No. 1

Japan International Cooperation Agency (JICA)

Electricity of Vietnam

Renewable Energy Master Plan

in the Northern Part of the Socialist Republic of Vietnam

Final Report

Summary

July 2002

PROACT International, Inc.
Tohoku Electric Power Co., Inc.

Japan International Cooperation Agency (JICA)

Electricity of Vietnam

Renewable Energy Master Plan

in the Northern Part of the Socialist Republic of Vietnam

Final Report

Summary

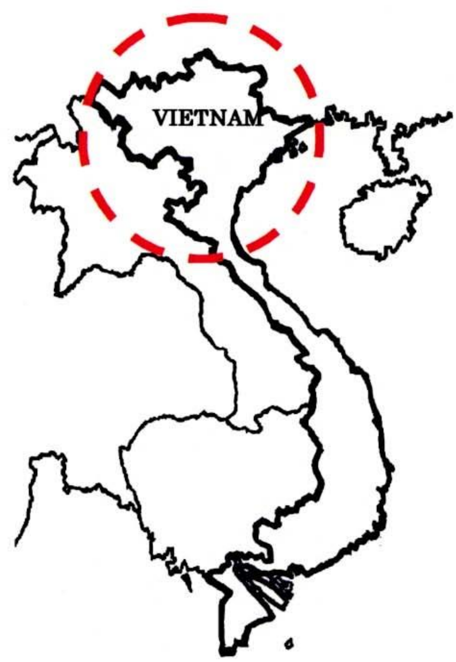
July 2002

PROACT International Inc.
Tohoku Electric Power Co., Inc.

Table of Contents

Study Area


CHINA
Ha Giang
Cao Bang
Lao Cai
Bac Can
Tuyen Quang
Lai Chau
Lang Son
Yen Bai
Thai Nguyen
Bac Giang
Phu Tho
Son La
Ha Noi
Quang Ninh
Hoa Binh
GULF OF
TONGKING
Thanh Hoa
LAOS
Nghe An
Ha Tinh


VIETNAM

1 Objective

1-1 Current Status of Rural Electrification

Like other developing countries, the Government of Vietnam (GOV) has been making strenuous efforts to provide electricity to rural people to improve their standard of living and to increase their incomes. The Prime Minister's Decision No.22/QD-TTg of 1999 set a goal that all districts, 80% of communes and 60% of rural households in Vietnam would be electrified by the year 2000. In fact, at the end of 2000, 96.4% of districts, 81.9% of communes and 73.5% of rural households benefited from the national power grid. Table 1 shows that the electrification of communes in the Red River Delta, Mekong Delta and Southeast regions is almost completed. However, in other regions the ratio of commune electrification is still low, and the northern part of Vietnam, in particular, has the lowest figure of less than 65%.

So far Vietnam has promoted rural electrification primarily by extending the grid. Electricity of Vietnam (EVN) has been investing, on average, $10 million in rural electrification every year. In order to electrify more households, the GOV is undertaking two major grid extension projects financed by the World Bank and by Agence Francaise de Developpment (AFD). However, there will still remain a large number of remote communes and villages where the grid cannot be extended for technical or financial reasons. In such cases, off-grid rural electrification must be considered. In particular, the northern part of Vietnam has strong needs for off-grid rural electrification.

Table 1 Electrified communes in Vietnam

Region	Number of Communes		Electrification Rate
	Total	With grid access	
Northern midland, mountainous areas	2636	1709	64.8%
Red River Delta	1388	1388	100%
North central coast	1632	1419	86.9%
South central coast	810	713	88.0%
Central Highland	501	389	77.6%
South-east	402	401	99.8%
Mekong Delta	1202	1200	99.8%
Whole Vietnam	**8571**	**7219**	**84.2%**

Source: EVN data (as of December 2001)

There was a period of EVN's overall responsibility for rural electrification, both on-grid and off-grid, before the Decision No.22 was issued in 1999. Now, implementing off-grid electrification projects has returned to the responsibility of Provincial People's Committee (PPC). Given this situation, EVN will no longer invest in off-grid electrification on their own, rather they will act as a coordinator of promoting off-grid projects and focus on technical support in the design, operation and maintenance of off-grid electricity.

At the request of EVN, the Japan International Cooperation Agency (JICA) started this study — Renewable Energy Master Plan in the Northern Part of the Socialist Republic of Vietnam — in January 2001 to assist EVN and 17 Provinces in northern Vietnam to implement off-grid projects on a large scale.

Northern Vietnam belongs to the tropical-monsoon climate, but has change of seasons. During the rainy season from May to October, it is hot and humid. On the other hand, in the dry season from January to March, cloudy weather continues with haze and drizzle. Most of the un-electrified communes that long for off-grid projects are located in remote and mountainous areas and often inaccessible by vehicles. On average, each commune has ten villages and 500 households.

