Japan International Cooperation Agency (JICA)

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Ministry of Electric Power
Myanma Electric Power Enterprise
Union of Myanmar

The Study on Introduction of Renewable Energies in Rural Areas in Myanmar

Final Report

Volume 1

Summary

September 2003

Nippon Koei Co., Ltd.
Institute of Energy Economics Japan

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MYANMA ELECTRIC POWER ENTERPRISE
MINISTRY OF ELECTRIC POWER
UNION OF MYANMAR

THE STUDY ON INTRODUCTION OF RENEWABLE ENERGIES IN RURAL AREAS IN MYANMAR

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Final Report
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ABBREVIATIONS

Organizations

JICA	Japan International Cooperation Agency
MADB	Myanma Agricultural Development Bank
MEPE	Myanma Electric Power Enterprise
MPBANRDA	Ministry for Progress of Border Areas and National Races and Development Affairs
MOC	Ministry of Cooperatives
MOEP	Ministry of Electric Power
NCEA	National Commission for Environmental Affairs
SPICL	Sein Pann Industrial Production Co-operative Limited
USDA	Union Solidarity and Development Association (an NGO)
VEC	Village Electrification Committee
VPDC	Village Peace and Development Council
VWSDC	Village Water Supply Distribution Committee

Economics, Finance

ATP	Ability to Pay
WTP	Willingness to Pay

Unit

kVA	kilo Volt ampere
kWh	kilo-Watt-hour
K	Currency unit of Myanmar (Kyat)
US$, $	Currency unit of USA (US dollar)

Others

BCS	Battery Charging Station
IPP	Independent Power Producer
NGO	Non Governmental Organization
O&M	Operation and Maintenance
RE	Rural Electrification
SHS	Solar Home System

Exchange Rates

US$ 1.00 = K500 = Yen 120 (May 2001)

US$ 1.00 = K1,000 = Yen 120 (May 2003)

SUMMARY

The present report summarises the findings and outputs of the Study for Introduction of Renewable Energies in Rural Areas in Myanmar (the Study). The Study was commenced in January 2001 and completed in September 2003.

1. The Study

1.1 Objectives of the Study

The objectives of the Study were as follows:

- Preparation of Guidelines for introduction of renewable energy into rural areas;
- Preparation of Manuals for design, operation and maintenance of small hydropower schemes;
- Formulation of Development Plans; and
- Technology and know-how transfer including establishment of Database.

Another important objective was the transfer of technology and know-how, not just limited to engineering, but also including a wide variety of other aspects, such as organizational and institutional issues, tariff systems and management/maintenance. This task has been conducted throughout the Study through joint operation by the two teams from Japan and Myanmar.

1.2 Scope of the Study

The Study has been carried out in accordance with the Scope of Work (S/W) and Minutes of Meetings (M/M), which were signed by the Ministry of Electric Power of Myanmar (MOEP), Myanma Electric Power Enterprise (MEPE), and Japan International Cooperation Agency (JICA) on 21 September 2000.

Another Minutes of Meeting were signed between the JICA S/W mission and MOEP on 23 August 2002 in Yangon to confirm that one of the existing small hydropower stations of MEPE be monitored in place of implementing a pilot project. The Zi Chaung hydropower station was then selected and monitored in accordance with the M/M.

1.3 Counterpart Agency and Executive Body

The counterpart agency for the Study was MOEP, which was in charge of the execution of the Study. The executive body for the Study was MEPE.

1.4 Phasing of the Study

The Study was implemented in two phases as shown in Figure 1 below:

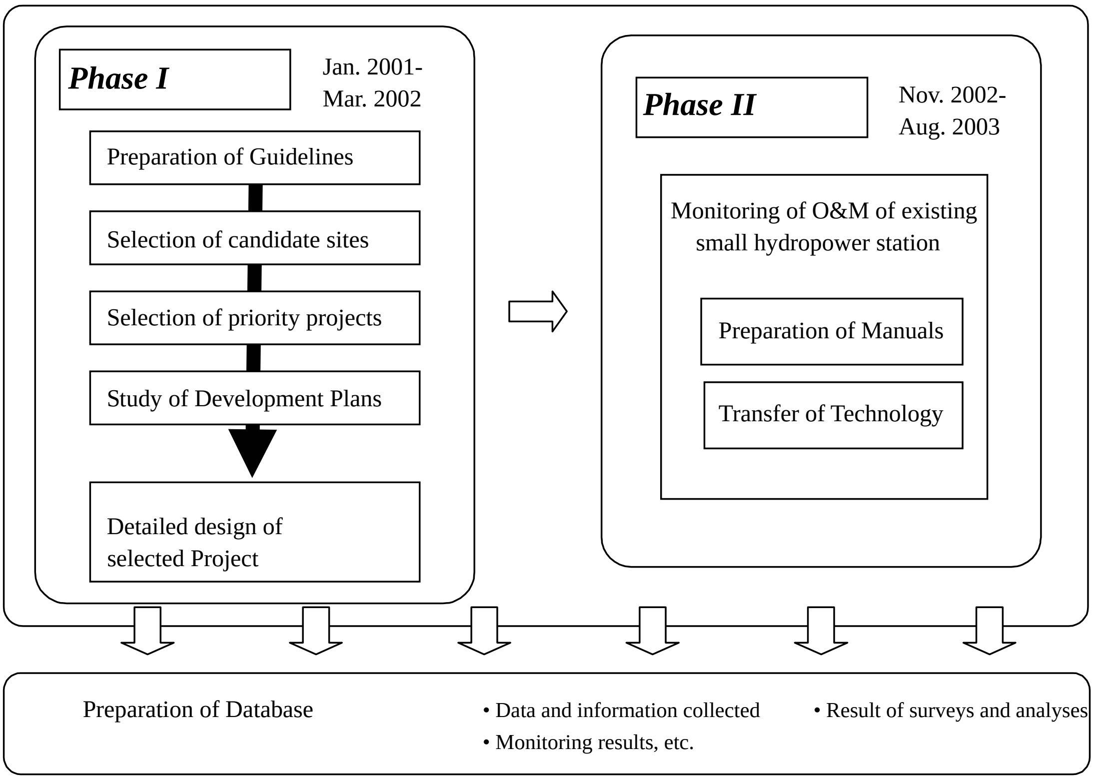


Figure 1 Work Flow and Study Components

1.5 Background to the Study

Geography

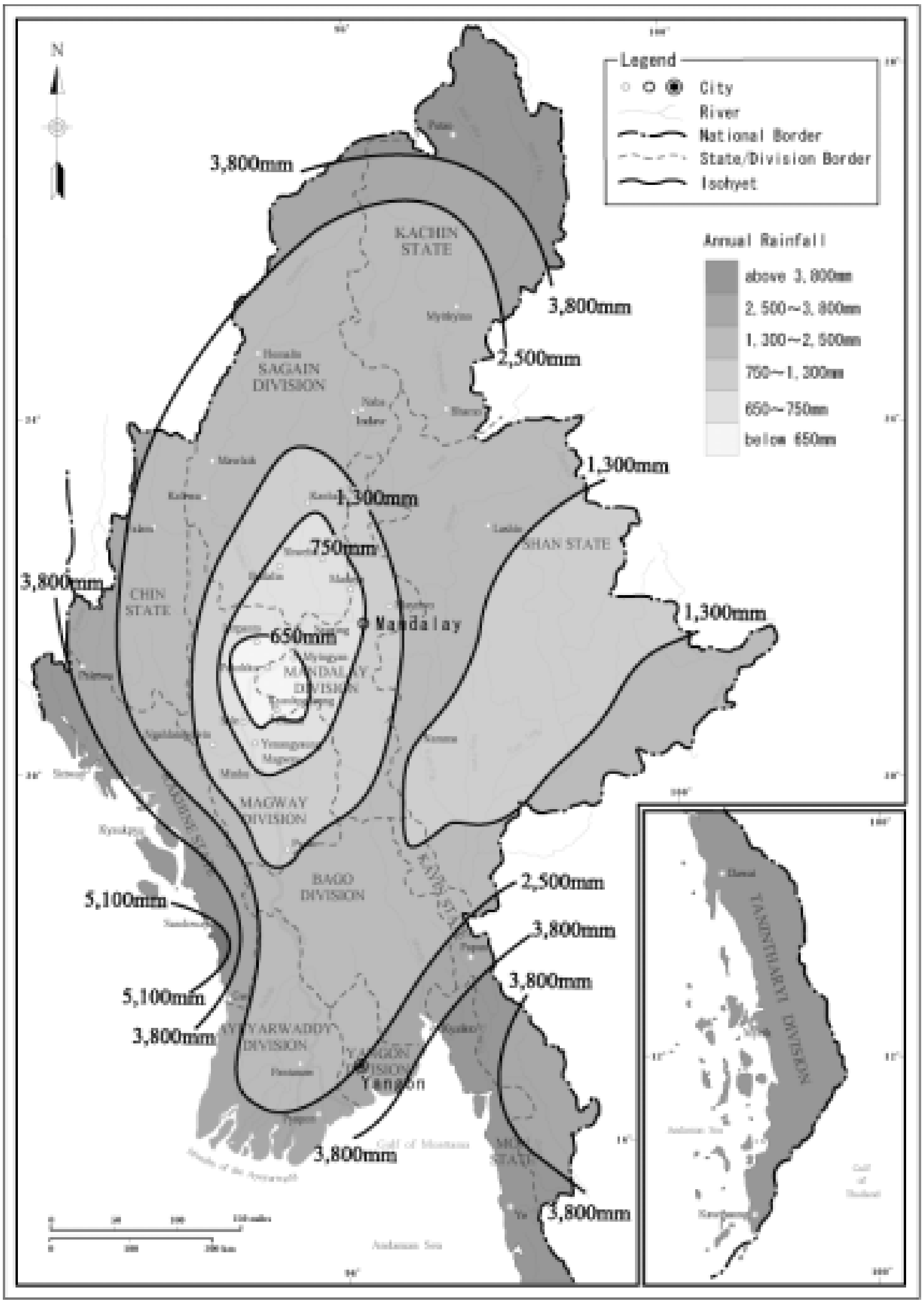
Myanmar has a territory of 676,000 km^2, population of 46.4 million in 1997/1998, per capita GDP at $161 (in 2000, an IMF estimate), ratio of literacy of 84%, and average life span of 61 for males and 64 for females (Source: Statistical Yearbook 2000, CSO).

Landuse is broadly classified into reserved forest of 12.5 million ha, cultivated land 9.67 million ha, and other forest 20.27 million ha. Paddy fields of 6.21 million ha are cultivated to yield 19.8 million tonnes of paddy in 1999.

Climate

Although Myanmar is in the monsoon region, the climate of the northern one third of the country ranges from subtropical to temperate. The southern two thirds are classified as tropical with high temperature and humidity. The precipitation differs by region and altitude. The central dry zone (CDZ) has the lowest precipitation, below 650 mm, while the coastal ranges have the highest, exceeding

5,000 mm as shown in Figure 2. Generally the wind speed is not high; however Rakhine State, which lies under the influence of the monsoon and sea currents, experiences winds of relatively high speed (>2.5 m/s on annual average). Solar radiation is high (>5 kWh/m^2/day) in the plains area but is relatively low (<4.5 kWh/m^2/day) in mountainous areas because of the formation of clouds.



Source: DOMH

Figure 2 Isohyets of Mean Annual Rainfall

Socio-economy

The total population of Myanmar was estimated to be over 51 million in 2001. The rural population is about 75%. Of the 10.7 million workforce, 56% are in the agricultural sector, 15% in the mining and industrial sector, and 28% in the commercial sector. The agricultural sector contributes 34% of the GDP, followed by the trade sector at 20%, and the processing and manufacturing sector at 9%. The processing and manufacturing sector showed a low growth rate at 0.2%/year in the last 10 years. Insufficient power supply has been one of the causes of this very low growth rate.

Current Level of Rural Electrification in Myanmar

The difference in electrification level is very large between urban areas and rural areas as shown in Table 1. According to Household Income and Expenditure Survey by Central Statistical Organization (CSO), 37% of the households in Myanmar have access to electricity while 24% depend on battery lighting. In urban areas (quarter/ward), 72% have electricity and 10% use batteries. In rural areas (village tract) 18% have electricity and 32% use batteries. Among the urban areas, Magway Division has the highest percentage (93%) of households with electricity. Among the rural areas, Rakhine State has the lowest percentage (2%) with electricity.

Table 1 Electrification in Myanmar

State/Division	No. of District	No. of Township	No. of Village	Poppu-lation	Electrification Level (%)		
					Urban	Rural	Total
Kachin S.	3	18	616	1,202	63.7	9.0	25.0
Kayah S.	2	7	79	246	64.3	50.3	54.1
Kayin S.	3	7	377	1,403	57.6	20.1	24.3
Chin S.	2	9	476	458	92.2	38.6	47.1
Sagaing D.	8	38	1,816	5,180	90.9	42.2	61.4
Tanintharyi D.	3	10	263	1,269	50.3	11.6	31.6
Bago D.	4	28	1,409	4,848	82.1	27.5	46.7
Magway D.	5	25	1,543	4,301	92.5	19.1	36.7
Mandalay D.	7	30	1,567	6,188	65.6	3.2	22.1
Mon S.	2	10	381	2,337	28.8	25.2	27.4
Rakhine S.	5	17	1,041	2,610	41.0	2.3	18.5
Yangon D.	4	45	677	5,295	67.3	9.9	49.9
Shan S.	11	54	1,627	4,629	55.1	13.1	30.5
Ayeyarwady D.	5	26	1,920	6,436	49.7	4.4	8.7
Total	64	324	13,792	46,402	71.6	17.7	37.0

Source:
Number of District and Township: "Myanmar Facts and Figures", Min. of Information (March 2000)
Population in 1997: Statistical Yearbook 2000, Central Statistical Organization (CSO)
Number of Village Tract: "Districts, Townships, Towns, Quarters, Village Tracts and Villages in the States and Divisions", Administration Department, Ministry of Home Affairs
Electrification level: Report of 1997, Household Income and Expenditure Survey, CSO, 1999

