through periodical servicing. Bearings should be replaced every five years and a complete overhaul should be done every ten years. The generator and controller have a long life and require parts replacement only when they are found out of order.

(3) Distribution lines

The overhead line should be clear of other trees and branches. If the line is sagging low, re-suspend it so that it does not create a nuisance for people and animals. Walk along the length of the distribution wires, inspecting each connection carefully. Re-make securely any suspect connections, and make sure that all parts are carefully insulated (and that it is not easy to take electricity from the wires without permission).

5-6 Training

For the sustainable promotion of Village Hydro, appropriate training targeting the villagers is extremely important to ensure proper operation and maintenance. However, there is neither a well-developed training program nor instructors who give training to the villagers. As a first step, a "trainer training" targeting DOI engineers of PPC should be conducted to develop necessary human resources. Then, a series of intensive training sessions will be provided to CEU members under the initiative of the DOI.

5-6-1 Trainer training

To facilitate rural electrification by local initiatives, it is necessary to foster skilled trainers who can provide good training to the villagers. They will play a major role in disseminating technologies necessary for the operation and maintenance of Village Hydro. DOI engineers are main candidates to become trainers. On the subjects stated below, a one-week long intensive training should be incorporated in the early phase of Village Hydro development.

① Planning on rural electrification
② Off-grid system designing
③ Financial management
④ Organizational development
⑤ Procurement and construction
⑥ Operation and maintenance of Village Hydro

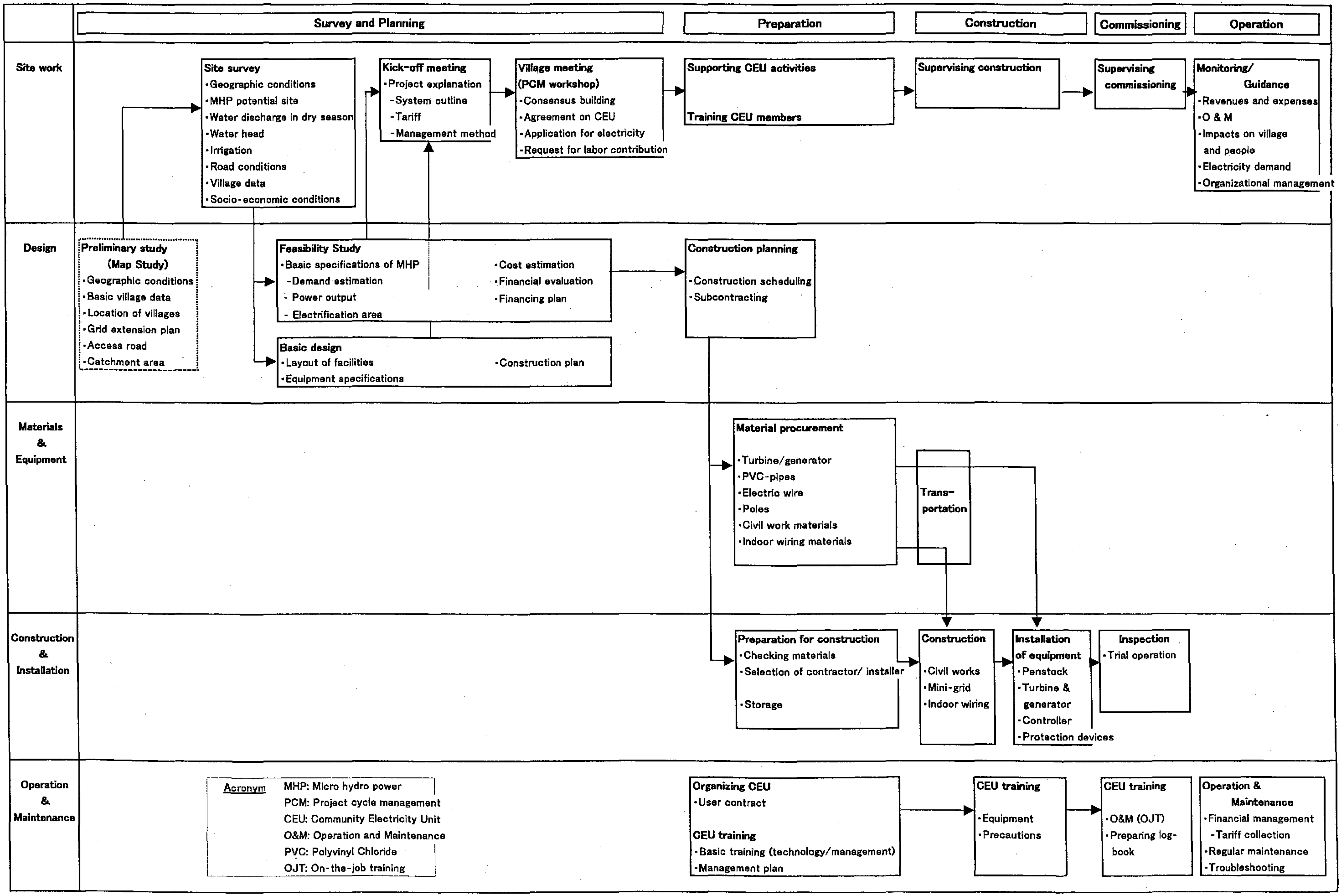
5-6-2 CEU training

Educating and training the local operators are indispensable to ensure the smooth operation and maintenance of Village Hydro. A series of hands-on training sessions will be given to the CEU core members, who will be responsible for operating and managing the installed power system, in three phases: preparation, construction and commissioning. Items for the training will include basics of power generation, operation technique of Village Hydro, precautions, troubleshooting, regular maintenance and repair. Administrative work such as accounting, record keeping, etc. will be also included in the training.