Although northern Vietnam is endowed with rich water resources, micro-hydro development has been fairly stagnant. This is attributed to the following reasons:

① Insufficient systematic inventory survey on potential micro-hydro sites
② Shortage of project implementers who have experience and expertise
③ Absence of financing guideline on off-grid rural electrification projects
④ Underdeveloped domestic engineering and manufacturing capabilities on micro-hydro

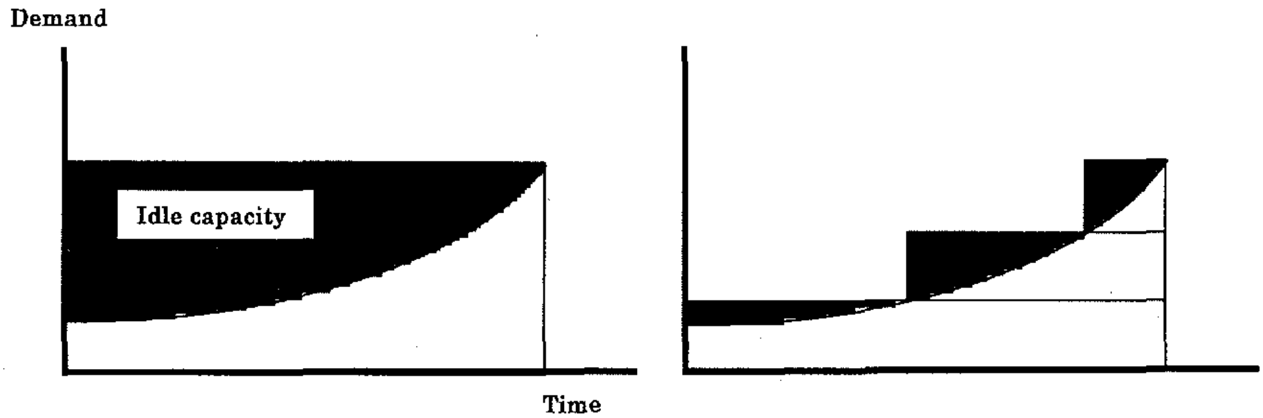
This study aimed at formulating model plans of sustainable off-grid rural electrification based on renewable energy sources such as micro-hydro or photovoltaics to contribute to the smooth implementation of off-grid projects by PPC. The focus of this study has been placed on developing concrete ideas and their implementation plans of sustainable off-grid renewable electricity schemes suited for rural Vietnam.

1-2 JICA's Approach

1-2-1 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 the 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 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 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 10kW 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 1 Demand growth and plant capacity

1-2-2 Small scheme and domestic technology

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. Past surveys have identified that Vietnam has a good technological potential for off-grid rural electrification. We worked to develop a low-cost but robust design giving priorities to the following points:

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

Our goal is to achieve "easy to finance, easy to build and easy to operate" models. The standardization effort is the key to lowering costs and improving the quality of equipment. Based on these standardized models, PPC engineers will be able to draw up off-grid plans on their own without relying on experienced consultants. And spare parts supply and repair service will become easier and less expensive. 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.

2 Database of Non-electrified Communes

2-1 Outline

At the first visiting, we visited all the 17 provinces in northern Vietnam and collected data on the communes that will remain not connected to the national grid even after the year 2005. A total of 277 communes will remain off-the-grid after 2005. Meanwhile, the number of the off-the-grid communes may change because the commune-level grid-extension plan in each province has not been finalized yet. (See Figure 2)

During the second visiting, we continued our investigation to gather data on socio-economic profile and renewable energy resources on those remote communes. After finishing the data collection, we created a database by using GIS software, ArcView, to enable easy data processing and mapping. The database will be used to select target communes and to examine an optimum electrification approach for each commune.