2. Guidelines for Rural Electrification

2.1 Introduction

Power Sector

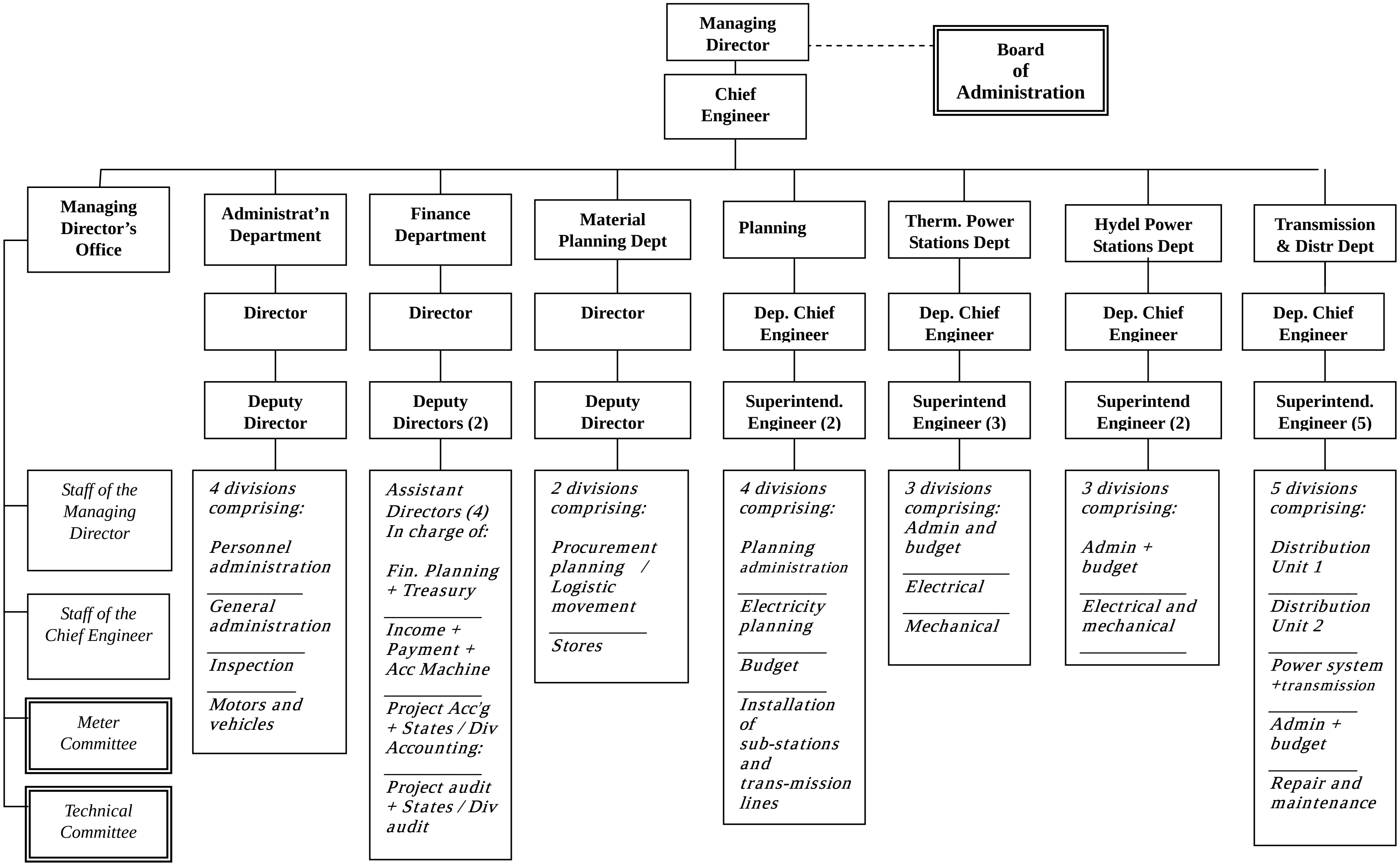
The power sector is administered by the Ministry of Electric Power (MOEP), under which there are two departments and one enterprise: the Department of Electric Power (DOEP) responsible for policy making; the Department of Hydroelectric Power (DHP) responsible for investigations, designing and implementation of hydropower projects; and the Myanma Electric Power Enterprise (MEPE) responsible for operation and maintenance of hydro and thermal power stations, construction and maintenance of transmission and distribution networks, and management of electricity business such as tariff collection. The organization chart of MEPE is presented in Figure 3.

The performance of the power sector has shown steady progress since 1988 to 2000 as summarized below:

Table 2 Power Sector and Rural Electrification

Items	1988/89	2002/03	Remarks
Nos. of customers	600,000	1,030,000	Annual growth rate at 4.6%
Nos. of Townships electrified	287	323	All the Townships electrified by 1996.
Nos. of Village Tracts electrified	749	1,117	8.1% of the 13,792 VTs electrified by 2000/01 (level of village electrification).
Generating Capacity	707 MW	1,172 MW	Annual rate 4.3%
Hydro	229 MW	360 MW	3.8%
Thermal around Yangon	110 MW	465 MW	12.8%
Firm Peak Output	407 MW	716 MW	Annual rate 4.8%
Peak Power Demand	332 MW	1,005 MW	Annual rate 9.7%
Annual Energy Generated	2,226 GWh	5,020 GWh	Annual rate 7.0%
Annual Energy Sold	1,428 GWh	3,715 GWh	Annual rate 8.3%
Length of 11-33-66 kV Distribution Lines	4,837 miles	7,915 miles	Annual rate 4.2%

Source: Compiled by the JICA Study Team based on the MEPE Statistics, April 2002



Source: MEPE

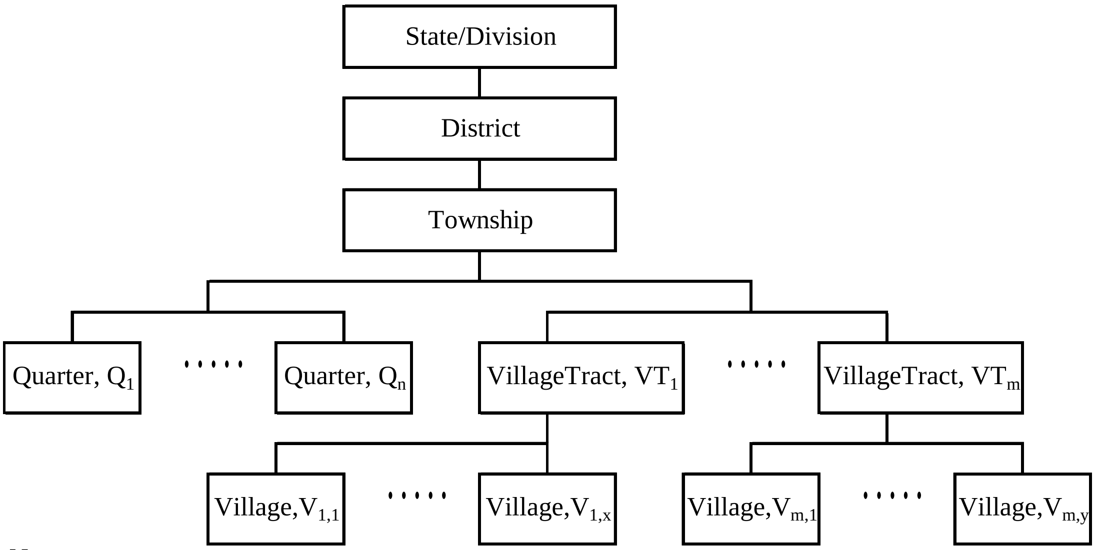
Figure 3 Organisation Diagram – Myanma Electric Power Enterprise (MEPE)

In addition to MEPE and in relation to the introduction of renewable energy into agricultural villages, the Ministry for Progress of Border Areas and National Races and Development Affairs (MPBANRDA), which has jurisdiction over the development of the border areas, plays an important role.

Administration Structure in Myanmar

As illustrated in Figure 4, the administrative structure in Myanmar consists of 14 States/Divisions at the top level, and 64 districts, 324 townships, quarters (or wards), 13,792 village tracts, and villages, as of year 2000.

Most of the townships have population over 10,000. Their central part consists of several quarters (wards). Village tract is a group of various sizes of villages geographically bordering to each other. Village tracts are under the administrative control of the Chairman of Township Peace and Development Council (TPDC).



Note:

Q_1・・・Q_n: The first Quarter to n-th Quarter

VT_1・・・VT_m: The first Village Tract to m-th Village Tract

$V_{1,1}$・・・$V_{1,x}$: The first Village to x-th Village of the first Village Tract

$V_{m,1}$・・・$V_{m,x}$: The first Village to the y-th Village of the m-th Village Tract

Source: JICA Study Team

Figure 4 Local Administration Structure in Myanmar

Power Grid of MEPE

In Myanmar, severe power shortages are experienced even in the areas served by the MEPE power grid (the Grid; hereinafter refer to Figure 5 for the distribution of the Grid in Myanmar). The total generating capacity feeding into the Grid is

1,172 MW, which consists of hydro 360 MW, thermal 216 MW, gas turbine (including combined cycle) 530 MW, and diesel 66 MW. The firm peak capacity of the Grid was 716 MW in 2000/01 while the peak demand (load) on the Grid was 1,005 MW resulting in a power shortage of 289 MW, which was managed by load shedding and suspending connections of new applicants.

The per capita power generation was as low as 22 W. Even the capital of Yangon, where about 70% of the electric power is consumed, as well as the urban part of Mandalay, suffer from a shortage of electricity. In the Five Year Electric Power Development Plan prepared by MOEP, the capital investment priority is given to the 2,000 MW generation expansion projects that will feed into the Grid. The generation expansion is essential also to facilitate future rural electrification by Grid extensions.

Nationwide Township Electrification by MEPE

In the remote areas not covered by the Grid, the central urban areas of all the townships are supplied by a local independent (isolated) power system of MEPE with diesel generators and/or small hydros. It is often inefficient to extend the distribution network from the Grid to these rural areas because the population density is low and the demand sites are dispersed and far from the Grid. Therefore, MEPE is operating 456 diesel generators and 30 small hydros for rural electrification by independent power systems. Diesel generators are operated for 3 hours a day due to the limitation of fuel budget. Since the operating costs of these local power systems cannot be met by operating revenue, the costs are covered by remittance from MEPE Headquarters. Hydropower plants are operating for 24 hours a day. However, since their output drops significantly in the dry season, power is supplied only to a limited area in the dry season. Most of the villages immediately surrounding the township center are not electrified.

Source: Compiled by the JICA Study Team

Figure 5 Power Grid of MEPE

Utilization of Battery-Lighting as Kerosene Lamp Substitute

Lighting systems supplied by BCS (battery charging station) have been widely introduced: 24% of households at the national level and 32% of rural areas (Household Income and Expenditure Survey by CSO). Lighting is by 4-8 W fluorescent lights. Battery-lighting systems were introduced when kerosene disappeared from the market after the first oil crisis in 1973. Before that kerosene lingts were the main source of lighting for farm households. As a result of the non-availability of kerosene, many BCSs, powered either by the Grid or by small diesel generators, operate on a commercial basis countrywide.

However, batteries and fluorescent lights available in the market have a short lifetime and need frequent replacement. In the households that cannot afford to buy a fluorescent light at about $1.00, people use small incandescent bulbs that are less bright but are cheaper and last longer than fluorescent lights.

These battery-lighting systems provide valuable lighting for dinner and communication among the family. However, such lighting is inadequate for children to read books and may even weaken their eyesight.

Solar Panel of BCS

Battery charging at BCS

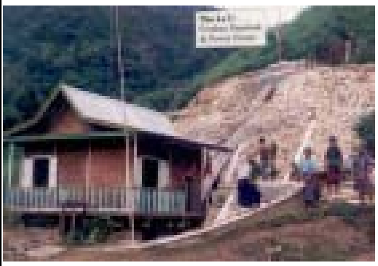
Battery powered fluorescent light

Diesel lamp

Rural Electrification (RE) with Other Power Sources

In addition to the electrification of township centers by MEPE and the usage of battery-lighting on an individual basis, there are many other forms of small scale rural electrification (RE) as listed below:

- Small diesel generators for self consumption, with some power also fed to neighboring households;
- Micro-hydros of smaller than 50 kW owned and operated by villages (hereinafter referred to as *Village Hydro*);
- 300 W to 1 kW package type turbine-generator introduced by individual or small groups of households, utilizing Chinese turbine generators available in the local markets;
- Solar Home Systems (SHS), examples of individual household installations are in Yangon Division, Bago Division, Chin State;
- Solar/wind-powered BCS systems contributed by NGO and donor;
- Vaccine Cold Storage Systems with solar power (SHS type) were installed by UNDP in cooperation with the Ministry of Health at 27 hospitals and clinics in total. Solar pumps were also installed by UNDP in cooperation with the Ministry of Agriculture at 31 locations; and
- Rice husk gas engines have been introduced to power rice-mills, and in some cases supply power to neighboring households.

Village Hydro (<50 kW)	Pico-hydro (<1 kW)	Biomass gas engine (rice husk, wood chip, etc.)
		

Power Tariff

According to the present power tariff system implemented on 1 March 1999, the energy charge is K2.50/kWh for general use up to 50 kWh per month. This is equivalent to about US ¢ 0.25 per kWh in 2003. This level of tariff cannot even recover the running costs of power stations.

Current Situation / Key Institutional Issues

Myanmar (where 75% of the population live in the rural areas) has one of the lowest level of village access to electricity in SE Asia. The Grid cannot meet existing demand and therefore cannot be extended to serve rural areas and this situation is unlikely to change in the medium term. There is no central regulatory body and there are no consumer representative groups.

Myanmar has abundant renewable energy resources and the geography/ topography/demography of the country is suited to isolated power supply systems. A start has already been made on using renewable energy sources for small-scale RE and the benefits are evident. Appropriate renewable energy technologies exist, and the skills to design and build such systems are available, but capacity building is needed. From an institutional point of view, some of the encouraging findings from the Study are:

- Communities are agreeable to participate in scheme implementation/self fund;
- Willingness and ability of rural communities to pay for the service;
- Already examples of entrepreneurship, innovation and private sector involvement (and funding);
- Co-operative system exists and cooperatives are already involved in the sector; and
- The concept of establishing Village Electrification Committees (VECs) exists and is working reasonably well.

Some of the weaknesses observed are:

- Many ministries/organisations are involved, but no central co-ordination of the sub-sector;
- Legislation is in need of updating (Electricity Law unchanged since 1984, MOI regulations do not cover the scope of renewable energy technologies under study);
- Poor maintenance is affecting sustainability of some existing renewable energy projects e.g. lack of manuals, no preventive maintenance, shortage of spares;

- Not enough publicity of achievements to date; and
- Research and development has declined in recent years e.g. MOST/YIT work on gasifiers, and should be encouraged in the future.

The key issues are perceived to be:

- No apparent ownership of the problems of meeting the RE need;
- No comprehensive RE policy or targets;
- Inadequate current budget for *Government RE Schemes* (50 kW – 10 MW);
- Lack of funding/credit facilities for *Village RE Schemes* (self-help/ <50kW);
- Lack of guarantee system to address the completion risk of *Village RE Schemes*; and
- No "champion" to promote RE using renewable energy.

Expected Benefits of Rural Electrification in Myanmar

Some 82% of the rural population (excluding the urban population) or about 30 million have been awaiting the electrification. The rural electrification in Myanmar will introduce significant benefits such as:

- Improvement of living standards by home electrification that facilitates book reading and study for children, pump supply of domestic water (in mountain region in particular), betterment of hygienic conditions through the supply of an adequate amount of water, security by street-lighting at night, income-raising home industry like dressmaking, primary processing of agricultural products, and so forth;
- Improvement of the educational environment by school electrification and introduction of information technology (IT);
- Improvement of the health environment by the introduction of medical equipment to electrified clinics/hospitals, such as cold storage systems for vaccines; and
- Stimulation of community activities by community hall electrification and telecommunications for introduction and development of new village industry.

2.2 Demand for Rural Electrification

According to the Village Social Survey conducted by interviewing 1,348 households under the Study in May-June 2001 (VSS2001), the order of priority for household basic needs is: 1) health, 2) electricity, 3) money, 4) education, and 5) food. It is notable that electricity is ranked higher than money, education, and food.

Electricity demand was projected by grouping consumers into four types: household, public, business, and industry. The result is a gross demand for new lighting in the order of 700-930 MW as shown in Table 3, which is a similar order of magnitude as the supply to the Grid at present.