5-6-3 Refresh training

In at least two years after the completion of Village Hydro, a series of technical training courses will be necessary to refresh the memories of CEU members and improve their skills on the operation and management of Village Hydro. This training will be ideally offered one month and three months after the commissioning, and every six months afterwards.

Basic Work Flow of Off-grid Rural Electrification by Village Hydro



Chapter 6

Village Solar-Rural Electrification by Photovoltaic System

6-1 Basic Concepts

Photovoltaic (PV) cells convert sunlight directly into electricity. PV is measured in units of "Peak Watts (Wp)". A peak watt figure refers to the power output of the solar module under "Peak Sunshine" conditions. Electro chemical storage batteries are used to store the electricity converted by the PV module. The batteries are charged by the electricity from the solar modules during the day. During the evening, the batteries are discharged to power lights and other appliances. The batteries are sized to provide several days of electricity. For rural electrification, inexpensive automotive batteries are recommended. The basic concepts of PV systems recommended for northern Vietnam are as follows.

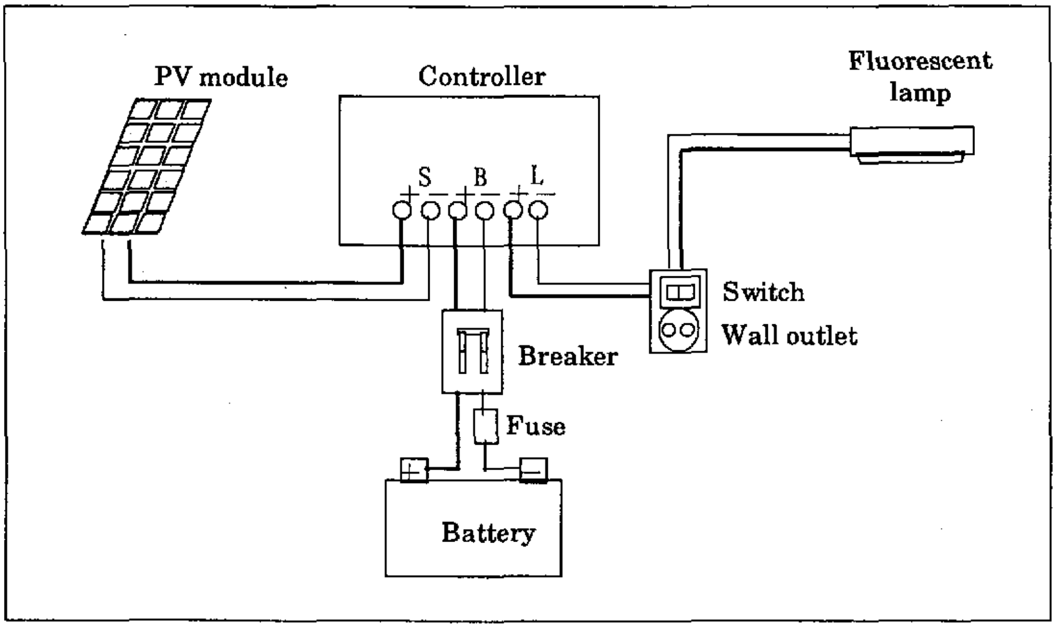


Figure 6-1-1 Basic Photovoltaic System

1. Dispersed small system

PV system components are still relatively expensive and also the users need to replace their batteries every two to three years, which hinders the dissemination of PV system application in rural areas of developing countries. As the income level of un-electrified communes in northern Vietnam is low, the number of households that can afford automotive batteries, which cost around $20 per unit, will be limited. Therefore, the initial PV system to be developed at an un-electrified commune for off-grid electrification would be a small-scale and low-cost system to meet the demand of limited potential users. To achieve this goal and to facilitate future expansion, we propose a modular design approach to develop dispersed small systems rather than a centralized system.

2. Easy implementation by standardizing the design and technical specifications

Unlike hydropower systems that require a substantial volume of civil work, PV systems can be constructed easily without worrying about geographical conditions. It is, therefore, strongly recommended to develop a standardized modular design suitable for rural electrification. The standardization effort will lead project implementers to successful solar-based rural electrification.

3. Low operation and maintenance costs by using reliable components

Except for the batteries, PV systems are basically designed to require minimal maintenance. Components used in PV systems are small and lightweight electronics devices that have no mechanical parts. If good-quality and reliable components are used, system failures seldom occur, which is the key to low-cost operation of PV systems for a long time.

6-2 Technology

Basically there are two types of small-scale PV systems used for rural electrification: Solar Home System (SHS) and Battery Charging System (BCS). An SHS, which can operate a few lights, a black-and-white TV, radio, etc., is a 12V DC stand-alone system to be installed at each household. On the other hand, a BCS is a larger-size battery charging system that is used by multiple users. Each BCS user is supposed to carry his battery to the BCS approximately once a week for charging after the battery is discharged. Appropriate size BCS can be less expensive than SHS because the PV system is shared among the users. Hence, BCS is advantageous with respect to project cost and regarded as suitable for low-income areas. Potential problems with BCS are limited electricity due to infrequent battery charging and the need to transport the batteries.

6-2-1 Communal system – Village Solar

In this study, considering the difficult economic conditions of the target areas, and the strong needs of villagers for electricity supply, a combined PV system having both BCS and SHS for village-level electrification is proposed. This system may be called "Village Solar", because it will serve public buildings (by SHS) as well as individual users (by BCS).

- Electricity use at public facilities

  Electricity for community lighting at public facilities such as UBND, clinics and schools is supplied by an SHS installed individually. The whole commune will benefit from the electricity supplied by these SHSs.

- Electricity use at individual households

  Villagers who can afford batteries and appliances will benefit from the BCS. They come to charge their batteries every week. Revenues from BCS users will cover the O&M costs and capital repayment of Village Solar.