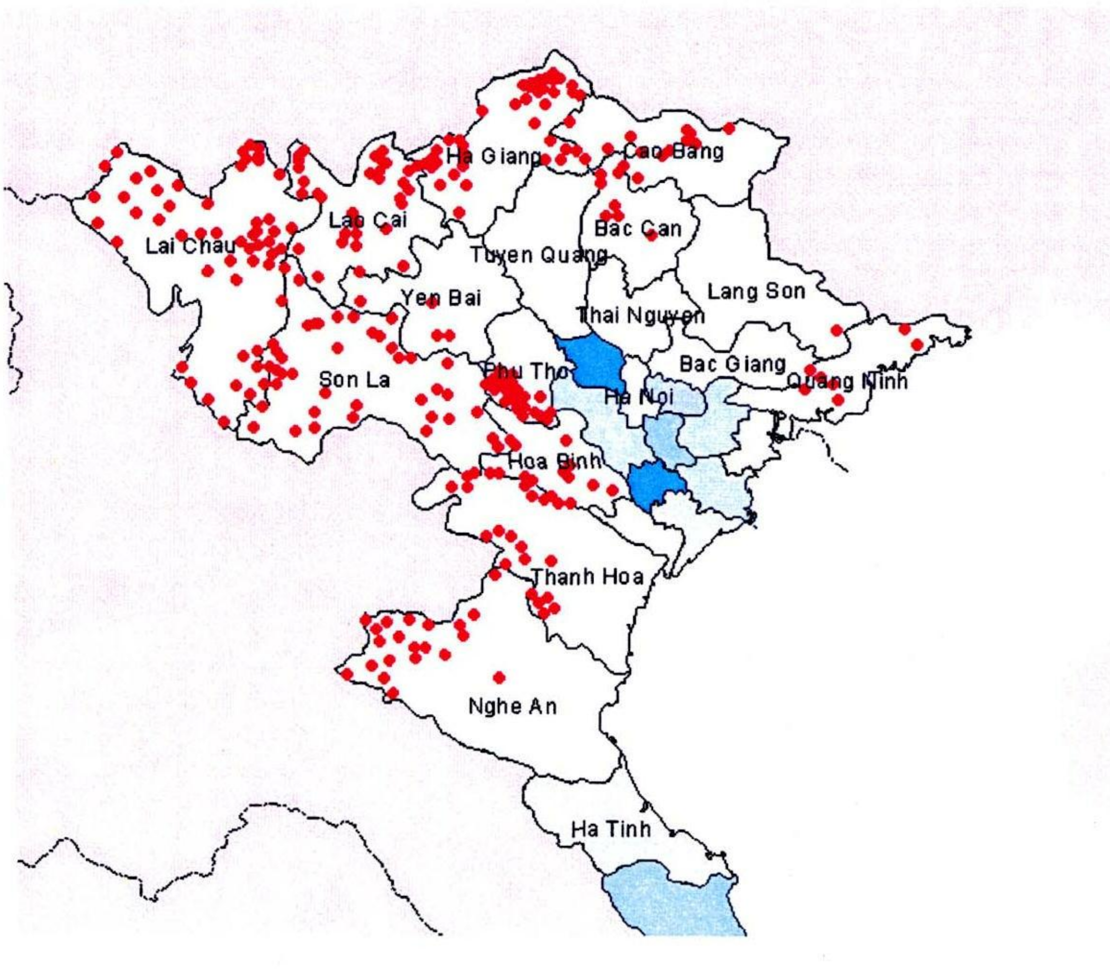


Figure 2 Distribution map of off-the-grid communes

2-2 Criteria for Selecting Communes

In northern Vietnam, due to the geographical and meteorological conditions micro-hydro is most promising. In many villages, irrigation channels are already developed, which can be used as a part of micro-hydro system. On the other hand, solar power is less attractive due to the unfavorable climate during the dry season. It is necessary to use larger size PV modules, which will push up the development costs. Solar power, therefore, should be considered only when micro-hydro resources are not available.

By using the database, PPC engineers will be able to assess the feasibility of off-grid electrification for each commune. The following discussions give general ideas about the criteria of screening communes.

2-2-1 Micro-hydro development

(1) Resources

It is unlikely that a 30 to 50kW class hydro site that is suited to cover a whole commune can be easily found in every commune. It is recommended to focus on smaller micro-hydro resources under 10kW. Even if a good micro-hydro site is found in an off-the-grid commune, the next criterion to be met is the distance between the site and the central area of commune. If the distance is quite long, the transmission cost will rise, which undermines the financial feasibility of the micro-hydro project.

(2) Coordination with irrigation

Water usage for irrigation purpose should be surveyed before deciding the amount of water to be used for hydropower generation. When the water resource is limited, compromise between irrigation and power generation will be necessary.

(3) Population distribution

In case of micro-hydro development, the cost of the transmission and distribution system has a significant impact on the overall economics of the plan. Densely populated areas should be given priority because those areas can reduce the length of wires and cables per household. For example, communes where houses are clustered along main roads are recommendable for early development.

(4) Accessibility

Considering the ease of constructing the micro-hydro plant, it is desirable to secure good roads to transport heavy equipment and materials by trucks. It is, therefore, necessary to check the road conditions and methods of crossing streams and rivers.

(5) Affordability and people's participation

As a rule in Vietnam, villagers need to pay the connection (service drop) fee when they apply for grid connection. In mountainous areas, houses are scattered out so that the wires necessary to connect houses to the low voltage distribution line are usually very long. The applicants, therefore, must pay a substantial amount of money for connection. In this regard, high-income communes should be considered first. At the same time, it is necessary to check the commitment and capacity (leadership and education) of villagers to manage the micro-hydro plant for a long time.

(6) Economy

By undertaking a rough economic analysis, the proposed micro-hydro project should cost less than alternative electrification methods. In some cases, the project must clear a financial or economic threshold, FIRR or EIRR, for investment approval.

(7) Securing technical assistance

In order to achieve the sustainability of the micro-hydro plant, it is essential to secure support from local technicians who can check and service generators and turbines, etc. In this regard, communes located in the vicinity of a Power Company branch are preferred.

(8) Strategic considerations

PPC needs to pay attention to the strategic impacts of the micro-hydro project on local economic development, capacity building of people concerned, technology dissemination, etc. during the process of selecting priority communes. Off-grid projects with bigger strategic implications deserve early implementation.

2-2-2 Solar system development

Solar systems will be considered in the areas where hydro resources are scarce.

(1) Resources

Target areas for solar power are those areas where hydro resources can be hardly found. However, it is important to note that in the mountainous region near China, the sunshine hours during the dry season are very short. The limited sunshine is a very tough condition for solar systems. It is recommended to choose communes that have relatively good sunshine data. Otherwise the solar system capacity needs to be scaled up, but this cannot be easily justified from an economic viewpoint.