Table 3 Electricity Demand for Rural Electrification by State/Division

No.	State/Division	Population 1983 Census			Population in 1997		Rural House-holds	Power Demand	
		Urban	Rural	Total	Total	Rural		Upon RE	After several years
		1,000	1,000	1,000	1,000	1,000	1,000	MW	MW
		1	2	3	4	5	6	7	8
1	Kachin State	181	638	819	1,202	936	156	19	25
2	Kayah State	42	118	160	246	181	30	4	5
3	Kayin State	105	528	633	1,403	1,170	195	23	31
4	Chin State	54	315	369	458	391	65	8	10
5	Sagaing Division	530	3,295	3,825	5,180	4,462	744	89	119
6	Tanintharyi Division	216	698	914	1,269	969	162	19	26
7	Bago Division	740	3,060	3,800	4,848	3,904	651	78	104
8	Magway Division	493	2,750	3,243	4,301	3,647	608	73	97
9	Mandalay Division	1,214	3,364	4,578	6,188	4,547	758	91	121
10	Mon State	473	1,207	1,680	2,337	1,679	280	34	45
11	Rakhine State	304	1,742	2,046	2,610	2,222	370	44	59
12	Yangon Division	2,706	1,260	3,966	5,295	1,682	280	34	45
13	Shan State	658	2,432	3,090	4,629	3,643	607	73	97
14	Ayeyarwady Divisior	742	4,252	4,994	6,436	5,480	913	110	146
	Union Total	8,458	25,659	34,117	46,402	34,913	5,819	699	930

Source: Forecast of JICA Study Team, with population data by Statistical Yearbook 2000, Central Statistical Organization, Yangon, Myanmar, 2000, Ministry of National Planning and Economic Development

Note: (1) Average family size was assumed at 6.
(2) Rural population 1997 was assumed based on total population in 1997 and rural population ratio in 1983.
(3) Column 7 shows demand just after electrification when unit demand is forecast at 120 W per household.
(4) Colume 8 shows demand after several years when electric appliances other than lights are introduced to increase the average unit demand to 160 W per household.

2.3 Factors which Support Promoting Rural Electrification

Potential Renewable Energy Sources for Rural Electrification

The local resources and technologies available for rural electrification in Myanmar are: 1) abundant small hydro potential and turbine manufacturing and installation technology, 2) rice husk potential amounting to 3.5 million tonnes a year and the gasification technology for gas engine generator, and 3) technology for recycling of batteries and the presence of a collection and distribution network of batteries on a commercial basis.

In terms of the small hydro potential, there are 154 sites suitable for small hydros (smaller than 10 MW per site) and 170 MW in total potential output as identified by the Department of Hydroelectric Power (DHP). Also, there are numerous *Village Hydro* sites (<50 kW) and turbine-generator installations of 1 kW or less in hilly regions like Shan State.

Timber, rice husks, and bagasse from sugarcane are the main biomass resources. 540,000 tonnes of timber are felled annually of which 20% is left in the forests as residue. Sawmills discharge about 30% of the timber processed as wood chips and sawdust, and this is effectively utilized as fuel for factories and homes. The wood residue left in the forest could be used as fuel for gas engines if it could be economically collected.

Rice husks (produced at about 3.5 million tonnes a year) have been used as fuel for home cooking, brick burning, alcohol distillation, litter-substitute for poultry farming, a power source for rice-mills (husk gas engine), and so forth. If it is assumed that 20% of the total husk production can be used for rural electrification purposes, it has a power generation potential of 127 MW, which can electrify (at 80 W per household) 1.6 million households or about 10 million people.

Bagasse resources amount to 1.3 million tonnes a year. Its production is limited to 5-6 harvesting months in the dry season. Since bagasse cannot be stored for long time due to its high moisture content, power generation fueled by bagasse is limited to the dry season. It has been used as source of heat and electric power at sugar-mills but is not suitable for rural electrification of small and isolated systems. However, since the bagasse production is limited to such dry season when the output of hydropower stations drops, it could augment the dry season output of hydros if bagasse power stations were operated in parallel (in synchronization) with the Grid to feed their excess power.

Solar potential is abundant all over Myanmar. Wind potential is low in general and limited to the western coasts and inland wind corridors (along the Ayeyarwady River, western edge of Shan Plateau, etc.). These can be implemented only with external financial supports due to their relatively high costs.

Manufacturing of Small Hydros in Myanmar

In Myanmar, equipment for small hydros is manufactured in MEPE's workshops as well as in private workshops as shown below:

Table 4 Workshops Manufacturing Small Hydros Inspected by the Study Team

No.	Workshops	Nos. of Installations	Remarks
1.	MEPE workshop in Yangon	30	A total output at 13,548 kW, average station output at 450 kW, including equipments imported.
2.	U Khun Kyaw, Rural Development & Hydroelectric Implementation Group, Taunggyi, Shan State	33	Manufactured and installed small hydros of 5-75 kW since 1984, and accumulated adequate technology, which can be the model for proposed *Village RE Schemes*.
3.	U Kyaw Kyaw, U Taing Kyaw workshops, Sein Pann Industrial Co-op Ltd., Mandalay	9	Manufactured and installed five Pelton turbines of 3 kW each in Kachin State in 1983. Manufactured two Crossflow turbines of 5-10 kW in 1987. Manufacturing Francis and propeller turbines in 2002.
4.	U Paung Kyaw workshops, Sein Pann Industrial Co-op Ltd., Mandalay	30	Manufactured Pelton turbines of 5-50 kW since 1983, for Northern Shan.
5.	U Chit Hla and Sons、Aye Thar Yar Industrial Zone, Shan State	56	Manufactured Pico turbines of 5-20 kW since 1989.

Source: Hearing by JICA Study Team

In addition, there are many workshops manufacturing 2 kW generators, casting foundry, steel products, and so forth in Industrial Zones in Yangon. Among others, Triangle Link Engineering Co., Ltd., Yangon has good experience of producing penstock pipes, gates, and screens for small to medium hydros. They also have the capacity to manufacture turbines of 100 kW class if provided with design.

There are also contractors for building small hydros including transmission and distribution lines. These include Rural Development & Hydroelectric Implementation Group (RDHIG), Taunggyi, Shan State, and Aung Pyi Tun (APT), Yangon.

Local Technology of Rice Husk Gas Engine

Although there are commercially successful examples of biomass gas engines in China and Thailand, the removal of tar from the gas produced from rice husks by pyrolysis has proved difficult.

However, in recent years Myanmar Inventors Cooperative Ltd. (MIC) has succeeded in overcoming the problem and started commercial production of a gasification and engine-generator system in 1995. A total of 109 units of husk engine were installed up to 2000. These are mostly being used to power rice-mills.

In 2001, application to rural electrification was started.

The husk combustion chamber and filtering devices of the gas are all locally made. They convert second-hand diesel engines from trucks to spark plug ignition. It is possible that the supply of spare parts for aged engines may become an issue.

The cost of this rice husk gasification engine generator set is low. No special expenses are required for water treatment, unlike the steam turbine generator. It may be noted that the distribution line would normally cost more than the gasifier-generator set.

According to tests carried out in Japan (Agriculture Mechanization Research Institute), it reportedly required 3-5 kg of rice husk to generate 1 kWh. In comparison, data from China quotes 2.0-2.2 kg/kWh.

It is essential to test and confirm the actual relationship between fuel consumption and power generation of the MIC unit.

Local Technology for Battery-Lighting

Battery recycling shops are in operation on a commercial basis in most parts of the country. Batteries are collected nationwide and recycling manufacturers in Yangon produce the recycled batteries. The cases and connectors are recycled at shops operating in local areas. This recycling process reduces the disposal of old batteries and therefore reduces environment pollution.

Willingness to Pay (WTP) and Ability to Pay (ATP)

Willingness to pay depends on the current spending on light and fuels, that would be replaced by electric power. On the other hand, the ability to pay depends on net household income level. The income level in electrified villages was higher than in non-electrified villages for all three areas surveyed. It was K380,000 in electrified and K270,000 in non-electrified villages on average, resulting in an overall average of K290,000 a year. The average expenditure for initial connection fee including 12 monthly payments for the first year was K41,000 per household per year (K44,000 in electrified and K40,000 in non-electrified villages).

The average household expenditure for fuel and lighting was 4.9% of the annual total expenditure (Household Income and Expenditure Survey, CSO). That for urban was 4.8%. The fuel type for cooking in rural households was firewood at 93%, charcoal at 4%, and electricity at 1%. Lighting source of rural household was 18% by electricity, 32% by battery, and 50% by others.

Willingness to pay (WTP) for RE should be considered for 2 cases; the initial connection fee (which recovers initial capital costs) and monthly payments (which recover the monthly O&M expenses). The survey results show that the average WTP for initial connection fee is around K10,000. The WTP for the monthly payment is K570 on average. ATP is estimated by utilizing the amount of savings as shown in Table 5. ATP in the surveyed area is about $80 (K39,000) in the non-electrified villages and $140 (K 70,000) in the electrified villages. ATP is significantly greater than WTP.

Table 5 WTP and ATP

(Unit: Kyat)

Items	Non-electrified Villages	Electrified Villages
WTP for initial connection fee plus 12 monthly payments for the first one year	15,300	24,400
Annual income	266,000	380,000
Annual expenditure	227,000	310,000
Saving (ATP)	39,000	70,000

Source: Village Social Survey under the Study, 2001

Prospects for Community Participation

Although RE will proceed with Grid extension and construction of small hydros, if villagers only depend on MEPE for the provision of electricity they will have to wait a long time. Even on the optimistic assumption that RE level is improved by 2% per year, it would take more than 40 years for the transmission and distribution networks to reach the majority of the local towns and villages. In this regard, small-scale RE in Myanmar can only make significant progress if it is implemented on a self-help basis under the leadership of the villagers themselves.

The survey of the Study shows that the majority (57.8%) of villagers out of the 1,348 households surveyed had a positive will to participate, 33.2% neutral, and 9% negative. Of the positive replies, the indicated modes of participation were 1) as a member of VEC: 32.4% 2) as money collector: 14.9%, 3) as maintenance team member: 14.3%, 4) by paying tariff without delay: 14.0%.

2.4 Financial Considerations

Required Scale of Fund

Since the first oil crisis in 1973 when kerosene oil disappeared from the market in Myanmar, "diesel oil lamp" and "battery lighting" with 4-8 W lights have rapidly spread countrywide.

The rural electrification that MEPE implements by extending distribution lines from the interconnected and isolated grids aims at 24 hour supply. Small scale rural electrification implemented by VEC usually aims to supply 5 hours a day

(6:00 p.m. to 11:00 p.m.) at the minimum, as proposed by the JICA study team, to power three fluorescent lights of 20 W per household.

The demand for rural electrification will require 700 MW for 5.8 million households if the unit demand is assumed at 120 W per household (average of *Government* and *Village RE Schemes*). Taking into consideration that rural electrification cannot benefit from scale, it may be assumed that unit construction cost, including distribution lines, would be around $2,000 per kW even if local technologies and local resources were utilized to the maximum possible extent. On this basis, the total capital requirement for achieving rural electrification would be in the order of $1,400 million.

It is assumed that the minimum target for rural electrification is 166 village tracts, i.e. about 350,000 people, are to be electrified for lighting purpose every year with renewable energy. This would improve the rural electrification level by 1.2% a year. As shown below, about $15 million will be required annually as the aggregate costs to achieve the assumed rate of electrification:

Table 6 Assumed Rates of Rural Electrification and Capital Requirements

No.	Type	Capacity	House-holds	Price per Scheme	New VT Electri-fied per	Annual Total		
						House-holds	Popu-lation	Amount
			nos.	$ '000	nos./yr	nos.	1,000	$ '000
1	Rice husk gas engine	50 kW	300	40	140	42,000	252	5,600
2	Mini-hydro by MEPE	300 kW	2,000	1,200	5	10,000	60	6,000
	Village Hydro	50 kW	300	100	15	4,500	27	1,500
3	Solar BCS	16 kWp	200	230	6	1,200	7	1,380
Total			-	-	166	57,700	346	14,480

Source: JICA Study Team

Note: Mini-hydro by MEPE is for rural electrification for general use while rice husk gas engine and Village Hydro are for lighting purpose.

Financial Aspects of MEPE

MEPE is one of the State Economic Enterprises (SEE). SEEs are dependent on governmental budget. Their focus is not on increasing income, which is essentially allocated by the government, but rather on controlling expenditure to keep income and expenditure in balance (i.e. the "balanced budget" approach). There has been no finance from the private market since 1989, when the authorities shifted all their financial requirements to the budget, and in effect finance became an inter-governmental budget allocation.

The MEPE's picture of financial performance in its financial statements is very different from reality for two major reasons. One is the gap between the official exchange rate and the real market exchange rate. The other is the subsidization on prices of fuels.

MEPE's income statement has very low figures of interest and depreciation charges. This is because all foreign loans that the Government (not MEPE, since 1989) has taken out for power plant construction and equipment are charged to MEPE at the official exchange rate of only K6.3 to one US dollar.

Another gap is in the fuel prices. MEPE buys fuels from MOGE (Myanmar Oil and Gas Enterprise) at fixed prices, which are far below the inflation-sensitive market prices. The governmental prices of gas, oil and diesel are respectively K10/1000 cubic feet, K12/gallon, and K160/gallon. The market prices, which have been rising under inflation, are around $1.00/gallon for oil and diesel and $3.00/1000 cubic feet for gas. Assuming K1000=$1.00, the government prices of gas, oil and diesel are only 0.3%, 1.2%, and 16% of the respective market prices.

Financial Aspects of Village RE Schemes

There are three characteristics in *Village RE Schemes* that are considerably different to those of *Government RE Schemes*.

The first is the large unit cost required for lighting one household. This is due to the uneconomic nature of small-scale power plants, long transmission and distribution lines for scattered villages if electrified by the grid extension, and high unit consumption of diesel oil due to low efficiency if electrified by small diesel generator. It is, therefore, proposed that independent *Village RE Schemes* be implemented by utilizing low cost local technology, renewable energy resources, and villagers' participation in construction works.

The second is the difficulty in responding to sharp load fluctuation. Output of *Village Hydro* is manually controlled by operators and, therefore, cannot respond to sharp load changes. It is difficult also for a biomass gas engine to respond to load changes. On the other hand, the lighting demand in rural area is in general stable. However, if electric appliances other than lighting, cassette radio and small TV are used in many households, concurrent switch-on of such appliances would cause a significant load change to the generator. The proposed *Village RE Schemes*, therefore, should limit use of electric appliances to lighting, cassette radio, small TV, and similar. Use of electric fans, rice cookers, electric heater, and the like should be prohibited.

The third is the higher value of electricity despite the small demand. Because of the low electrification level, electricity is still rare and valuable for lighting and TV and radio, which cannot be used without electricity. Also, the prices of diesel and candle—substitutes for electric lighting—tend to be higher than in the urban area because of the additional cost of transport. This high value of electricity is the main driving force for *Village RE Schemes* on a self-help basis.

2.5 Proposed Strategy for Promoting Rural Electrification

It is proposed that substantial improvement in the level of rural electrification be made as early as possible by following two basic approaches as shown below:

- ***Government RE Schemes for 24 hour supply***: MEPE will, from the long-term viewpoint, develop small hydros of greater than 100 kW in remote areas on the one hand and extend distribution lines from the Grid on the other hand, in order to materialize the full scale electrification on a 24 hour basis for lighting and industrial/commercial demand as well.
- ***Village RE Schemes for lighting***: Villagers are to be encouraged to realize low-cost and sustainable electrification by rapid introduction of rural electrification schemes on a self-help basis in the short to medium term utilizing the domestic technology and local renewable energy.