Figure 6-2-1 shows the system configuration of a typical Village Solar communal system. The BCS is recommended to install near the village center and housed where space is available.

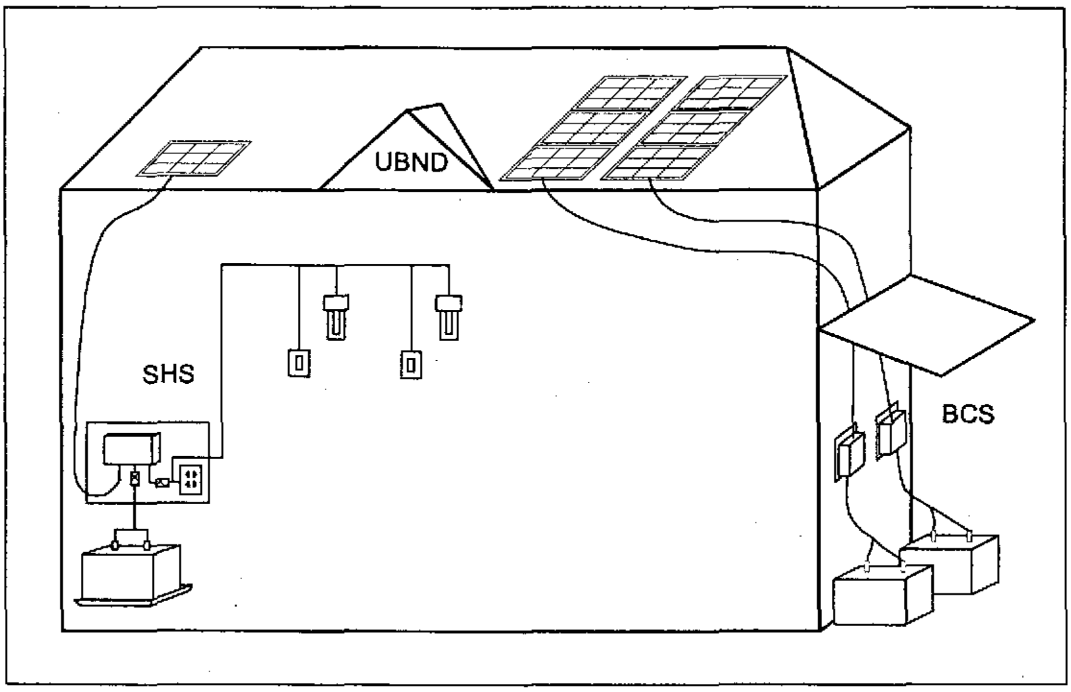


Figure 6-2-1 A typical communal system; Village Solar

The standard specifications of an SHS in a Village Solar system that has four fluorescent lamps are as follows.

Table 6-2-1 Specifications of a SHS of communal system

Items	Unit	Technical specifications	
PV module	1	Nominal power: Type: Number of cells: Expected life:	50Wp Monocrystalline silicon or poly crystalline silicon (Amorphous silicon- not recommended) 36 +20 years
Frame and mount structure	1	Type: Frame: Tilt angle :	Rooftop mount or pole mount Metal frame to attach module to a roof or pole 20 to 25 degrees
Battery	1	Capacity : Quality : Expected life :	50Ah Lead-acid automotive battery 2 to 3 years
Battery box or tray (protection of floor)	1	Material :	Durable material such as polypropylene
Charge controller	1	Capacity : Functions : Indicator : Warranty period :	minimum 6A Over-discharge/charge protection, reverse polarity protection, equalization, PWM control Charging status, low voltage 1 year
Control board	1	Terminals, power outlet, Poly Switch(3A)	
Compact fluorescent light	4	Type : Power : Tube : Protection : Warranty period :	DC 12V 5W to 7W (0.4Ah to 0.6Ah) U-shape or straight line tube Reverse polarity, broken or missing tube 1 year
Switch for light	4		
Sundry items		Cables ($2.5mm^2$, $4mm^2$, $6mm^2$), terminals, clips, nails, sealant, etc.	

A charge controller is used to control the flow of electricity between the module, battery and the loads. It prevents battery damage by ensuring that the battery is operating within its normal charge level. If the charge level falls below a certain level, a " low voltage disconnect" will cut the current to the loads to prevent further discharge. Likewise, it will also cut the current from the module in case of overcharging.

The standard specifications of one unit of BCS with a capacity of 150W are as follows.

Table 6-2-2 Technical specifications of a BCS of communal system

Items	QTY	Technical specifications	
PV module	3	Nominal power : Type : Number of cells : Expected life:	50Wp Monocrystalline silicon or poly crystalline silicon (Amorphous- not recommended) 36 cells +20 years
Blocking diode	3	Capacity :	10A
Frame and mount structure	1	Type : Frame: Tilt angle : Size :	Rooftop mount or support structure on the ground Metal frame 20 to 25 degrees three PV panels/set
Control box	1	Ammeter : Voltmeter : Switch : Clips :	DC15A DC30V two pole, knife-edge type for battery terminals
Sundry items	1set	Cables (4mm², 6mm²), nails, screw nails, etc.	