(2) Affordability and people's participation

Villagers are requested to buy batteries and other appliances needed to use solar systems, which is not easy in underdeveloped villages. In this regard, high-income communes should be considered first. At the same time, it is necessary to check the commitment and capacity (leadership and education) of villagers to manage the solar system for a long time.

(3) Economy

By undertaking a rough economic analysis using the database, the proposed solar system project should cost less than alternative electrification methods. In some cases, the project must clear a financial or economic threshold, FIRR or EIRR, for investment approval. It is important to note that solar system costs will go down in the future by the emergence of new technologies such as Light Emitting Diode (LED) lamps as well as cost reduction from economies of scale.

(4) Strategic considerations

PPC needs to pay attention to the strategic impacts of the solar project on local economic development, capacity building of people concerned, technology dissemination, etc. in the process of selecting priority communes. Off-grid projects with bigger strategic implications deserve early implementation.

3 Off-grid Model Plan

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. Rural electrification plans with a custom design that only meet the conditions of target sites 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, developed off-grid systems will eventually fail.

PPC engineers have almost no experience in the field of off-grid rural electrification. Therefore, it is necessary to make off-grid model plans simple and standardized. Also, it is important to note that necessary equipment should be manufactured by local companies, which will facilitate the smooth conduct of operation and maintenance by villagers.

3-1 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 2 shows a summary of our electricity demand survey in rural Vietnam, which indicates typical household power demand.

Table 2 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.

3-2 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.

We are requested to develop good model plans that can be financially sustainable with the revenues from users. The estimated construction cost of micro-hydro based on our design is around $1,500 to $2,000 per kW, which is significantly lower than that of previous micro-hydro projects. A typical 5kW system, which serves about 100 households, can be built for less than $10,000, or $100 per household. The goal is challenging but achievable when a standardized design is applied and domestic technology and equipment are used. In other words, achieving this level of development costs is viewed mandatory in rural Vietnam for securing financial sustainability. Also, the low cost design will ease the task of GOV to secure development funds for promoting off-grid rural electrification under the financial restraints of the public sector.

3-2-1 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 of off-grid electricity. 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 off-set the revenue shortage, which may be well understood among the government officials concerned. On the other hand, the battery charging fee would be around 3,000VND (US ¢ 20) per charge based on the market pricing.

3-2-2 Cost allocation and financial evaluation

(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.

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 Summary of financial evaluation—5 kW micro-hydro

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

(2) Solar system

As for solar systems, 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. 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 4 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%	

3-2-3 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.

In addition to project financing, micro financing, if available, would help low-income villagers apply for electricity service. The villagers will borrow money to pay the connection fee or buy electric appliances. This would lead to higher household electrification rate.

3-3 Organizational Development

Two kinds of organizations need to be studied: one is the organization to implement off-grid 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 5 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

3-3-1 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.

3-3-2 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.

3-3-3 Organizational development for off-grid rural electrification

(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 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.

(2) District

District Office is expected to act as coordinator (or intermediary). They will help PPC engineers find appropriate sites, 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.

(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.

(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.

3-3-4 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.

3-3-5 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.

Figure 3 illustrates the role of major players of off-grid projects, and the expected flow of know-how and money.