In order to improve the rural electrification for domestic use as early as possible, *Village RE Schemes* should first be implemented to provide electric lighting.

Government RE Schemes

It is essential that MEPE continues the ongoing Generation Expansion Plan of the Grid, which will alleviate the severe load shedding being imposed in the Grid and will also contribute to securing the power source for rural electrification by grid extension. In addition to the Generation Expansion Plan, *Government RE Schemes* needs to implement the following rural electrification strategies to:

- Rehabilitate or augment the capacity of existing power stations of isolated systems (small hydros and diesels);
- Implement small hydros outside the Grid;
- Extend distribution lines from the Grid.

Village RE Schemes

- Provide electrification for lighting first, preceding full scale electrification by grid extension that may take even 10s of years depending on the location;

- Aim at electricity supply for lighting for 5 hours a day from 6:00 p.m. to 11:00 p.m.;
- Implement RE on villager's self-help basis with technical support from MEPE.

Even when the two basic approaches above are implemented, it is foreseen that some villages that lack renewable energy potential and are situated far from the Grid could be left un-electrified even after 30 years.

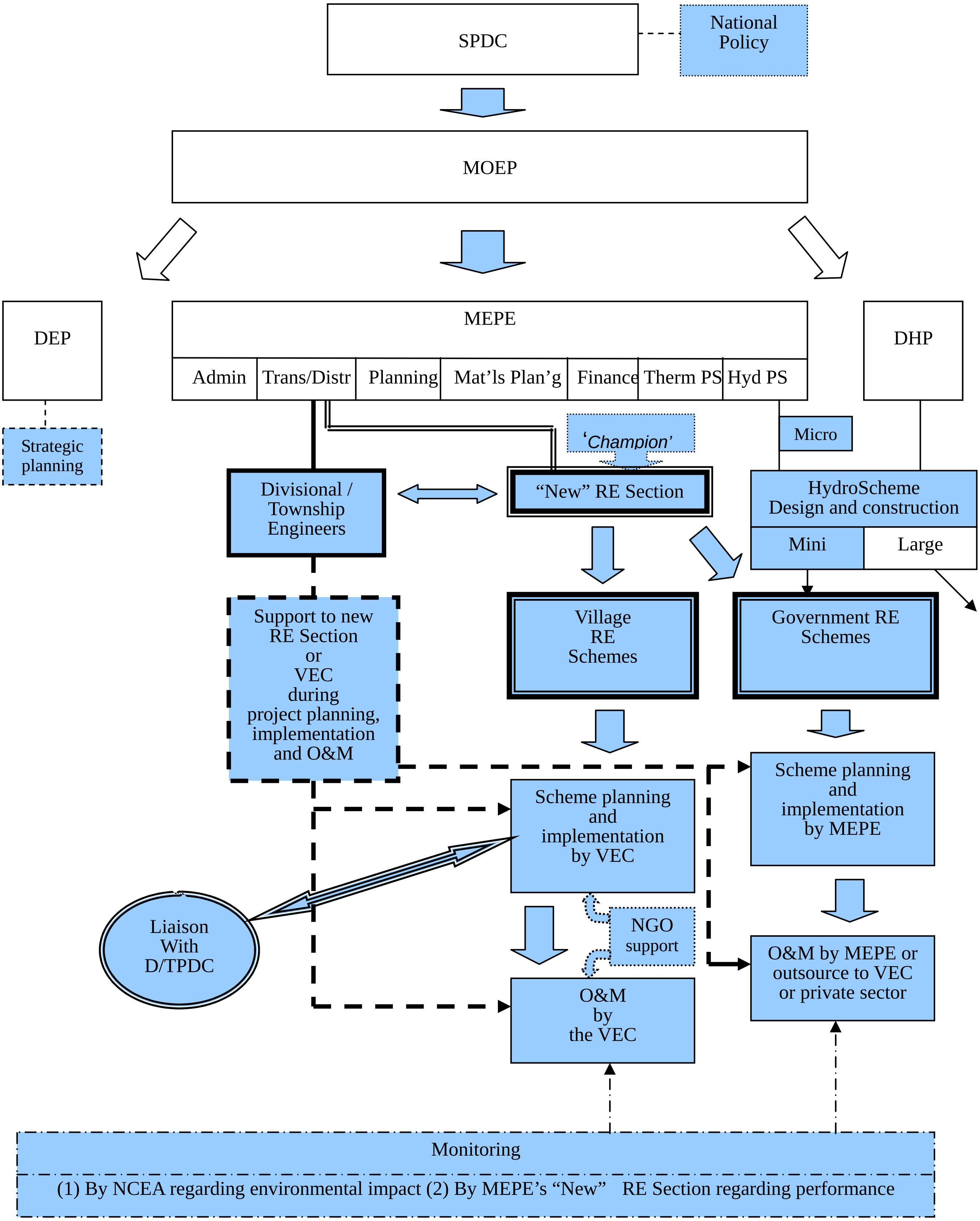
Social RE Schemes

In villages that would remain un-electrified by *Village RE Schemes* or *Government RE Schemes* for 30 years, it would be desirable that MEPE install BCSs to charge batteries for 8 W lighting as a semi-BHN (basic human needs) as well as to improve spatial imbalance. Such BCSs should be powered by solar or wind power and be complemented by Community Hall Lighting System of SHS type. Light emitting diode (LED) can be employed in such lighting systems for their high brightness and long life.

2.6 Necessary Measures for Facilitating Rural Electrification

Institutional and organizational proposals

The proposed institutional structure for sustainable RE is shown in Figure 6. This structure reflects the proposals of the Study for the most appropriate organisations to have responsibility for the central roles. These organisations and their roles are shown in Table 7.



Source: JICA Study Team

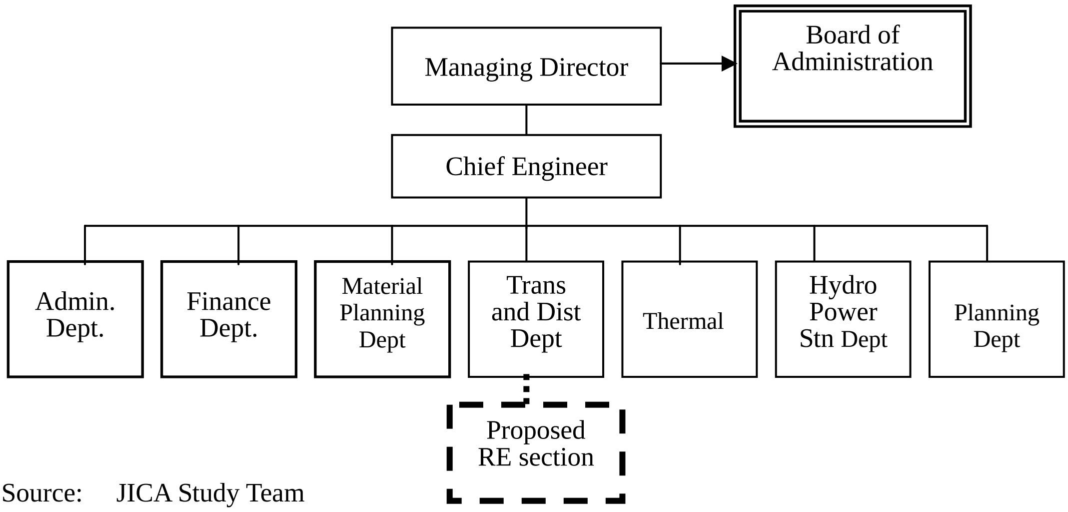
Figure 6 Institutional Arrangements for Sustainable RE

Table 7 Organisations Proposed for the Key Roles in RE

Role	Responsible organization	Other organisations involved
National policy	SPDC	
Strategic planning body	MOEP / DEP	
RE Champion	MEPE (through a new RE Section)	
RE scheme planning and implementation	MEPE or VECs or private sector	NGOs
RE scheme construction	Private Sector or MEPE or MELC and / or beneficiary community	Equipment fabrication cooperatives and NGOs
RE scheme operation and maintenance	MEPE or private sector or VECs	MEPE and NGOs will support VECs
Monitoring and evaluation	DEP + MEPE	NCEA

Source: JICA Study Team

In order to address the weaknesses and the key issues identified earlier, it is proposed to establish an RE Section within MEPE as shown in Figure 7. The diagram reflects the changes made to MEPE's departmental structure during 2002.

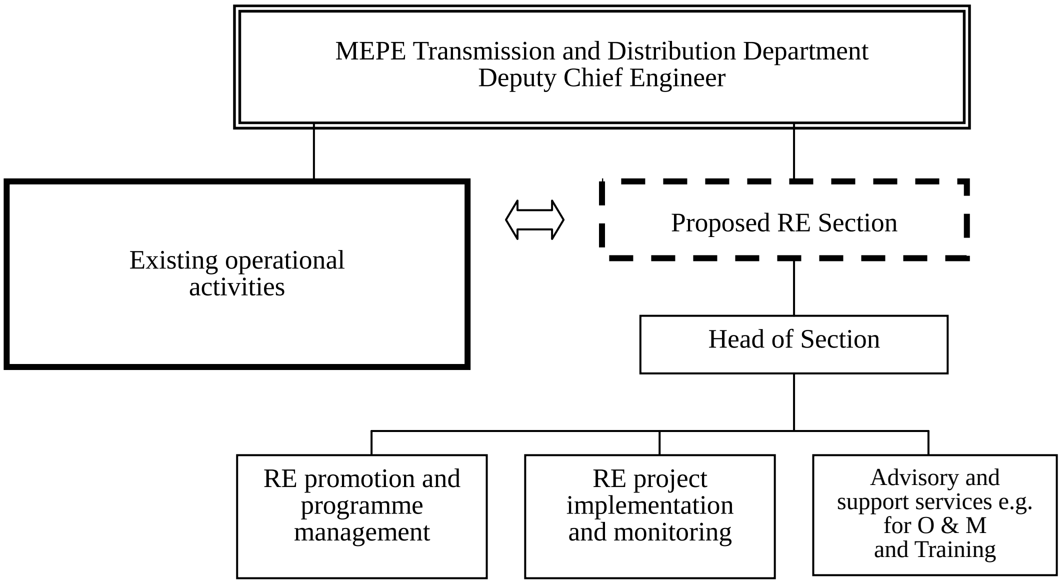


Source: JICA Study Team

Figure 7 Proposal for Introducing a New RE Section into MEPE

The proposed organisational structure for the RE Section of MEPE would have three units and each one would benefit from particular deliverables from the Study.

The organisational structure proposed for the RE Section is shown in Figure 8.



Note: Scope of work of all three units is to be related to RE Schemes using "all" relevant forms of renewable energy

Source: JICA Study Team

Figure 8 Proposed Structure of the New RE Section in MEPE

The new RE Section would provide the full scope of services (for *Government RE Schemes*) from scheme planning through implementation and O&M where appropriate. It would also promote, encourage and support *Village RE Schemes* and would manage the necessary information/publicity campaigns.

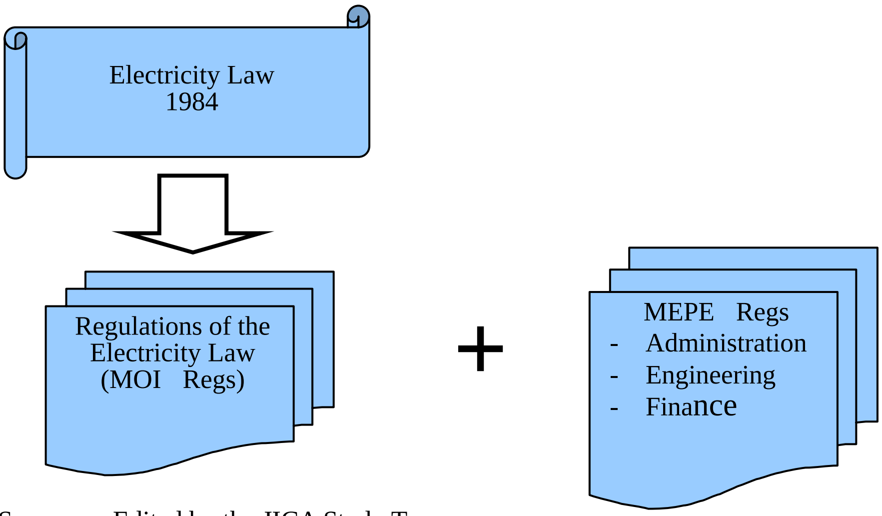
The Head of the RE Section would have the key responsibility for acting as the "champion" for rural electrification using renewable energy and, in addition, would be responsible for the performance of the three units in the section and for meeting the overall performance targets for the RE Section set by MEPE management.

If possible, the existing team of MEPE staff forming the "Energy Sub Committee" (acting as the liaison agency for RE work in the Border Areas requested by SPDC's Works Committee) should be incorporated in the new RE Section.

NGOs are foreseen to make a positive contribution to the promotion and implementation of RE schemes. There are already some capable NGOs / cooperatives active in Myanmar regarding renewable energy / RE.

In order to kick start the promotion of RE using renewable energy particularly regarding self-help schemes, there will be a benefit if a new NGO could be encouraged to become established.

The existing legal framework related to RE has been reviewed and is shown in Figure 9.



Source: Edited by the JICA Study Team

Figure 9 Existing Legal Framework

In a general sense, much of the necessary policy and legislation is in place. However the legislation is now quite old and in need of modernisation.

A major policy thrust to boost the level of RE would include (1) a restatement by the government of its commitment to the development of the rural areas, and (2) the preparation of a strategic plan (with targets and a budget) to improve the level of RE with a focus on the use of renewable energy sources/technologies.

In support of the above, effective publicity demonstrating the opportunities for self help for RE (including reference to examples of what has and can be achieved) is also needed.

The Electricity Law 1984, a relatively brief document, is in need of review, expansion and modernisation. The MOI Regulations that support the implementation of the Electricity Law 1984 are likewise in need of review, expansion (particularly to cover the different technologies related to the various forms of renewable energy) and modernisation.

There is a need for a set of model regulations to serve the VECs in their role of developing, operating, managing and maintaining small isolated RE schemes. Such model regulations could form an attachment to the updated MOI Regulations. They will no doubt need tailoring in some instances to suit particular RE schemes.

With reference to VECs it may be noted that the existing ones have usually been set up on an ad hoc basis with some external assistance e.g. from MEPE, an NGO, the Ministry of Cooperatives, or the equipment/technology supplier.

Operation and maintenance of existing isolated electrification systems in the rural areas of Myanmar (i.e. all systems outside the Grid) is generally carried out by either MEPE or VECs. The isolated systems operated and maintained by MEPE are either small hydropower schemes or diesel generator plants.

The systems operated and maintained by VECs cover a wider range by types i.e. micro hydro, solar power (battery charging or village water supply), and biomass (rice husk) schemes.

Common problems currently affecting operation and maintenance of both *Government and Village RE Schemes* have been identified and demonstrate that there is a need for:

- Guidance on setting up operational management organisations
- O&M manuals and operational guidelines
- Better availability of spare parts
- Improved funding
- Technical support from MEPE and/or NGOs
- Training of O&M staff

With regard to capacity building, a summary of the main areas where this is needed is given in Table 8 together with the related training options.

In order to address the skills shortage of engineers for RE schemes using renewable energy it is proposed to develop the MEPE training centre in Yangon as the focus for capacity building of staff from the divisional offices. The trained staff will, in turn, guide and support the VECs on the *Village RE Schemes*.