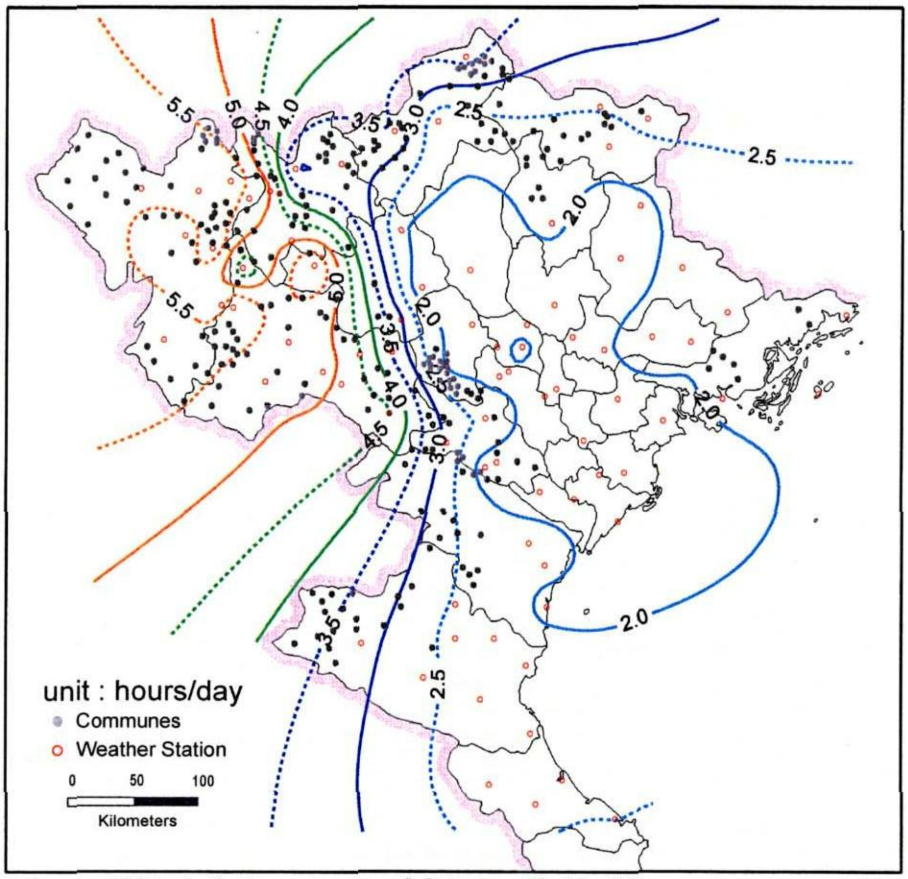
Options

Charge Controller	1	Capacity : Functions : Indicator : Warranty period :	Minimum 20A (more than breaker capacity) Over charge protection, PWM control Charging status One year
Breaker	1	Capacity	15A

6-2-2 Review of solar energy potential

(1) Required insolation

The most critical point in planning solar-based rural electrification in northern Vietnam is the long-lasting cloudy weather during the dry season, from January to March. Our standard design of Village Solar is based on the average daily sunshine hours of five or more even in the dry season. If the candidate commune is expected to have less sunshine hours (See Figure 6-2-2), it is necessary to measure actual insolation at site to determine the appropriate size of the solar module and review the financial assessment.



Source: JICA study team processed data provided by IE

Figure 6-2-2 Average sunshine hours from January to March (h/day)

(2) Available power from an SHS

Available electric power of an SHS is shown in the following table. It becomes less during the dry season from December to March, because there is high possibility of having continuous days of no sunshine. The users must be aware that electricity consumption per day will be limited during this period.

Table 6-2-3 Available power from an SHS

Period	December – March		April - November	
Sunshine hours	5	Cloudy day	5	Cloudy day
Insolation (kW/m²/day)	3.5	0.35	4.5	0.35
Available power	9.7Ah	1Ah	12.5Ah	6.2Ah *
Typical lighting	5W×4 4.5h	5W×1 2h	5W×4 6h	5W×4 3h

* : As charge recovery is fast during April to November, half of standard power can be used on a cloudy day

(3) Available power from a BCS

The critical point in designing a BCS is whether a low battery can be recharged full in one day. It is assumed that the charging schedule of each user is fixed. When the assigned charging day is cloudy, the batteries would not be fully charged. If so, the available power will be limited until the next charging day. In the dry season, this will often happen, so it is important to reduce electricity consumption during the period from December to March.

Table 6-2-4 Available power from a 150Wp BCS

Battery capacity	50Ah		20Ah	
Number of users per system	5		10	
Sunshine Hours (h/day)	5	Cloudy day	5	Cloudy day
Insolation (kW/m²/day)	3.5	0.35	3.5	0.35
Charge interval (Charged power)	7 days (25Ah)	7 days (2.5Ah)	7 days (10Ah)	7days (2.5Ah)
Available power	3.6Ah	0.4Ah	1.4Ah	0.4Ah
Typical power use	5Wlamp×2 3h cassette player 2h	5W×1 1h	5Wlamp×1 2h cassette player 1.5h	5W×1 1h

6-3 Cost Estimation

The project cost of Village Solar consists of the following items:

① Equipment cost -- Equipment and wiring materials
② Installation cost -- Transport of equipment and installation
③ Training cost -- Training cost of local electricians and users

Since there is no civil work, the project cost without transportation is almost constant regardless of site location.

Table 6-3-1 Total cost of Village Solar- model plan

No.	Items	QTY	Unit Cost (US$)	Cost (US$)
1	50Wp SHS	5 Systems	348.1	1,740.5
2	150Wp BCS	4 Systems	722.9	2,891.6
3	Installation cost	1 Set	435.0	435.0
Total				5,067.1

Table 6-3-2 Breakdown of SHS costs

No.	Items	QTY	Unit Cost (US$)	Cost (US$)
1	PV module 50Wp	1 Unit	200.0	200.0
2	Frame and mount	1 Unit	23.4	23.4
3	Battery 50Ah	1 pc.	23.4	23.4
4	Plastic tray	1 pc.	1.3	1.3
5	Charge controller (minimum 6A)	1 Unit	35.0	35.0
6	Control board with poly switch, socket	1 Unit	12.0	12.0
7	Compact fluorescent light	4 Units	7.0	28.0
8	Switch for light	4 Pcs.	0.5	2.0
9	Sundry (cables, etc.)	1 Set	23.0	23.0
Total per system				348.1