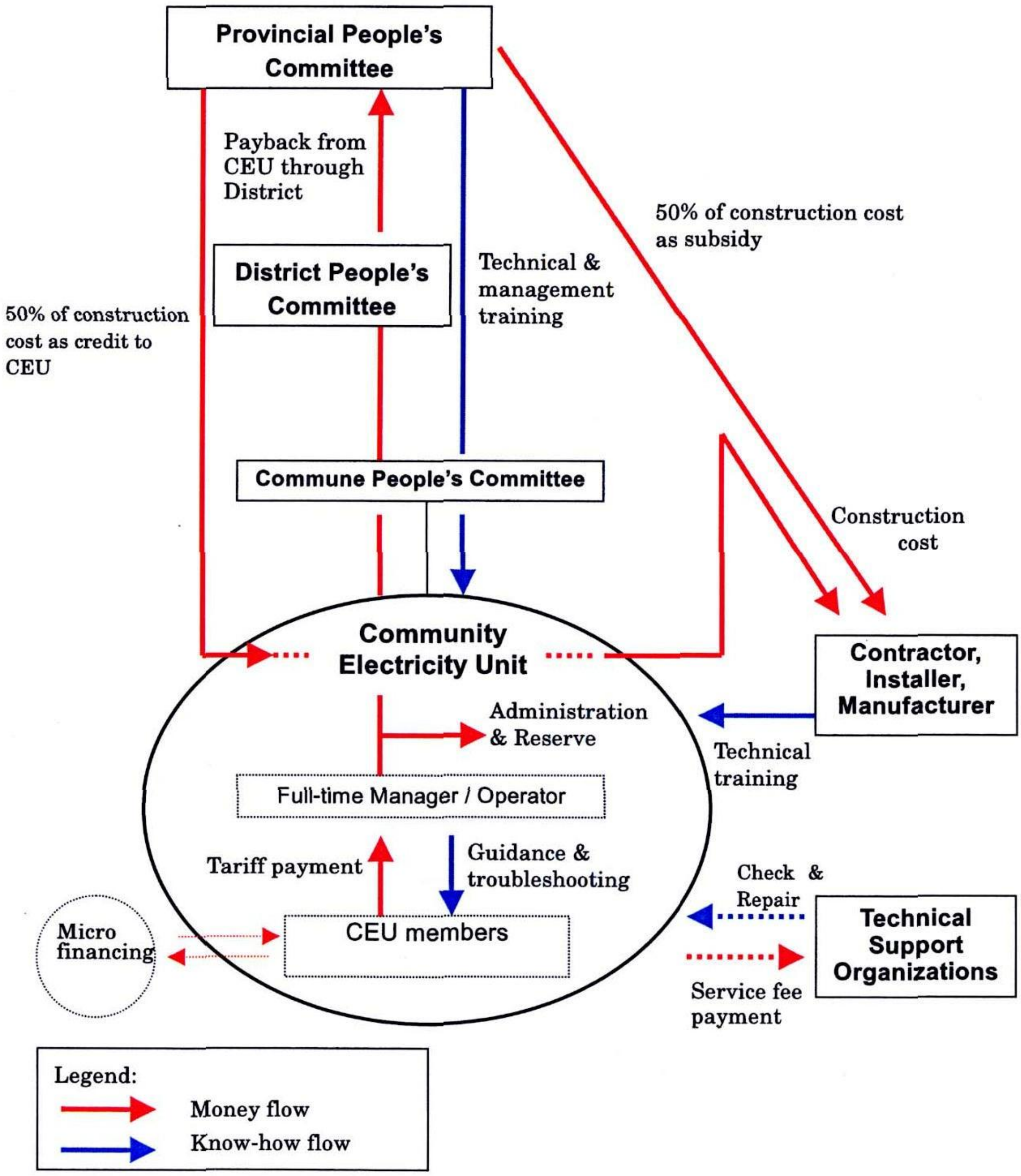


Figure 3 A typical flow of money and know-how in off-grid (micro-hydro) project

3-4 Technology

On the technical side, it is extremely important to use appropriate technology suitable for remote areas. The key technical concept is to develop a simple but robust design paying attention to easy maintenance.

3-4-1 Village Hydro

This JICA study proposes a strategic development idea—Village Hydro, which is suited to northern Vietnam. It is expected that the GOV will take necessary measures to materialize this proposal. 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. 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.

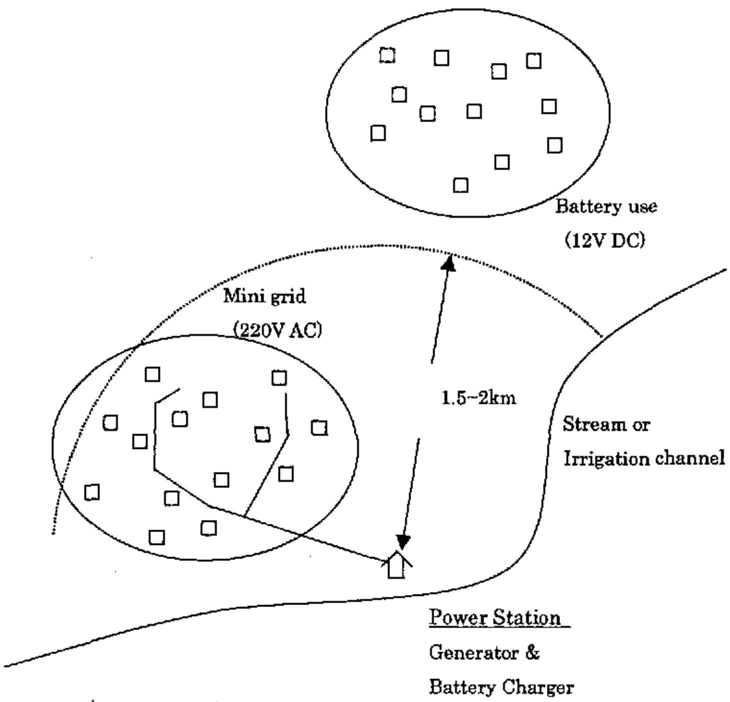


Figure 4 Concept drawing of rural electrification by Village Hydro

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.

(1) Generation

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. 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.