Table 8 Summary of Areas Needing HRD and the Options for Training

Areas needing capacity building / HRD	Options of potential sources of training or skills transfer
MEPE Engineers – mini-hydro design and project management skills	MEPE
MEPE Engineers – site survey / investigation and construction management	On the job training arranged by MEPE
MEPE Management – strategic planning, social components in development of RE projects	External sources
NGOs – programme management	Consultant
VECs – implementation, community participation, operational, administration and financial management	MEPE + NGO
VEC's O & M staff – technical and operational safety aspects of particular technologies	MEPE + MICL + MSTRD + NGO

Source: JICA Study Team

Tariff aspects

The chronic shortage of budget for new investment is directly linked to the shortage of income and the low level of cost recovery. The main reason is the very low level of the MEPE tariff, which is fixed despite nation-wide inflation being 10 to 20%. The current tariff level was fixed to the level of the other ASEAN countries in 1999. However, because of inflation and the depreciation of the kyat, the comparable MEPE tariff calculated with 1000K/$ for year 2003 is less than one tenth of the other ASEAN countries. Power companies in the other ASEAN countries suggest the unit (kWh) tariff level should be at least five cents without profit or at least six to seven cents to become sustainable with profit. Maintaining the fixed tariff will continue to exacerbate the shortage of income. The long overdue requirement is for a flexible tariff system linked to major cost components, especially imported fuel.

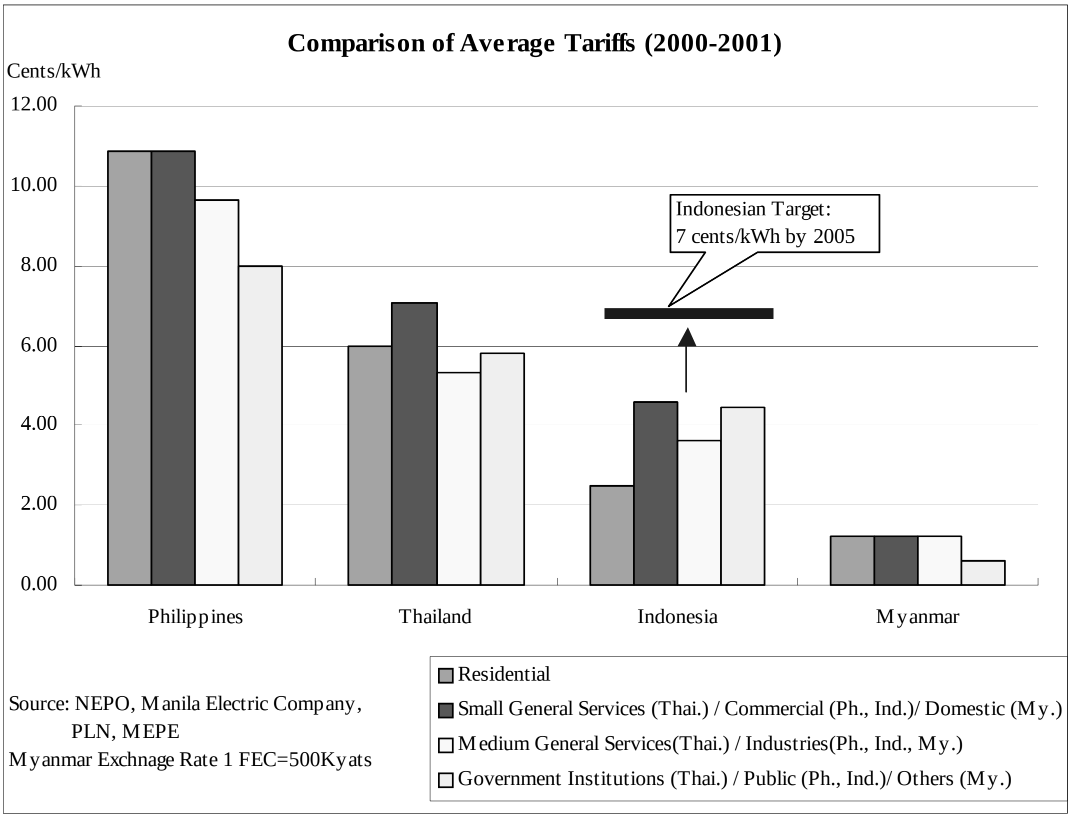


Figure 10 Comparison of Average Tariffs

Financial Aspects of Rural electrification

For rural electrification, the options of *Village Hydro* and rice husk gas are now emerging in Myanmar as locally available technologies. The cost is in the order of $130 per household. This is much larger than the willingness to pay—about $1-2 per household for monthly payment and about $20 at one time for the initial connection fee, although the ability to pay is around $80 per year.

- Financial Source

  The initial investment cost is several times larger than the amount one household can afford at one harvest. This is the financial bottleneck of the *Village RE Schemes*. Financial sources for villagers are very limited—self-funding, suppliers' credit, cooperative bank loan, donation, and MADB loan—and most villages have to rely on self-funding. In fact, according to examples of *Village Hydro*, the typical construction cost is about $130 per household, which is too large for one household to pay in a year. Therefore, they cannot pay the initial cost at one time, rather they need several payments over two to three years. This is the reason why a financing system such as a rural electrification fund for small-scale short-term loans, if established, would greatly improve the prospects of *Village RE Schemes*.

- Completion Guarantee

  One of the big obstacles to implementing *Village RE Schemes* is the anxiety of both villagers and local suppliers (experts/contractors). Although villagers want electric lighting, they are not sure about outsider expert opinion. Their main anxieties relate to understanding the technical feasibility and reliability of the cost estimate presented by an outsider. On the other hand, the local expert/contractor worries about the ability and willingness of the villagers to pay for the power plant once constructed. Because there is no competitive market for rural electrification, the price and quality of *Village RE Schemes* are a matter of mutual trust between the villagers and the expert/contractor. In this regard, it is proposed that a completion guarantee system be established to support villagers in making the final decision for implementing *Village RE Schemes*. As the first and practical step to this end, a third party opinion on the technical feasibility and fairness of cost estimates, if provided by a neutral expert like MEPE, would greatly enhance mutual trust between the two key parties involved.

Framework for Selecting Source of Renewable Energy for Rural Electrification

A framework for the preliminary selection of the most appropriate form of renewable energy for electrification of villages in each region is given in Table 9.

- Small hydros are most suitable in the Shan Plateau, Chin State and Kachin State.
- Biomass gas engines are suitable countrywide wherever there is an excess of rice husks or wood chips/sawdust available at low cost from nearby rice-mills or sawmills.
- In the remote mountainous areas, Pico hydro is suitable if there is a suitable stream: if not, solar-powered BCS may be adopted provided external financial support is available. Subject to financial capacity, Solar Home System (SHS) could be implemented elsewhere.
- Wind-powered BCS may be employed where local wind potential exists.

3. Manuals for Sustainable Small Hydros

3.1 Preparation of Manuals

The Manuals were prepared during the planning and design of the priority projects and also during the monitoring of Zi Chaung small hydropower station, Kalaymyo, Sagaing Division. The Manuals consist of the following four parts:

Part 4-1 O&M Manual-Small Hydros

Part 4-2 Design Manual-Small Hydros

Part 4-3 Design Manual-Village Hydros

Part 4-4 Institutional and Financial Aspects

3.2 O&M Manual-Small Hydros

The O&M Manual is intended for the use of operators and maintenance staff of the small hydropower stations of MEPE. The installed capacity is assumed to be 50 kW to 1,000 kW per unit. The manual consists of four chapters and appendices.

Chapter 1 presents organization and rules, which cover recording and management of O&M data, liaison and reporting system, custody of manuals and drawings, capacity building of maintenance and management engineers. Chapter 2 presents the operation manual, covering operational procedure, operation skills, and operation for peak load.

Chapter 3 deals with inspection, maintenance and repairing aspects. It presents maintenance works, an outline of principal equipment, and points of maintenance, characteristics and tests of principal equipment, and maintenance rules.

Chapter 4 covers inspection, maintenance and repair of civil works, including hydro-meteorological monitoring, inspection works required, civil works and hydro-mechanical works to be maintained, and sand-flushing operation and countermeasures.

3.3 Design Manual-Small Hydros

The Design Manual-Small Hydro is intended to serve those engineers of MEPE and DHP including maintenance staff of small hydropower stations of MEPE. The station scale would be in the range of 50 kW to 10,000 kW. It consists of three chapters. Chapter 1 presents investigation and planning and Chapter 2 the design of civil structures. Chapter 3 presents the design of hydro- and electro-mechanical equipment.

3.4 Design Manual-Village Hydros

Design Manual - Village Hydro is to serve those MEPE engineers who design and construct small electrification schemes with *Village Hydro* having a unit capacity smaller than 50 kW. Design Manual - Village Hydro would also be useful to those people and organizations in the private sector who support or undertake design, manufacturing and construction of electrification schemes with *Village Hydro*.

A Visual Guide has also been prepared in the Myanma language containing the essence of the Guidelines and Design Manual-Village Hydro, targeting villagers who wish to electrify their village on a self-help basis. It provides the following:

- Selection of renewable energy sources suitable to villages;
- Explanations of *Village Hydro*, Rice Husk Gas Engine, Solar and Wind Power;
- Visual manual for *Village Hydro*; and
- Technical references.

3.5 Institutional and Financial Aspects

This manual illustrates the organizational structure and role of the proposed RE Section which is to be attached to the Transmission and Distribution Department of MEPE. The RE Section is expected to perform the following functions:

- RE promotion and program management;
- RE project implementation and monitoring; and
- Advisory and support services for the implementation and O&M of *Village RE Schemes*.

It contains procedures for 16 key tasks proposed to be undertaken by the RE Section.

4. Preparation of Development Plans for Priority Projects

4.1 Identification of Potential Schemes

The potential sites for small hydropower schemes were first identified by requesting hydropower engineers of DHP to select 15 schemes from its long list. The list was further shortened to nine schemes by analyzing past study reports and maps and by interviewing hydropower engineers of MEPE who had actually been to the sites. Out of these schemes, the Study Team conducted site reconnaissance of seven schemes. For the two sites that seemed most feasible, topographic survey, discharge measurement, and test pitting were conducted.

During the field inspection, there were opportunities to visit five existing small hydropower stations of MEPE. Serious sedimentation and the malfunctioning of the turbine/generator controller were the most prominent problems common to all the hydropower stations visited. The grave importance of timely rehabilitation of these small hydropower stations has also been recognized by the MEPE staff concerned. Rehabilitation is one of MEPE’s priorities.

It is judged that the introduction of the rice husk gas engine being manufactured by a local cooperative since 1995 is appropriate for rural electrification in the paddy growing areas and in semi-urban areas with big rice-mills. However, the use of the rice husk gas engine for rural electrification has only recently begun, and its operation by VECs is not yet well established. Therefore, it was deemed necessary to implement a model project to demonstrate the performance of the system to the public.

4.2 Selection of Priority Schemes

The 15 schemes in the initial long-list was composed of seven hydropower schemes, four biomass schemes, two solar-wind BCS schemes, one rehabilitation scheme of three small hydropower plants, and one capacity building scheme. These were evaluated according to the Selection Criteria proposed in the Guidelines. These schemes were ranked in three classes: Priorities A, B and C according to the points acquired.

Out of these candidate projects, one scheme each of 1 MW-class, 100 kW-class, and 10 kW-class were selected as the Priority Development Projects. Although the three proposed rehabilitation projects also have a high priority, they were excluded from the selection of the new Development Projects.

Eventually the following three schemes were selected as Priority Development Projects:

- Electrification Plan of Nyaung Shwe Township by Heho Small Hydro;
- Electrification Plan of Nam Lan Township by Mini Hydro; and
- Lighting of Sama Lauk Village by Rice Husk Gas Engine.

The Nam Lan scheme was selected jointly by the JICA team and the MEPE counterpart team as the Pilot Project to be implemented and monitored as part of the Study. However, it was finally decided not to implement the Nam Lang scheme as Nam Lang Township would be electrified in 2005 by extending transmission lines from Hsipaw where a new Grid substation will be erected connecting Shweli power station (200 MW) and Mandalay.

Accordingly, another Minutes of Meeting was exchanged between the JICA S/W mission and MOEP in August 2002. It was agreed to select one of the existing small hydropower stations of MEPE and to monitor it for preparation of the O&M Manual.

4.3 Electrification Plan of Nyaung Shwe Township by Heho Small Hydro

The Heho scheme is a run-of-river type hydropower plant with an installed capacity of 8 MW. It is located on the Negyiya Chaung, which has an average discharge of 4.1 m^3/s. It will develop a gross head of 229 m via a waterway of about 2 km long. The power generating facilities will include a headrace tunnel about 1,220 m long and penstock about 770 m long.

The scheme is to electrify the villages of Nyaung Shwe Township situated along the shore of Inle Lake. Nyaung Shwe Township covers eight quarters and 35 village tracts. It has a population of about 153,000 in 23,552 households. The households in the villages are 21,690 with population of 140,454 (92% of the township total). The household electrification level is 52% in the eight quarters of Nyaung Shwe Township as of 2001 but only 0.4% in the 35 village tracts where 92% of the population reside.

Data from the topographic survey, discharge measurements, and test pitting were utilized to design the scheme. Electricity demand and WTP were also surveyed through the village social survey.

4.4 Electrification Plan of Nam Lan Township by Mini Hydro

A run-of-river type hydropower plant with an installed capacity of 320 kW is planned on the Ho Sant Chaung, situated 4.5 miles from Nam Lan, Nothern Shan. This is to electrify the villages of Nam Lan and substantially improve the present supply conditions in the households having power supply of 3 hours a day at very low voltages, or having only an 8 W tube-light with small battery.

Although the power system will be the property of MEPE, its O&M and management of the electricity business may be entrusted to a VEC, except for major inspection and overhaul of the turbines, generators, etc.

The target of the scheme is to achieve a significant financial surplus of the electricity business before depreciation costs, as well as to realize the O&M and management of the business without stationing MEPE staff at the site.

Nam Lan covers 11 quarters and 5 satellite villages. There are 2,082 households including 237 in the villages and the population is 12,229 including the village population of 1,182. Nam Lan may be considered to be a semi-urbanized village.

Of the 2,082 households, only 284 are electrified with 3 hour power supply by MEPE. The electrification level is only 15.4% in the 11 quarters and nil in the five villages.

Assuming 100 W is to be supplied at the initial stage to 93% of the 2,082 households in Nam Lan, the required capacity for power supply will be 270 kW (including 15% as distribution losses).

There would be day time demand in the order of 250 kW from 18 rice-mills, six oil mills (ground nut), and four existing mechanical repair shops.

Nam Lan is 2-3 hour by road from Hsipaw (even in the rainy season). The road from Nam Lan to the site requires significant improvements.

4.5 Lighting of Sama Lauk Village by Rice Husk Gas Engine

Sa Ma Lauk Village was selected as a Model Village for electrification with rice husk gas engine. Sa Ma Lauk is located approximately 50 km to the west of Yangon along the Yangon-Pathein Highway near the border of Yangon and Ayeyarwady Divisions. It belongs to Nyaung Don Township, Ayeyarwady Division.

The main objective of the Model Village is to test and monitor the implementation, O&M, and management of *Village RE Schemes* by VEC on a self-help basis in order to best-adapt the concept of RE using husk gas engine to the paddy cultivating villages in Myanmar.