Table 6-3-3 Breakdown of BCS costs

No.	Items	QTY	Unit Cost (US$)	Cost (US$)
1	PV module 50Wp	3 units	200.0	600.0
2	Blocking diode 10A	3 Pcs.	0.2	0.6
3	Frame and structure	1 unit	46.6	46.6
4	Control box with ammeter, voltmeter	1 Box	44.7	44.7
5	Sundry (cables, etc.)	1 Set	31.0	31.0
Total per system				722.9

Options

6	Charge controller (minimum 20A)	1 unit	142.0	142.0
7	Breaker (DC 15A)	1 unit	16.0	16.0

Table 6-3-4 Estimated installation cost

No.	Items	QTY	Unit Cost (US$)	Cost (US$)
1	Transportation of equipment	1 Set	120	120.0
2	Installation fee (SHS : 5 systems, BCS : 4 systems)	9 systems	35	315.0
Total				435.0

This model is designed to have four units of 150Wp BCS. Assuming that only 50Ah batteries are used, this Village Solar battery charging unit will be able to serve about 20 users. When more people apply for battery charging, more units will be added. This step- by-step approach is exactly the same as Village Hydro.

6-4 Operation and Maintenance

6-4-1 Operation of SHS and BCS

Daily operation of SHS is simple, requiring only that the cables be connected properly and short circuits be avoided. When operating a BCS, an operator is necessary because dealing with users requires a lot of work, such as receiving discharged batteries in the morning, checking the state of charging, returning the batteries and collecting bills. The operator needs to check the condition of solar panels and the connection of cables regularly for stable operation.

6-4-2 Maintenance of SHS and BCS

The most important issue in PV system maintenance is to keep the electrolyte level of batteries within the suggested range by regularly adding distilled water. This is a widely acknowledged practice in remote areas so that the CEU members, who are responsible for the maintenance of SHS at public buildings, will follow the instructions without difficulty. This point should be reiterated at many occasions to make other individual battery users also maintain their batteries properly.

It is recommended that the CEU ask local electrical technicians to check wiring and connections in the first three months after installation. The local technicians should have the capability to do the following:

① Service installed PV components
② Check the state of batteries
③ Conduct basic repair (replacement of fault components)

Sometimes, as a result of regular checking, the technicians will be asked to replace fuses, fluorescent tubes, ballasts, charge controllers and other parts. They will be paid, of course, in such cases.

6-5 Training

Like micro-hydro systems, appropriate training targeting the villagers is extremely important to ensure proper operation and maintenance of Village Solar system. Fortunately, a PV system is simple and easy to maintain. The intensity of required training would be much less than Village Hydro, which is an advantage of Village Solar. The system installers and the DOI are supposed to provide a series of training sessions to the CEU members.

6-5-1 Trainer training

At the early stage of PV system development for rural electrification, it is important to give training to the DOI engineers who are expected to provide good training to villagers every time a new PV system is constructed. They will play a major role in disseminating technologies necessary for the operation and maintenance of Village Solar. Just like the training on Village Hydro, a one-week long intensive training should be conducted on the following topics:

① Planning on rural electrification
② Off-grid system designing
③ Financial management
④ Organizational development
⑤ Procurement and construction
⑥ Operation and maintenance of Village Solar

6-5-2 CEU training and role of local technician

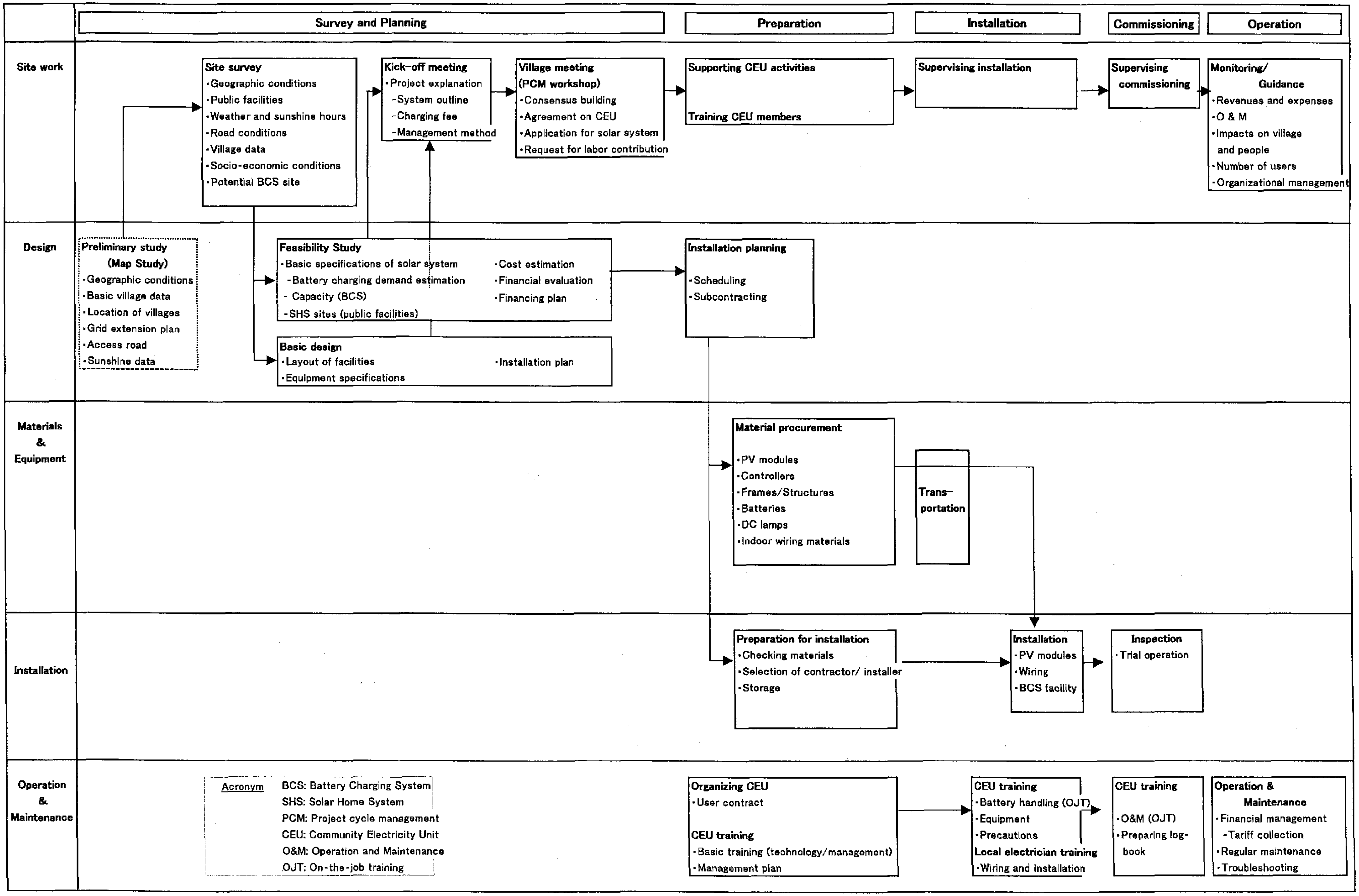
Since many rural villagers have used batteries as a means of electricity supply, they are familiar with 12V DC electricity from batteries. However, it may be questionable whether they really understand correctly how to handle their batteries. It is important to instruct them how to maintain their batteries properly in order to achieve the long-term sustainability of Village Solar. In this regard, training programs for the CEU members and users should focus on batteries. Financial management of PV systems is another important topic.