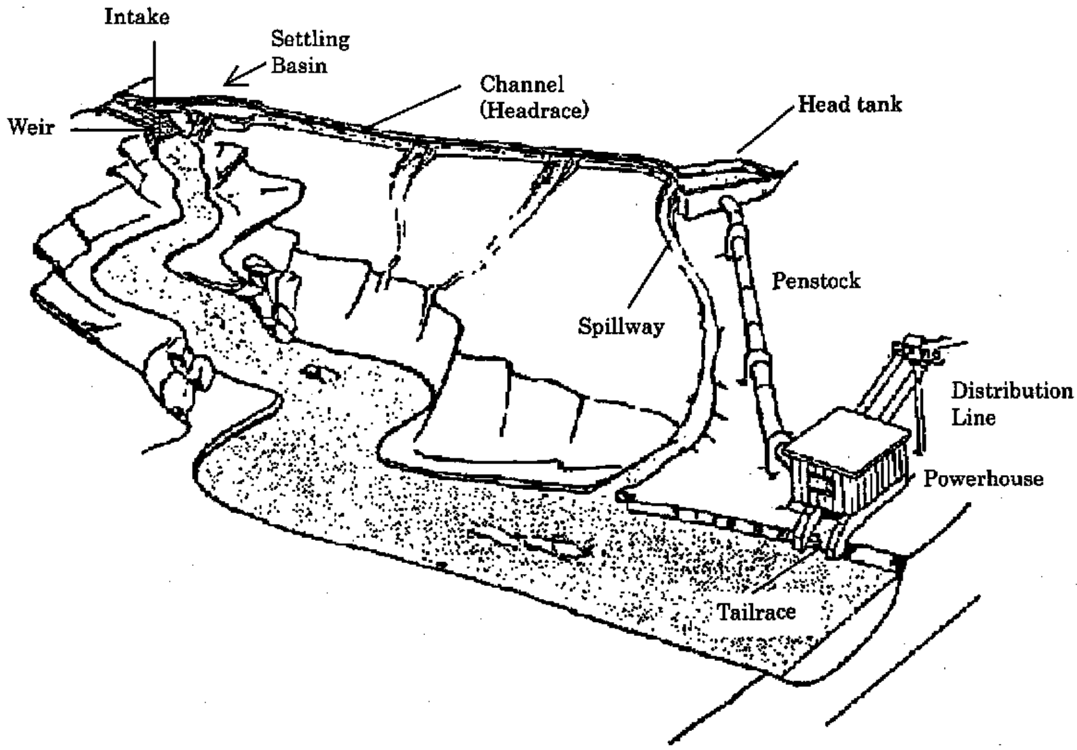


Figure 5 Run-of-river micro-hydro

One of the key features used 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.

Table 6 Basic specifications of Village Hydro (Run-of-river)

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	220V	
(2)Connection	Single Phase	
(3)Supply voltage	220V – 198V	
(4)Frequency	50Hz± 5%	

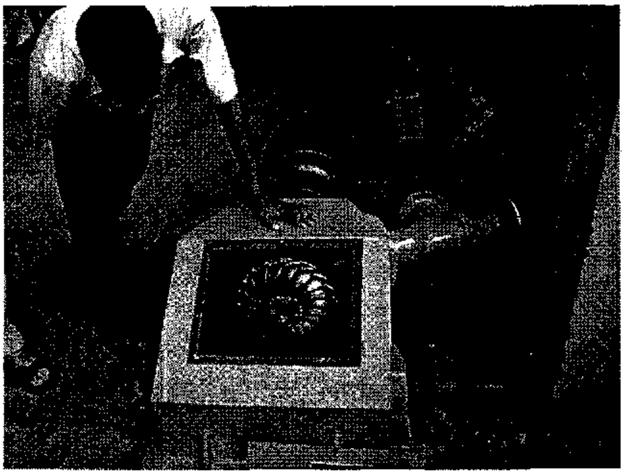


Figure 6 Packaged turbine and generator

2) Pico-plus generator

A 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 a special structure (i.e. flume) to guide the water to the turbine, but the penstock and valves are eliminated.

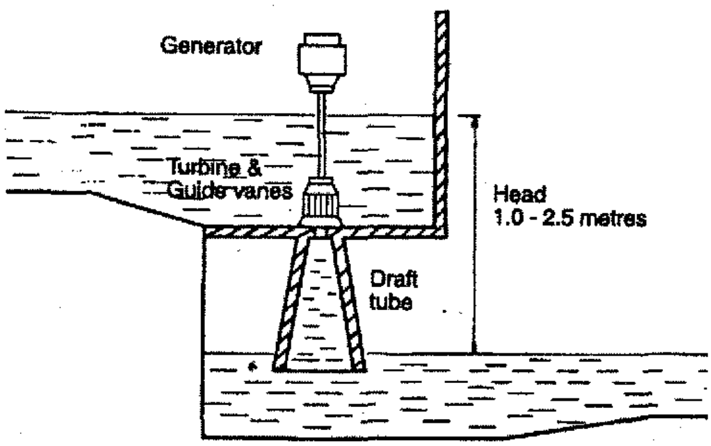


Figure 7 Pico-plus Generator

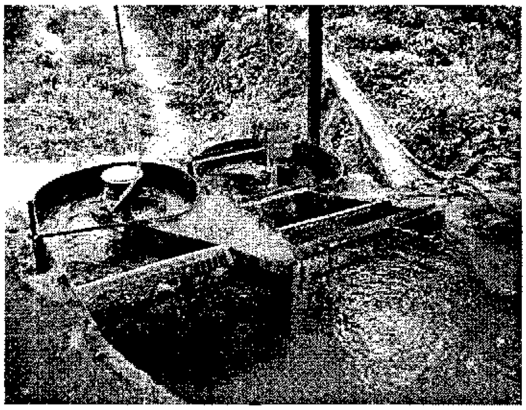
 

Figure 8 Testing two units of Pico-plus(1kW each)

(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. The controller compensates for variations in the village load by automatically changing the amount of power dissipated in a resistive load (i.e. dummy load), in order to keep the total load constant. This improves the safety and operability of installed power systems.