Assuming three 20 W lights per household and one 60 W TV per four households (or one 15 W radio per household), the average household demand will be 75 W. The lighting demand would be about 13 kW upon commissioning with about 200 households. The rice husk gas engine will electrify those households that are located in the central part of the village within about 1,000 m of the engine-generator. The electricity generated will be supplied to each household by 230 V distribution lines. The electricity will be supplied for only 5 hours a day from 18:00 to 23:00. The capital cost of the husk gas engine generator system and distribution lines is estimated to be about $130 per household. The operation and maintenance cost is estimated to be $6 per household per annum.

For the industrial demand, it is required that business should supply their own diesel or husk engines as power sources until such time as the Grid connection is realized.

Power consumption per household would be:

75 W x 0.75 (factor of concurrent use) x 5 hour/day x 30 days/month

= 8.4 kWh/month

The monthly tariff would be in the order of K600 per household per month. The unit price would be about 71 K/kWh or about 0.11 $/kWh (i.e. much higher than the current tariff of MEPE at 2.5 K/kWh).

5. Database for Rural Electrification using Renewable Energy Sources

A Database for rural electrification using renewable energy sources was compiled during the course of the Study. It contains the outputs of the Study such as Guidelines, Manuals and Development Plans. It also contains data and information collected through the Study that may be referred to in promoting rural electrification using renewable energy such as project reports, references, and catalogues.

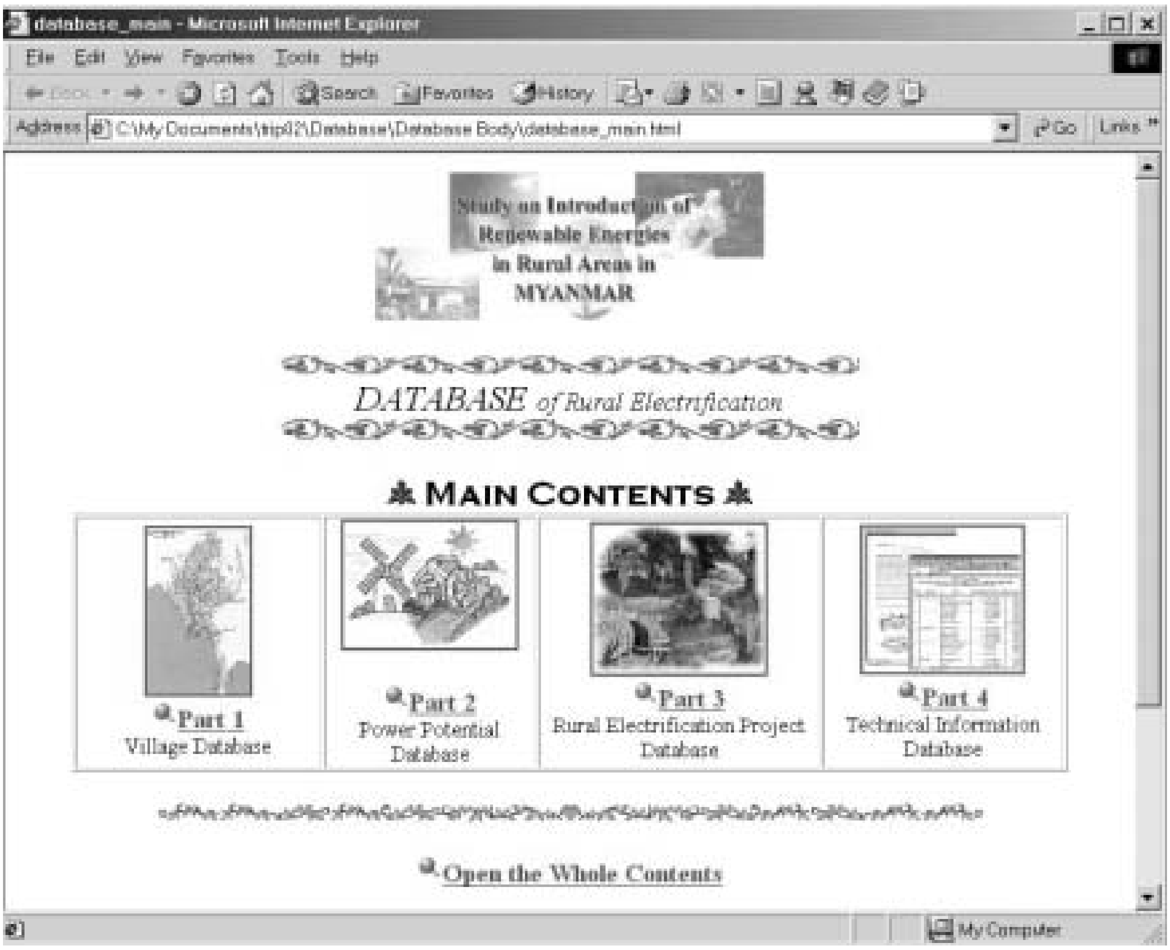
The Database consists of four parts as shown below:

Item	Title	Description
Part 1	Village Database	Database of rural areas in Myanmar such as township and village information, statistical data, and maps.
Part 2	Power Potential Database	Database of potential for renewable energy including hydro, biomass, solar, and wind power.
Part 3	RE Project Database	Rural electrification project database for reference in planning.
Part 4	Technical Information Database	Database of technical reference that would be useful for rural electrification such as catalogues, computer programs, project reports, thesis, and so on.

It consists of electronic files, a search system, and a HTML viewer with hyper links to files.

Training of MEPE staff in the use and contents of the Database was given during the period 9-15 June 2003 and included:

- Operation of Database Viewer;
- File system and updating;
- Introduction of search system; and
- Getting started and installation.



Source: JICA Study Team

Figure 11 Main Menu of the Database

6. Conclusions and Recommendations

The opportunity exists to make a significant improvement to the current low level of electrification in the rural areas of Myanmar putting in place the institutional capacity to promote, fund, implement, co-ordinate and monitor a long term RE programme comprising *Government and Village RE Schemes* using appropriate sources of renewable energy. The Study provides several of the key tools needed to support such a programme.

Myanmar is blessed with abundant renewable energy such as hydropower potential, biomass (rice husk, wood chips, etc.), and solar power. Moreover, Myanmar has its own unique technology such as manufacture/construction of *Village Hydros* smaller than 50 kW, biomass gas engine, technology for battery lighting and market system for battery recycling. These resources and technologies facilitate low cost *Village RE Schemes* which would be affordable to many of the villages in Myanmar.

It is recommended that the following measures be taken to accelerate and sustain rural electrification in Myanmar:

- Appoint MEPE as ***Champion for Rural Electrification*** and establish a ***Section of Rural Electrification (SRE)*** and attach it to the Transmission and Distribution Department of MEPE;
- Rehabilitate existing small hydros and diesel generators owned and operated by MEPE;
- Implement, as *Government RE Schemes*, full scale rural electrification for 24 hour supply by constructing new small hydros in remote areas and extending distribution lines in the areas near the Grid after reinforcement of the generation capacity by the ongoing projects;
- Endorse and encourage *Village RE Schemes*;
- Study the establishment and management of a ***Rural Electrification Fund*** and ***Completion Guarantee System*** to support the implementation of *Village RE Schemes* on a self-help basis;
- Implement ***Capacity Building*** for design, construction, operation and management of rural electrification projects; and
- Financially support *Social Schemes*.

VISUAL GUIDE

September 2003

Visual Guide

Contents

1. Selection of Renewable Energy Source for RE

- Framework for Preliminary Selection of Form of Renewable Energy by Location
- Flow Chart for Selection of Renewable Energy Source for RE

Framework for Preliminary Selection of Form of Renewable Energy by Location

No.	Region	DHP		MEPE and VEC			
		Extension of Distribution Lines from National/Local Grids	Small & mini-hydro	Village Hydro (Micro/Pico)	Solar BCS	Wind BCS	Biomass gas engine
			50-10,000 kW	<50 kW	0.1-3 kW	0.5-3 kW	10-50 kW
1	Mountain Regions	★	★★★★★	★★★★★	★	★★	★★★★★ with rice husk or sawdust
2	Delta and Paddy Cultivating Regions	★	-	★ on irrigation channel	★	★ where wind prevails	★★★★★ with rice husk
3	Coastal Regions	★	★★	★★	★	★★	★★★★★ with rice husk or sawdust
4	Remote and hardly accessible areas	-	★★	★★★	★★★★★	★★	★★★★ with rice husk
5	Urban Areas including Suburbs	★★★★★	-	-	-	-	-

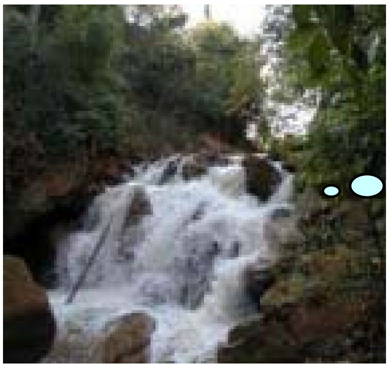
Legend: [shaded box] This pattern means out of scope of the current study.
★ to ★★★★★ Shows level of potential for implementation.
Biogas may be useful for lighting and cooking in those households in the border areas which are scattered in wide areas and, therefore, favor such individual system as for own home use rather than the distribution line-connected RE system.

Need for Rural Electrification

↓

Establishment of VEC

↓

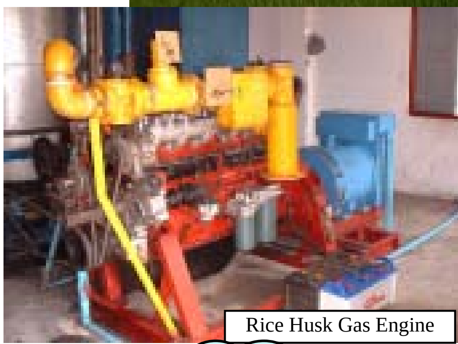


Hydropower can be developed efficiently by use of water falls

Existence of Existing Hydro → Yes → **Rehabilitation of Existing Hydro**

Consult MEPE Township Engineer

↓ NO



near MEPE Grid → Yes → **Extension of Grid**

Distance to Grid < 10 km

↓ NO

Site Specific Hydro Potential near Demand

Existence of Hydro Potential → Yes → **VILLAGE HYDRO(< 50kW)**

Check Points for Hydro

① Q_{min} < 0.5 m^3/s
② Head < 30 m
③ Household < 300
④ Distance to site < 1 km

→ **P < 1 kW : Module Type Turbine**

→ **P > 1 kW : Site Specific Design**

↓ NO

Existence of Biomass Potential → Yes → **BIOMASS (10 ~ 50 kW)**

Availability of Biomass is Essential

Check Points for Biomass

① Rice Husk or Saw Dust
② Household 100 - 500
③ Village area < 1km^2

↓ NO

SOLAR/WIND BCS (0.1 ~ 3kW)