A series of hands-on training sessions will be given to the CEU members and users in three phases: preparation, construction and commissioning. Items for the training will include basics of PV system, operation technique of Village Solar, precautions, trouble-shooting, regular maintenance and repair. Administrative work such as accounting, record keeping, etc. will be also included in the training.

In addition, training of local electricians, who are supposed to play an important role in the maintenance of Village Solar, would be quite effective to secure good services from them. If they get skills to deal with problems that cannot be resolved by the CEU members, the installed PV system will be able to run constantly even in remote areas. It is, therefore, recommended to ask their participation in the training primarily given to the villagers. Items necessary for their training are as follows:

① Characteristics of rechargeable battery
② Functions of charge controller
③ Measures against over-charge and over-discharge
④ Basics of DC lights and appliances
⑤ Maintenance of PV systems and batteries
⑥ Sizing of PV module

Basic Work Flow of Off-grid Rural Electrification by Village Solar



Chapter 7

Other Models of Off-grid Rural Electrification

7-1 Wind Power

Wind power generators for battery charging are primarily designed to be used in combination with PV systems in the high latitude region where people have high winds but not much sunshine in the winter. Power (P) in the wind is a function of air density (ρ), the area intercepting the wind (A), and wind velocity(V). Power (P) can be calculated by the following formula.

$$P= 1/2 \rho AV^3$$

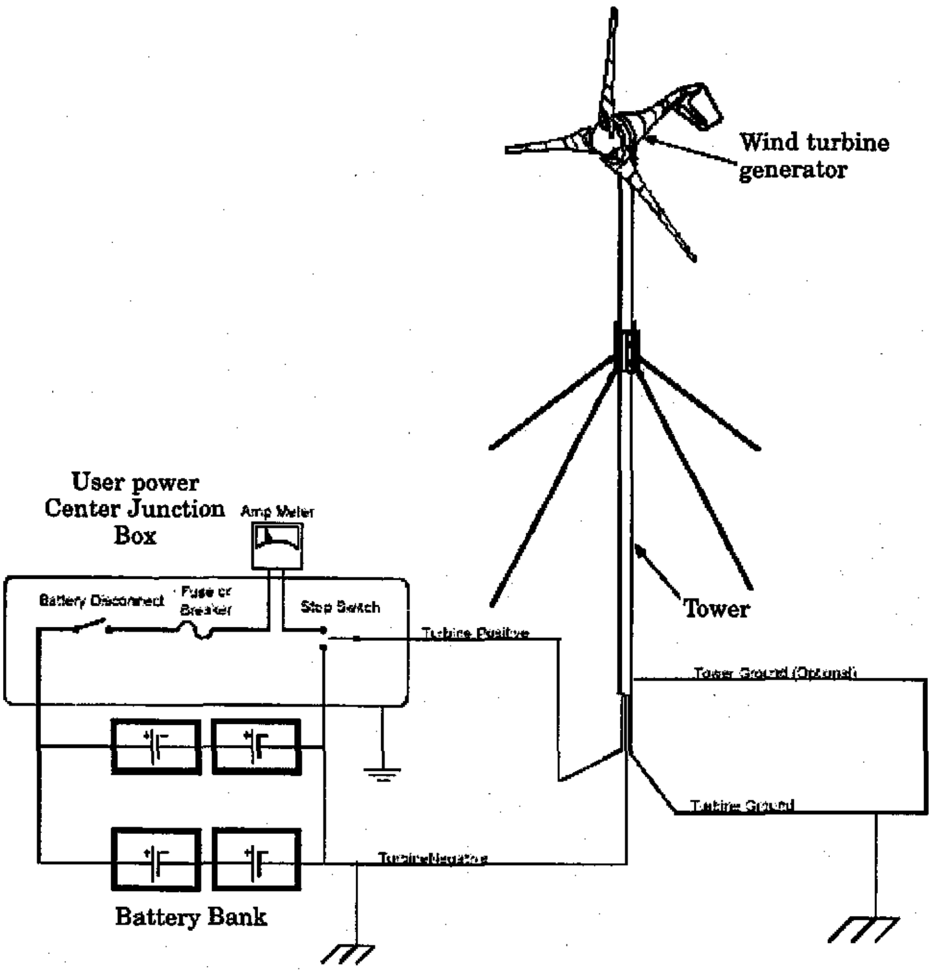
Thus, wind power is a cube function of wind speed, which suggests that small changes in wind speed have a significant effect on the power in the wind. Doubling the speed of the wind increases the power by eight times. To look for windier sites is always a must when planning wind power projects. To get more power the height of turbine is also important, because obstructions near the ground disrupt the flow of the wind. Wind speeds typically increase with height.