(3) 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.

<u>Technical Features of Village Hydro</u>

Packaged turbine and generator
Electronic voltage controller
Use of induction motor as generator
Low voltage (220V) mini-grid
Battery charging to serve outside of supply area

It is confirmed that all the necessary components of Village Hydro can be manufactured in Vietnam.

3-4-2 Village Solar

Solar systems should be considered only when hydropower resource is not available in the target commune. Photovoltaic (PV) cells convert sunlight directly into electricity. 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 biggest advantage of solar system in case of rural electrification is that its operation and maintenance is easy. Remote villagers can quickly learn how to manage solar systems if appropriate training is provided.

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. However, the cost of PV modules is continuously decreasing and new products such as LED lamps are emerging. The basic concepts of PV systems recommended for northern Vietnam are as follows.

(1) Modular design

The initial PV system to be developed at an unelectrified 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. Unlike hydropower systems that require a substantial volume of civil work, PV systems with a standardized modular design can be constructed easily without worrying about geographical conditions.

(2) Maintenance-free with 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.

(3) 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 Solar Home System (SHS) and Battery Charging System (BCS) 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). The BCS is recommended to be installed near the village center and housed where space is available.

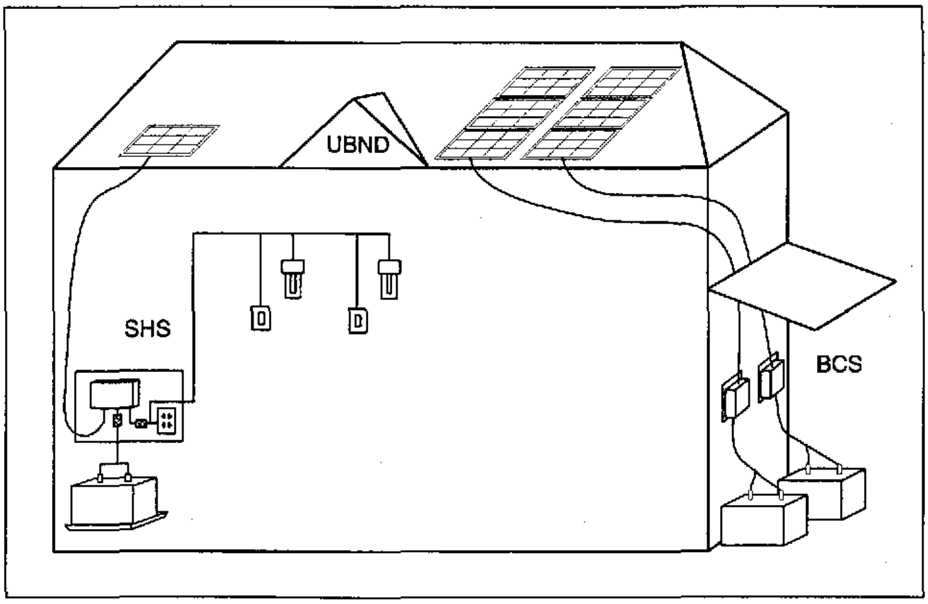


Figure 9 A typical communal system; Village Solar

Technical Features of Village Solar

Solar Home System at public facilities to provide basic services such as lighting, radio and communication to villagers

Battery Charging is added to serve individual customers

Major components are currently all imports. Efforts to develop domestic manufacturing are underway on some components.

4 Promotion of Off-grid Rural Electrification

4-1 Obstacles in Promoting Off-grid Rural Electrification

So far, very few off-grid rural electrification projects have been actually implemented in Vietnam. The stagnant project undertakings can be attributed to the following points:

1) Systematic inventory survey on potential small hydro sites, which is the starting point of project planning, has not been conducted so far.
2) Organizational structure, from the provincial level to the district and commune level, and financing mechanism for planning and implementing off-grid rural electrification projects, have not been fully developed yet.
3) New technologies for micro hydropower and solar systems are not fully acquired by domestic manufacturers.

Table 7 summarizes the underlying problems in promoting off-grid rural electrification.

Table 7 Difficulties in off-grid rural electrification

	Planning	Construction	Operation
Finance	Provincial budget is insufficient for survey and design.	Using the 135 Program budget for off-grid projects is possible, but there are few cases so far. Financing by overseas donors is under preparation.	Regulated tariff in remote areas Micro-finance is unavailable.
Technology	PPC engineers are not fully aware of the technology.	Domestic technology development is not completed.	Domestic technology development is not completed.
Organization	Collaboration between PPC and EVN is weak.	Difficult to find a reliable and experienced contractor	Training programs for villagers are not developed. Support mechanism from outside is not developed.

The off-grid model plans we proposed include some new technologies, but Vietnam has a good technological base. Domestic manufacturers and contractors can quickly master necessary technologies for Village Hydro and Village Solar.

Financing small-scale off-grid projects requires only $10,000 to $20,000 in project costs.