Not Site Specific, but Temporary Electrification

① Remote/Isolated areas
② Household < 100

Flow Chart for Selection of Power Source for Rural Electrification

2. Small Hydro

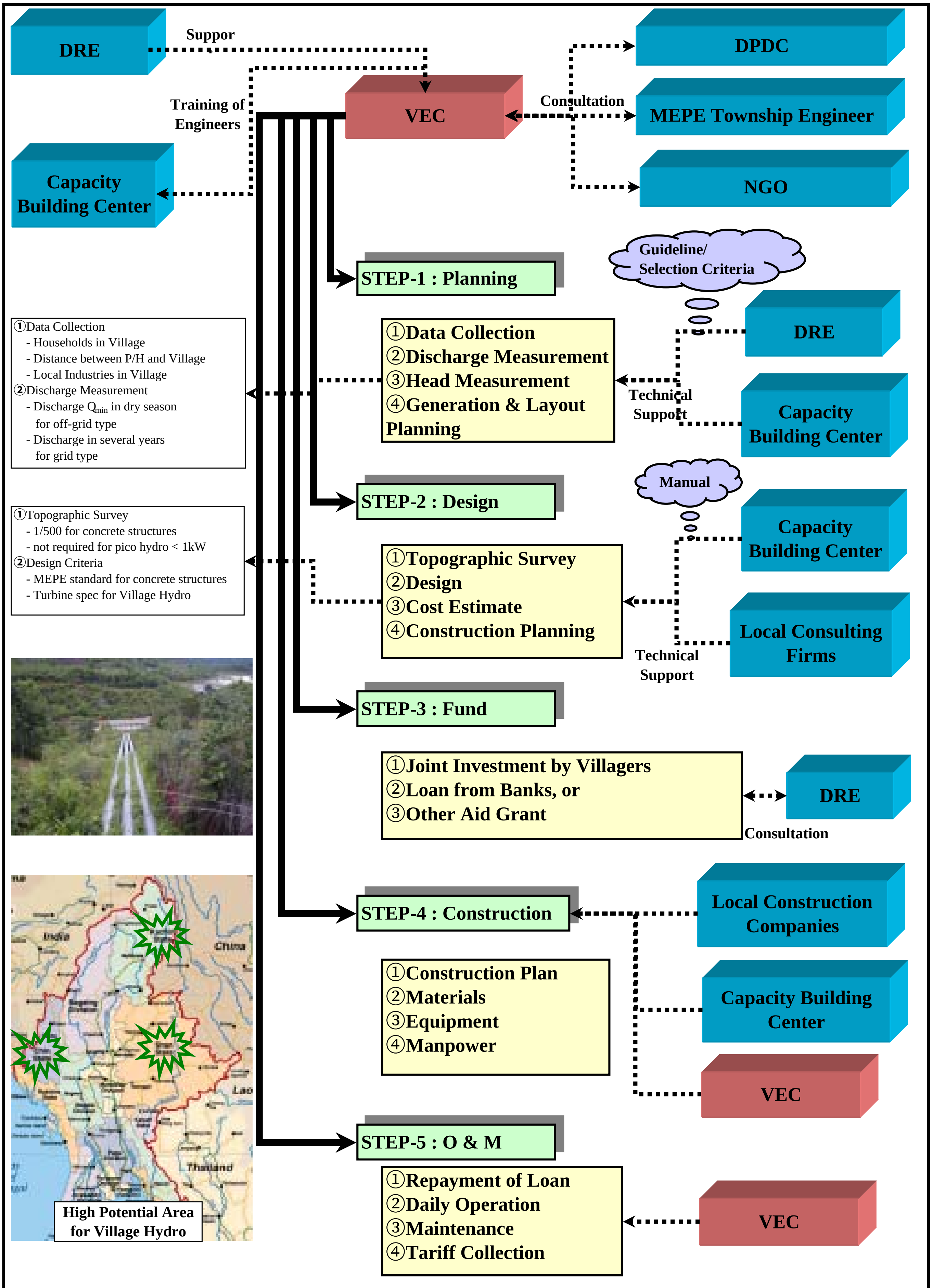
Small hydro 1,000-10,000 kW by DHP

Mini hydro 100-1,000 kW by DHP

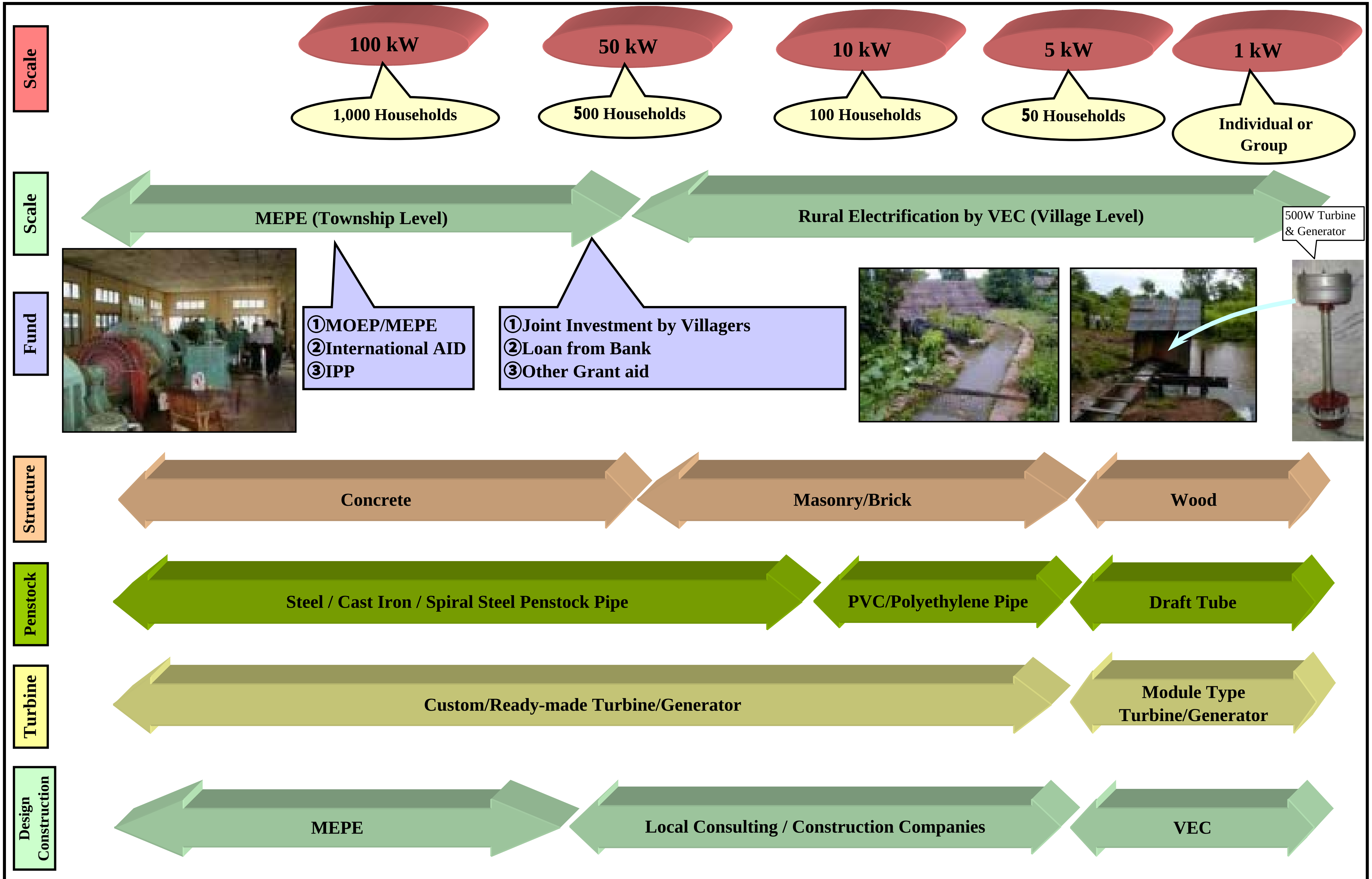
Micro hydro 50-100 kW by MEPE

Village Hydro 1-50 kW by VEC

Pico hydro <1 kW by individual or household group



Flow Chart for Implementation of the Micro Hydro for Village Scheme



Demarcation of Work by Project Schale

MICRO HYDRO DEVELOPMENT

Discharge Measurement

Head Measurement

Power = 9.8 Q(m^3/s) x Head(m) x η

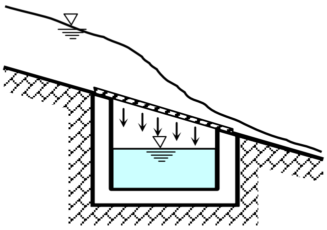
Topographic Survey

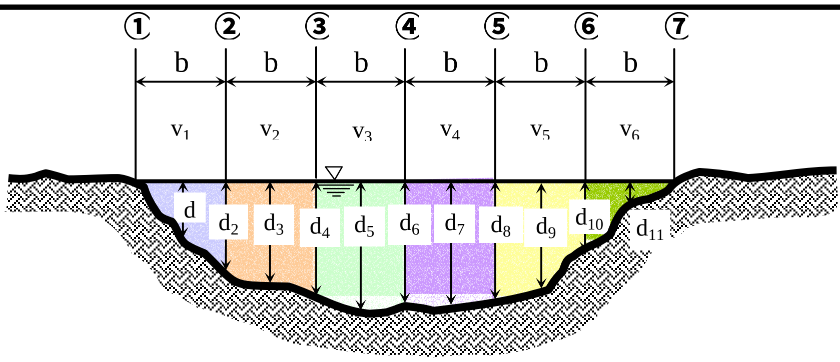
Design

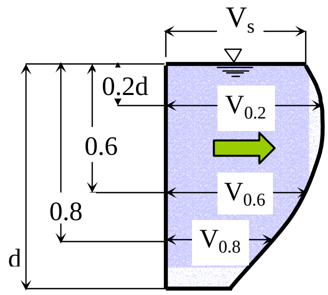
Construction

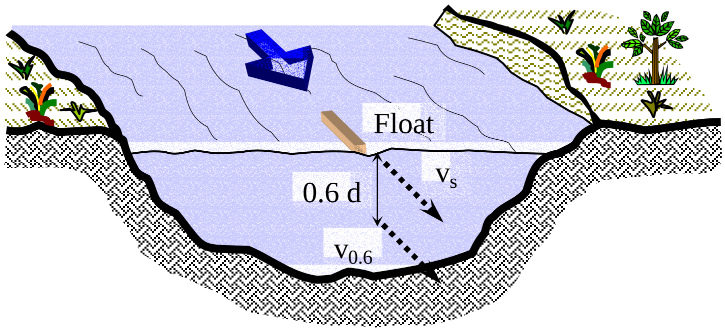
Tyrolean - type Intake

Tyrolean-type intake is suitable for steep river containing boulders









Discharge Measurement
(1) Velocity Measurement
(2) Area Measurement

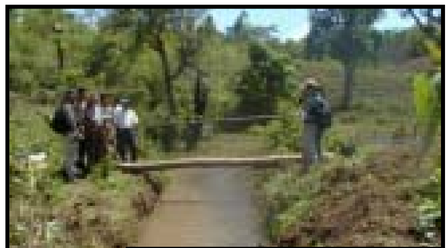
Discharge Measurement Using Float or Current Meter

①Float $V_m = 0.8 \cdot V_s$

②Current meter (1 point) $V_m = V_{0.6}$

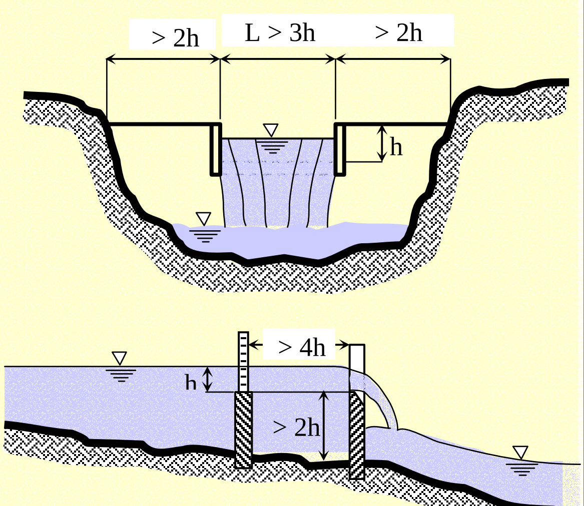
③Current meter (2 points) $V_m = (V_{0.2} + V_{0.8}) / 2$

Q (m^3/s) **= Area** (m^2) $\cdot$ **V_m** (m/s)



Velocity Measurement Using Current Meter

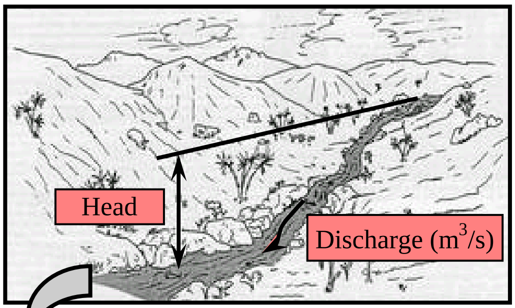
Area Measurement

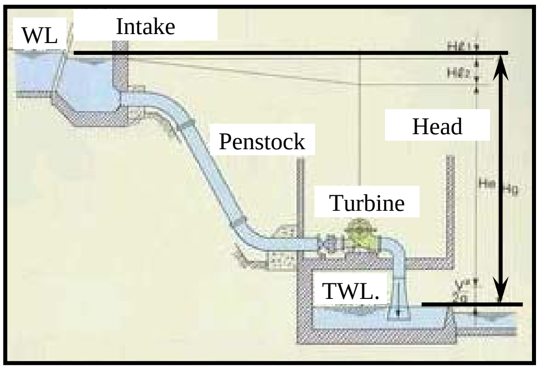


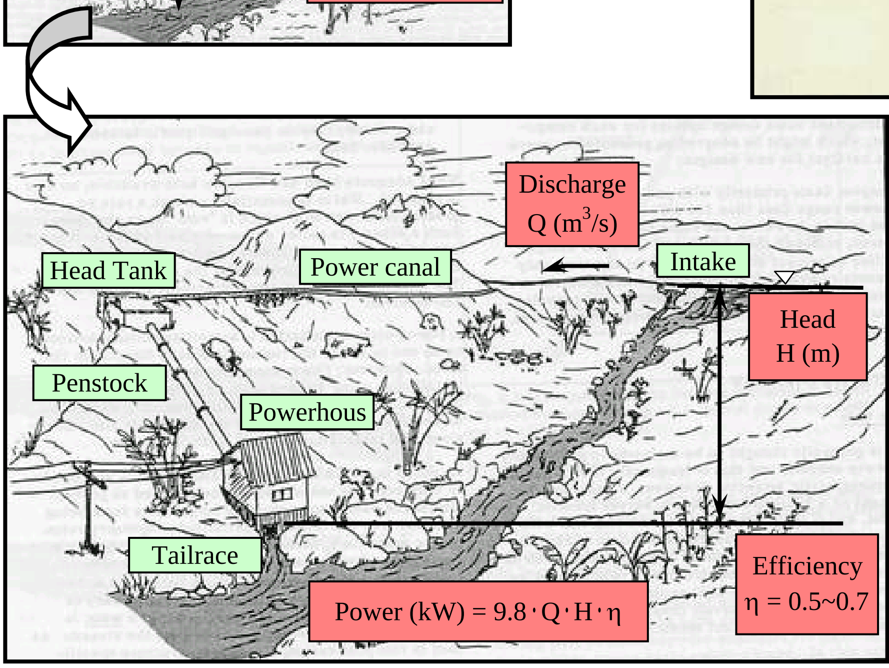
$$Q\ (m^3/s) = 1.8\,(L - 0.2\,h) \cdot h^{1.5}$$

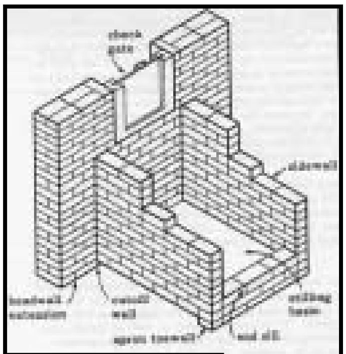
Discharge Measurement Using Weir

Discharge Measurement for Village Hydro



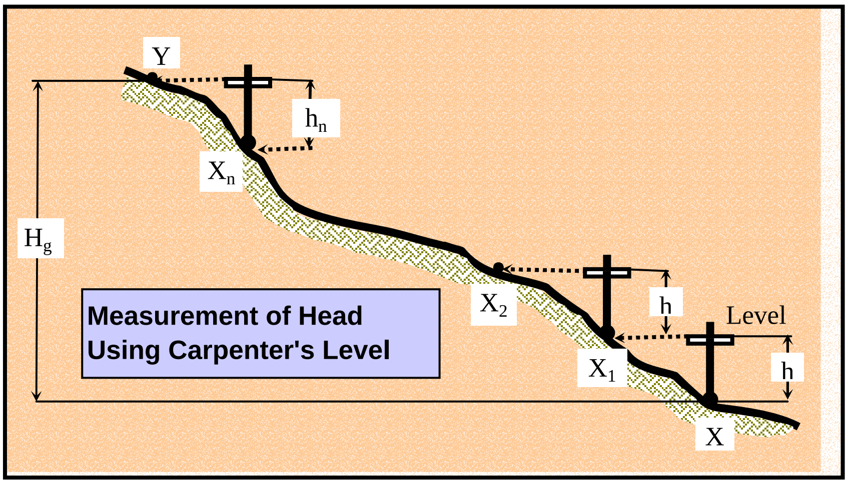




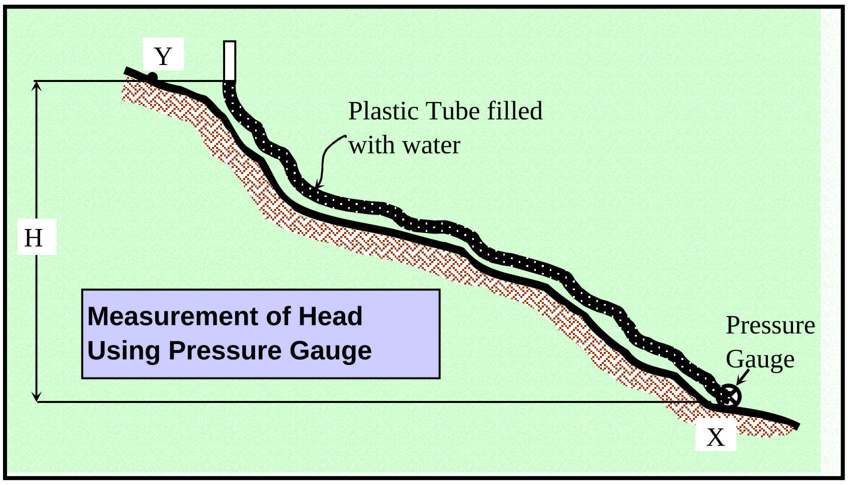


Brick Masonry Intake

GPS to measure coordinates & altitude



Measurement of Head Using Carpenter's Level



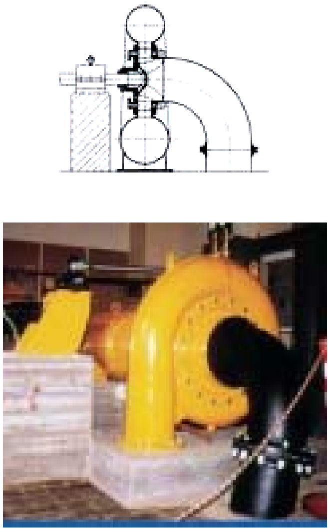
Measurement of Head Using Pressure Gauge