7-1-1 Technology

(1) System configuration

A typical small wind generator is equipped with a rotor and alternator with permanent magnets. A wind power system for battery charging includes a rectifier to convert AC to DC and an electronic charge controller to ensure proper charging. The charge controller regulates the amount of electricity that gets stored in the battery and goes to the appliances. Thus, wind power application for off-grid use is very similar to that of a PV system. For the safety of wind turbines, the rotor can be stalled when the wind velocity reaches the safety limit by twisting the rotor blades or swinging the rotor toward the tail vane.

As mentioned earlier, small wind turbines are supposed to be installed on high towers. Recommended height is more than eight meters. Some manufacturers offer low-cost, lightweight tower systems suitable for small wind turbines.



Source: Southwest Wind power company

Figure 7-1-1 Configuration of wind power system (400W class)

(2) Wind power estimation

Small wind turbines start operation at a wind speed of 3 m/s, and usually reach the rated power (kW) at around 12 m/s. As mentioned earlier, the wind energy is a cube function of wind speed so that the power increases significantly when the speed goes up. Therefore, when the wind speed is 5 m/s, only seven percent of the rated power is produced. It is difficult to estimate annual power output because we need to know the distribution of wind speeds. In theory, by matching the distribution of wind speeds and the power curve of the wind turbine provided by its manufacturer, we can estimate the annual power output.

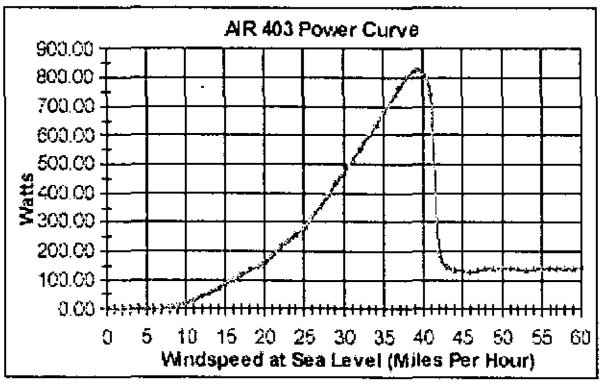
(3) Compatible wind system

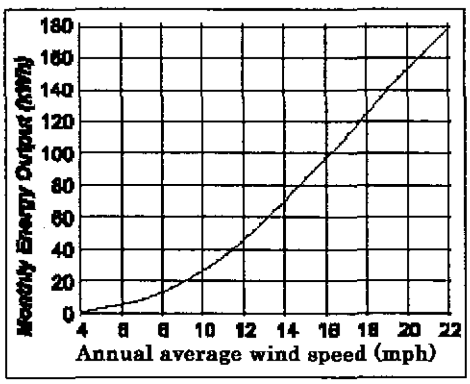
An advantage of a wind system is that it can generate power even in the nighttime.

However, wind power is usually not so constant as sunshine. Normally the wind speeds at one site fluctuate significantly so that securing a stable power supply from wind power is really difficult. It is not common to use a wind power system alone for off-grid rural electrification. One idea is to install a large size battery bank to compensate for days with no wind. However, adding solar panels would be more cost effective to get the same result.

When choosing a wind power system instead of a PV system for off-grid rural electrification, the wind system should be able to supply the same amount of electricity expected from the PV system. A typical 50W PV system is compared with a low-cost micro wind generator system that is suitable for off-grid use in developing countries. The smallest class of wind generators that have a rotor of about one meter in diameter are quite popular in the global market. (See Figure 7-1-1) Their rated outputs often reach 400W (at the wind speed of 12.5 m/s or 28mph).

It is assumed that a 50W PV system generates 200Wh per day, or 6kWh per month. According to the technical data of a 400W class wind-power generator that falls in the smallest wind generator category, it can generate more than 30kWh per month at the average wind of 5m/s (11mph). (See Figure 7-1-2) However, only a fraction of this gross electricity will be actually used, because the batteries that are fully charged will not take more energy. Excess energy will be dumped. If windy days are concentrated in certain periods of year, this is a serious issue in case of stand-alone wind power application. There may be some uncertainties like this, but, in general, it can be said that a 400W class-wind power system will work as a substitute for a 50W PV system at windy sites.