The villagers who benefit from off-grid power systems will pay some money for the electricity supply service, which can cover the operational costs at least. The GOV needs to provide a subsidy to buy down the capital cost. The balance of capital cost is to be borne by the villagers. This financial arrangement is quite feasible as long as rural development programs, such as the 135 Program, are applied. In addition, financial assistance from overseas donors will help to accelerate off-grid projects.

Based on these ideas, we strongly recommend that the GOV push small-scale off-grid projects, which we think fit the conditions of rural areas in northern Vietnam. Potential problems to be considered are related to human resources. We need to target PPC engineers, key players in off-grid rural electrification, in developing the strategic plan to accelerate off-grid projects. Also, the local villagers are underutilized. If adequate training is given, they can do a lot of work to take care of off-grid power systems. After commissioning, they need to manage the systems on their own anyway.

4-2 Strategy for Off-grid Rural Electrification

4-2-1 Action plan

In order to promote off-grid renewable projects based on our model plans and to achieve the goal of off-grid rural electrification in northern Vietnam, it is recommended that the GOV and PPCs take actions as follows.

2002-2003 (Preparatory Stage)

Conduct pilot projects to train PPC engineers and develop the technical capability of domestic industries

Identify candidate communes and formulate development plans including design and financing

2004- (Implementation Stage)

Develop off-grid projects based on the formulated plans using funds from various sources. By doing this, PPC engineers can gain know-how on off-grid development.

Disseminate the off-grid technologies to help local people develop off-grid plans

It is unlikely that private companies will get into the off-grid market quickly because the expected investment is too large to recover quickly. Electricity tariffs in rural areas are virtually regulated even in the case of off-grid systems. Hence, the public sector is expected to play a key role for some time until the income level of rural farmers goes up so that they can pay for small power systems. In this regard, PPC is responsible for improving our model plans taking the local conditions and resources into consideration. Also, what we proposed in this report requires the strong commitment of local people. A lot of field work to convince and motivate the local leaders will be required to implement off-grid projects, but it will be rewarding in the long-run.

(1) Financial arrangement

The recommended model plans are very small in terms of initial investment, which will range from $10,000 to $20,000. Therefore, the first choice of a financial source would be the 135 Program. There may be an approach to build a micro-hydro plant whenever an irrigation channel is constructed. Also, it would be possible to get financial assistance from the World Bank or JBIC in the future. The GOV is expected to accelerate the discussions on these financing programs and to set out a guideline on financial assistance for individual off-grid projects as soon as possible.

The local communities need some subsidy to implement off-grid projects. The appropriate rate of subsidy will be defined based on the estimation of revenue and expenses. The proposed scenario of rural people receiving a 50% subsidy and paying back the balance over 20 years would be achievable as long as the investment cost is reduced and the quality of system components is improved.

Also, the GOV needs to establish a micro-finance system to help those who cannot afford the one-time costs of electrification such as the connection charge or the purchase of electrical equipment or batteries. This will significantly improve the household electrification rate in remote areas.

(2) Technology development

Technologies for off-grid rural electrification should be basic and simple, and developed from the existing technological base in Vietnam. The simple but robust design is the key to long-term sustainability. Of course, Vietnam lacks some new technologies that will be required for easy operation and maintenance of off-grid systems. Given the high technological potential in Vietnam, it would be quite possible that domestic manufacturers digest these new technologies and develop their own products.

As a first step, it is recommended to undertake pilot projects to demonstrate and disseminate technology. In these pilot projects, some leading manufacturers and contractors will be involved so that they can learn the required technologies quickly. Also, it is important to develop O&M manuals and related training programs so that off-grid system users can easily master the necessary know-how to run off-grid systems.

(3) Organizational development

It is urgent to strengthen the planning capability of PPC engineers regarding off-grid rural electrification. Conducting pilot projects would help a lot in this regard. On the state level, it is expected that the Project Management Board of MOI, which was already established to promote off-grid rural electrification, and many provinces will tie up for strong collaboration. Manufacturers and contractors in Vietnam have a good potential to grow in the course of off-grid projects and, in future, will play an important role. The GOV needs to take necessary measures to help these enterprises improve their services from the viewpoint of securing higher sustainability. For example, it is recommended that the GOV direct them to provide training to the villagers and provide regularly scheduled checking after the construction work is completed.

On the user side, developing a CEU will proceed without difficulty owing to the fact that such organizations have been common in remote areas. However, some of the CEU's assignments are new and complicated to the villagers. It is, therefore, important to give them a well-coordinated training to ensure their daily work is conducted smoothly.

4-2-2 Recommended actions

In summary, it is recommended that the GOV take the initiative to undertake the following measures to promote off-grid rural electrification in a timely manner.

(1) Securing funds

Acceleration of negotiation with overseas donors
Develop a rule of financial assistance for off-grid projects
Establishment of micro-finance program

(2) Technology development

Implementation of pilot projects
Development of technical manuals
Quality improvement of off-grid equipment

(3) Organizational development

Capacity building of local PPC engineers

Strengthening the relationship between the GOV and PPCs

Backup support from EVN and PCs

Development of operation and management manuals for CEUs