5.2 ASSESMENT OF DEMAND AND POTENTIAL

5.2.1 Assess the Village Power Demand

In order to assess the village power demand, the following method can be applied.

Village demand P_d :

P_d = Unit demand x Numbers of household

Unit demand may be planned as 100 W per household. However, if most of the villagers use TV and other light load appliances in addition to lighting, the unit demand of 100 W may not be sufficient. It should be estimated in accordance with the procedure given in Sub-section 4.2.2.

Village demand P_d is prepared village by village or by groups of households to be electrified. Such demand of each village should be prepared and listed, of which list is later used for selection of target villages to be electrified.

<List of power demand by village>

1) Village demand in village A: P_{d-A}
2) Village demand in village B: P_{d-B}
3) Village demand in village C: P_{d-C}
4) Village demand in village D: P_{d-D}

Above list of each village demand is used for judging power demand-supply balance later on, by comparing demand against supply capacity.

5.2.2 Assess the Dry Season Power Output

It is aimed for villages to be electrified throughout the year. In case of micro hydropower, the power become lowest in the dry season when the discharge become smallest in the year. Accordingly dry season power is assessed using dry season discharge in order to supply electricity even in the driest season of the year. Dry season discharge is obtained through measurement of river discharge in the dry season.

Measurement should be made in the driest season of the year. As for driest season of the year, it is good ask village people living in the area. If the river water level is the lowest, it is the driest season in a year. Please refer to Sub-section 5.1.5 for the discharge measurement.

After knowing dry season discharge, dry season power output is estimated with the following equation.

$$P_g = g \ \eta \ Q \, He$$

where, P_g : generator output (kW)

g : gravity acceleration (9.8 m/s^2)

η : combined efficiency of turbine and generator (η =0.7 to 0.8)

Q : dry season river flow (m^3/s)

He : head available for power generation (m)

For example, for a site having a discharge of 0.10 m^3/s and head of 10 m, the potential output in the dry season will be calculated to be 6.9 kW as shown below:

$$P_g = g\,\eta\,Q\,He$$
$$= 9.8\ m/s^2 \times 0.7 \times 0.10\ m^3/s \times 10\ m$$
$$= 6.9\ kW$$

5.2.3 Demand-Supply Balance

Using power demand assessed in Sub-section 5.2.1 and dry season output assessed in Sub-section 5.2.2, demand-supply balance is assessed and formulation of electrification plan is made as follows:

Compare the dry season potential power P_g of micro hydro power above with the village demand P_d:

P_i = 1.30 x P_d

where, P_i : installed capacity of turbine-generator (kW)

P_d : total power demand of the villages to be supplied under the scheme (kW)

if $P_g >= P_i$: Villages can be electrified only by MHP

if $P_g < P_i$: In addition to MHP, needs back up power by diesel/biomass or load saving in the dry season

5.2.4 Identification of Villages to Electrify

The process to identify the villages which can be electrified by micro hydropower is as follows.

(1) Map Study

➢ Confirmation of Head

As shown in the Figure 5.2.1, the Head which is one of the essential factors for hydropower generation shall be confirmed on the topographical maps. The map scales of 1/50,000 and 1/100,000 are appropriate for map study. The large Head in the short distance is preferable, because it creates large power economically. If there are large Head sites on the topographical maps, micro hydro potentials are expected.

Intake is generally constructed around the beginning of high Head area, and powerhouse is around the end of the area.

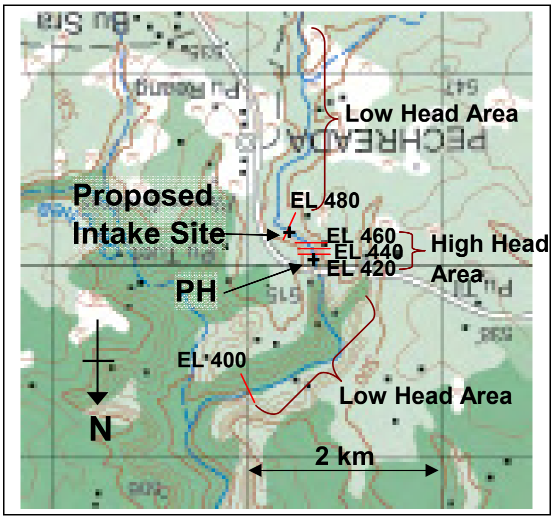


Figure 5.2.1 Map Study Sample

For the settlement of the locations, the detail study is required taking the conditions into consideration such as topography, geology and hydrology and so on.