Source: Southwest Wind power company

Figure 7-1-2 Technical data of 400W class-wind power generator-AIR 403

Table 7-1-1 presents the rough estimation of development costs of the micro wind power system discussed earlier. The wind system is recommended to have a 400Ah or larger battery bank to effectively use the generated power. However, this is not a practical idea in case of rural electrification. In this analysis, therefore, only two units of 50Ah batteries are considered. On the other hand, the capital cost of a 50W SHS is estimated to be $348. (See Table 6-3-2)

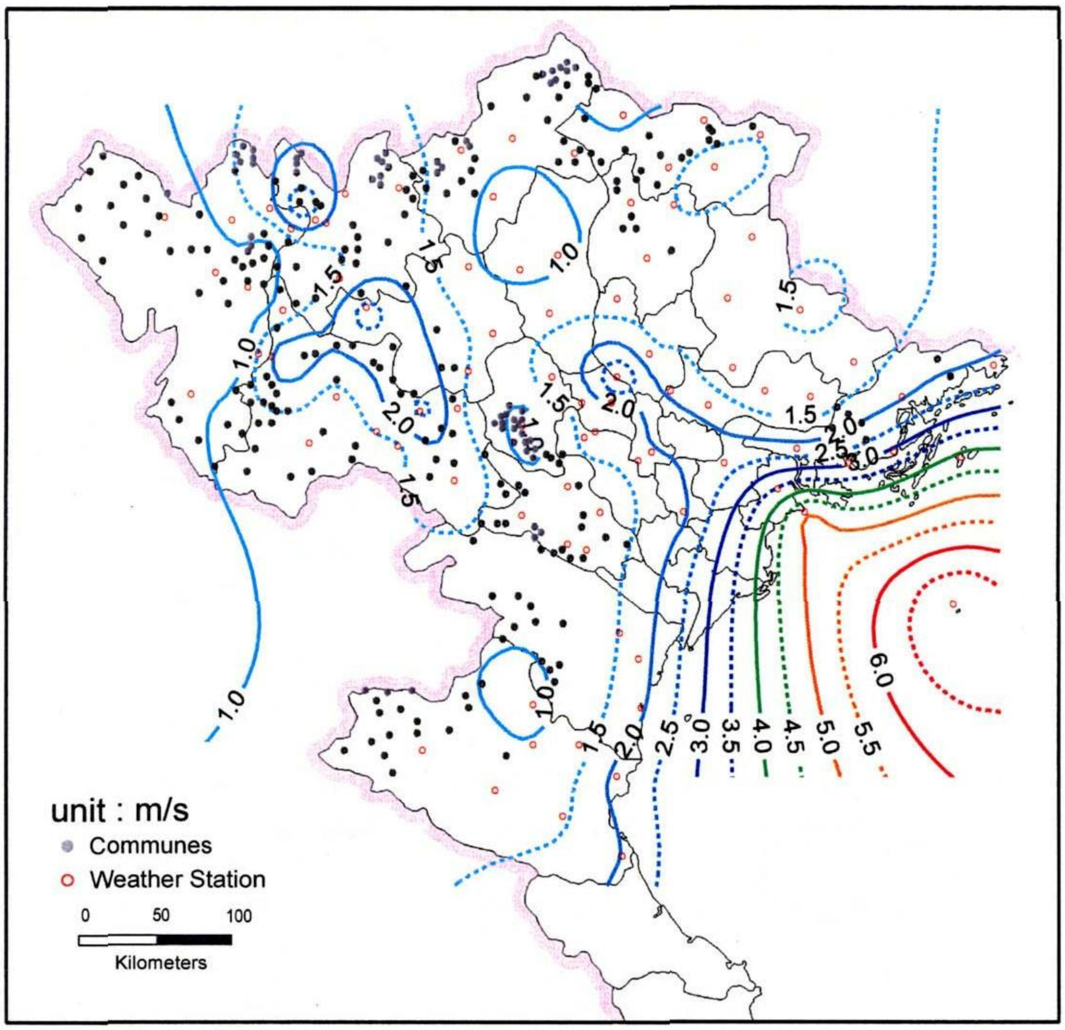
Table 7-1-1 Estimated costs for a micro wind power system

No.	Items	Unit	Unit price ($)	Total($)
1	Wind power generator (AIR403)	1	600	600.0
2	Tower system	1	800	800.0
3	Batteries 100Ah (50Ah×2)	2	23.4	46.8
4	Fluorescent lamps	4	7.0	28.0
5	Miscellaneous		200	200.0
	Total			**1,674,8**

Thus, the wind power system is far more expensive. Also, it requires some maintenance work such as replacing the blades and bearings, which is also a difficult point in remote areas. In conclusion, using wind power systems for off-grid application cannot be justified easily.

7-1-2 Wind power potential in Vietnam

PV system is viewed as superior to a wind power system in terms of cost and ease of maintenance work. In addition, in northern Vietnam it is rare to find a place where the average wind speed exceeds 4 m/s. (See Figure 7-1-3)



Source: JICA study team processed data provided by IE

Figure 7-1-3 Wind conditions in northern Vietnam

7-2 Hydro-Solar Hybrid System

Here we analyze a typical hydro-solar hybrid system that can generate electricity by PV modules during the dry season to make up for the stoppage of the hydropower system.

7-2-1 Solar system design for hybrid system

The basic assumptions are to build a solar system to back up a 5kW micro-hydro which serves 100 users. In the model plan, a micro-hydro system is designed to generate 220V AC power that will be distributed to users through a mini gird. In case of a hybrid system, therefore, the solar system needs to be big enough to have a DC-AC inverter to supply 220V AC. Switching from hydro to solar will be done manually. The solar system needs to supply enough electricity for lighting a 20W fluorescent lamp at each household for three hours. Therefore, the total amount of electricity required is,

20W x 3h x 100 households=6,000Wh

For this, the generated power by solar should be,

6,000Wh /0.9 (DC-AC conversion efficiency) /0.8 (charging efficiency) = 8,333Wh,

which requires 3 kWp PV panels (assuming 3.5kWh/m2/day). And the associated battery bank would consist of 56 units of 50Ah batteries (assuming 20% discharge).

The additional solar panels alone—60 units of 50W panels—will cost about $12,000. The total investment for the whole PV system would be more than $20,000, which is much bigger than the cost of the base system–5kW micro-hydro. Rural people cannot afford this. The hybrid system being a dual system will apparently improve the electricity supply but lead to "double investment". In case of rural electrification, hybrid systems cannot be recommended because reducing the project costs is a priority issue to meet the difficult economic conditions of rural villages.