Distance Meter

Clinometer

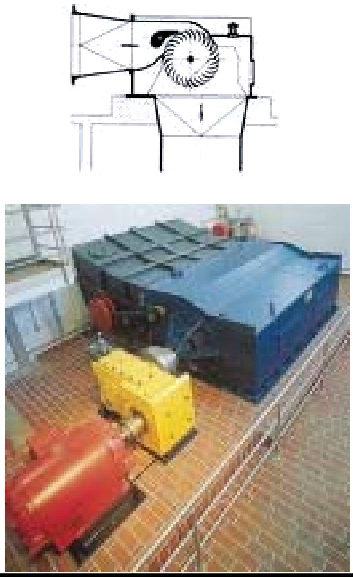
Head Measurement for Village Hydro

Francis Turbine



Pelton Turbine

Crossflow Turbine



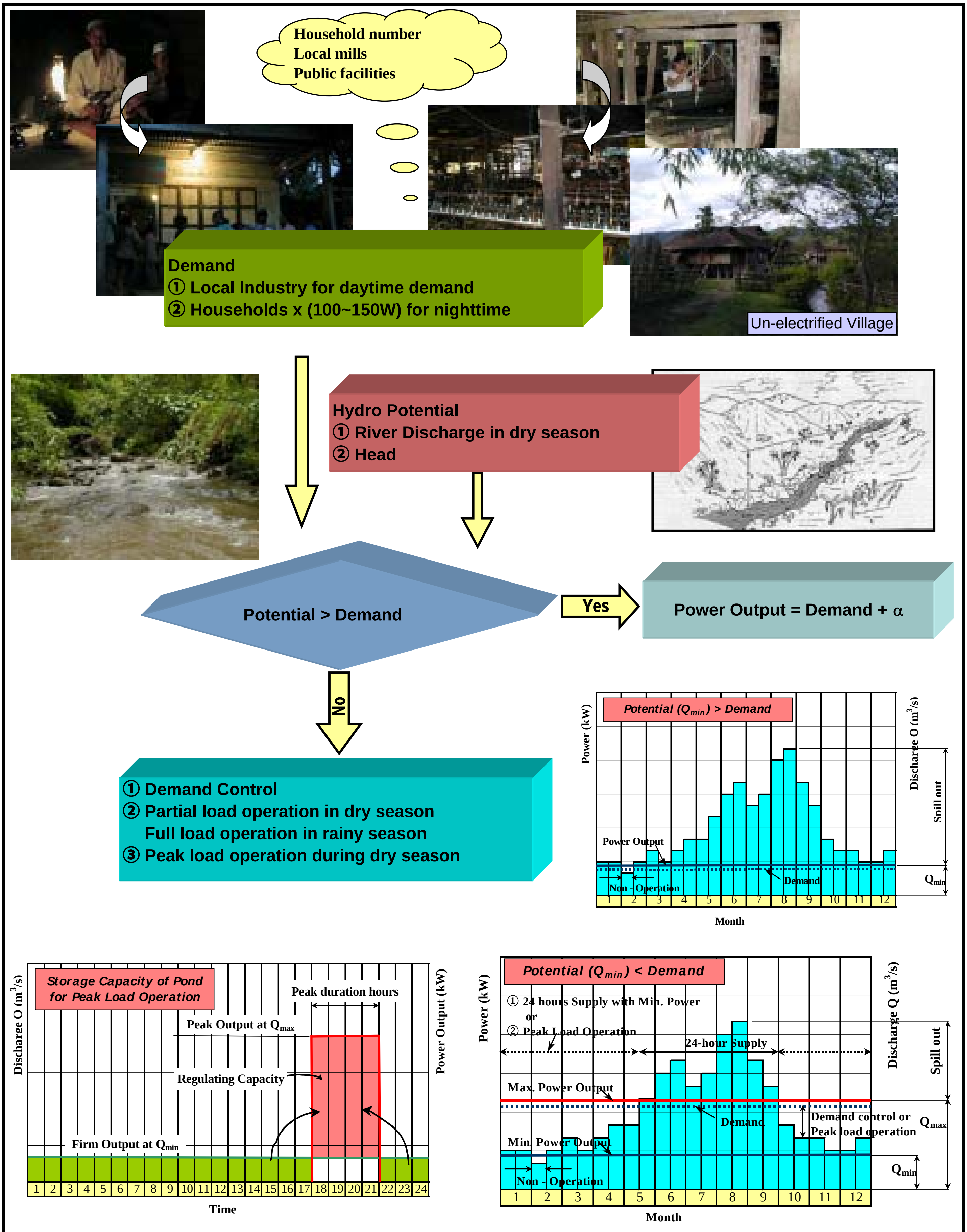
Suitable for Village Hydro

Type of Turbines

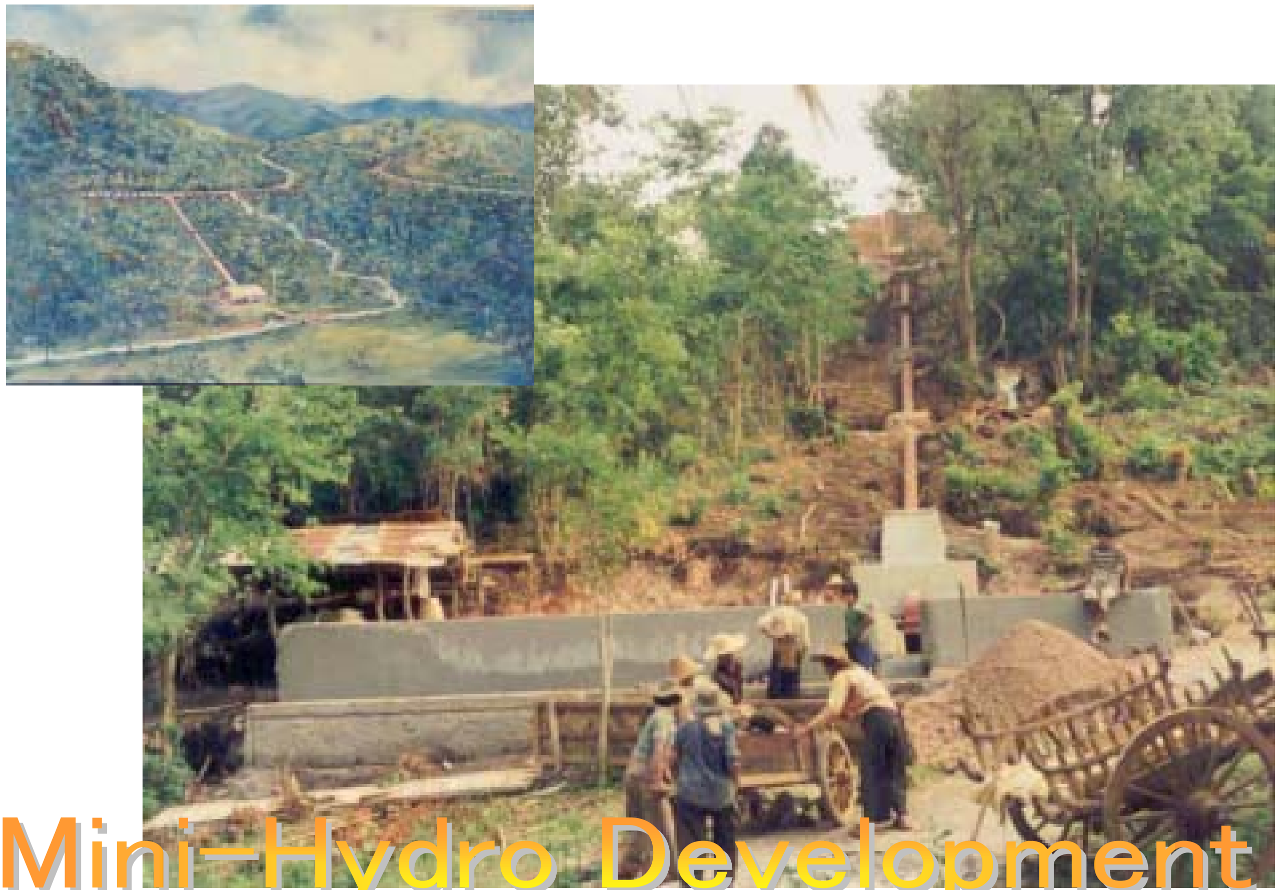
500 W Turbine & Generator
33,600 Kyats (Sep. 2001)

Module Type
Pico Turbine & Generator
300 W ～ 1 kW

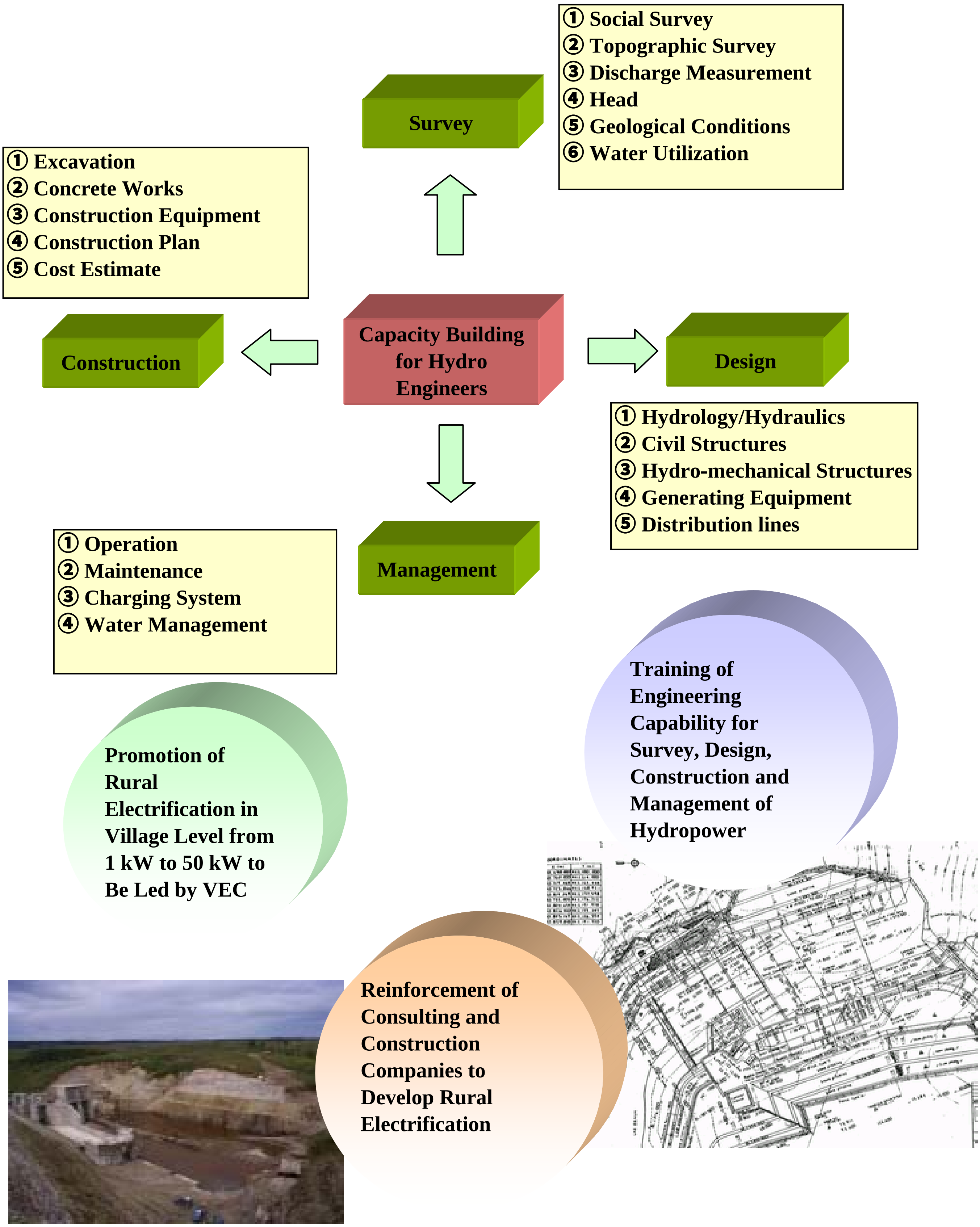
Turbine for Village Hydro



Establishment of Project Scale



Mini-Hydro Development by VEC in Shan State



Capacity Building for Rural Electrification

Data Sheet for Basic Planning of Small/Micro Hydro

No.	Item	Fill in			Range	Advice
1	Name of Village					
2	Division / State					
3	Distance to National Grid (km)				L > 30 km	OK. Proceed further below.
					30 km > L > 10 km	OK. Proceed with micro hydro < 100 kW
					L < 10 km	Extension of distribution line is to be studied.
4	Possibility of power supply by rehabilitation of existing hydros nearby				Yes	Rehabilitation is to be studied.
					No	OK. Proceed further below.
5	Road length to be constructed newly				L > 10km	Not suitable, search for other potential sites
					10 km > L > 1 km	OK suitable for small hydro (>50 kW)
					L < 1 km	OK suitable for Village Hydro (<50 kW)
6	Distance from site to target villages (km)				L > 20 km	Not suitable, search for other potential sites
					20 km > L > 1 km	OK suitable for small hydro (>50 kW)
					L < 1 km	OK suitable for Village Hydro (<50 kW)
7	Households to be electrified				100 ~ 500	Installed capacity required : 10 kW-50 kW
					50 ~ 100	Installed capacity required : 5 kW-10 kW
					< 50	Installed capacity required < 5 kW
8	List of public facilities	No.	Facility	Nos.		
		1				
		2				
		3				
		4				
		5				
		6				
9	List of village industries	No.	Industry	Nos.		
		1				
		2				
		3				
		4				
		5				
		6				
10	Ability to pay (Kyat)					
11	Discharge in dry season (m^3/s)				Q > 2.0m^3/s	Possible, but special care for flooding.
					2.0 > Q > 0.5 m^3/s	OK but discharge partially used.
					Q < 0.5 m^3/s	OK suitable for Village Hydro.
12	Date of discharge measurement				Jan. - May	OK
					Jun. - Dec.	Try again in Jan. to May.
13	Head available for power generation (m)				H > 500 m	Not suitable, but to consider cascade plan.
					500 > H > 30 m	Suitable for small hydro by MEPE.
					H < 30 m	Suitable for Village Hydro.
14	Distance from Intake to Powerhouse (km)				L > 5 km	Not suitable, but to consider other routes
					5 km > L > 500 m	OK suitable for small hydro by MEPE
					L < 500 m	OK Suitable for Village Hydro.

Table 9 Framework for Preliminary Selection of Form of Renewable Energy by Location

No.	Region	DHP		MEPE and VEC			
		Extension of Distribution Lines from National/Local Grids	Small & mini-hydro	Village Hydro (Micro/Pico)	Solar BCS	Wind BCS	Biomass gas engine
			50-10,000 kW	0.5-50 kW	0.1-3 kW	0.5-3 kW	10-50 kW
1	Mountain Regions	★	★★★★★	★★★★★	★	★★	★★★★★ with rice husk or sawdust
2	Delta and Paddy Cultivating Regions	★	-	★ on irrigation channel	★	★ where wind prevails	★★★★★ with rice husk
3	Coastal Regions	★	★★	★★	★	★★	★★★★★ with rice husk or sawdust
4	Remote and hardly accessible areas	-	★★	★★★	★★★★★	★★	★★★★ with rice husk
5	Urban Areas including Suburbs	★★★★★	-	-	-	-	-

Legend: [shaded box] This pattern means out of scope of the current study.
★ to ★★★★★ Shows level of potential for implementation.
Biogas may be useful for lighting and cooking in those households in the border areas which are scattered in wide areas and, therefore, favor such individual system as for own home use rather than the distribution line-connected RE system.

Source: JICA study team