➢ Measurement of Catchment Area

Drawing the line from intake site along the ridge, the Catchment Area is recognized (Figure 5.2.2). The large Catchment Area collects much water from rainfall and it makes the discharge large which is another essential factor for hydropower generation. After making the border of Catchment Area, the Area is measured by using the planimeter or the graph paper, etc. The site with both high Head and large Catchment Area has large hydro potential.

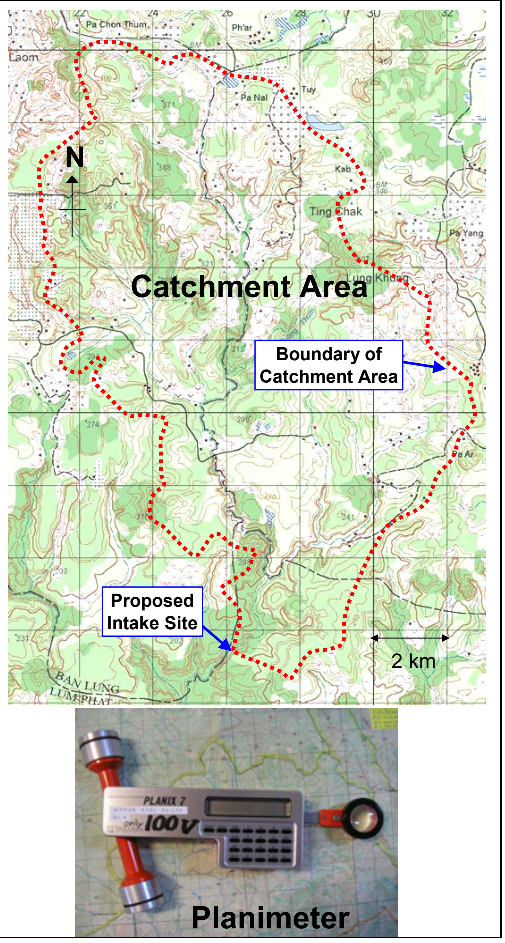


Figure 5.2.2 Catchment Area

➢ Estimation of Dry Season Discharge

Power output is controlled by the dry season discharge which is the lowest in the year. The best way to confirm the dry season discharge is to observe it. For the details of observation, please refer to the Sub-section 5.1.5.

However it is difficult to observe the discharge without current meter. Accordingly it is usually applied to estimate it from Catchment Area using the specific discharge as follows.

$$Q_{dry} = Q_{sp} \times CA$$

Where, Q_{dry} : Dry season discharge (m^3/s)

Q_{sp} : Dry season specific discharge ($m^3/s/km^2$)

CA : Catchment Area (km^2)

The specific discharge is variable depending on the climate, topographic and land use conditions and so on. Figure 5.1.6 shows the specific discharge in Cambodia for reference.

➢ The Measurement of MV Line Length

The distance from powerhouse to villages and between the villages is also important, because it decides the length of MV line which conveys electricity to the villages and influences to the construction cost (See Figure 5.2.3). It is useful to measure the distance not straightly but along the route on which MV line can be constructed. The distance along existing road can be the reference for the MV line length. These distances will be used in the cost estimation stage.

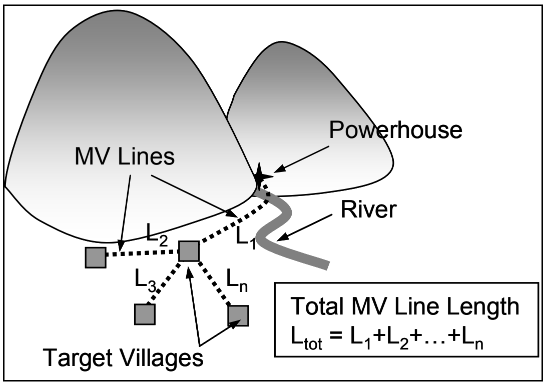


Figure 5.2.3 MV Line Length

(2) Estimation of Power Output

From the Head and dry season discharge acquired as above, the power output is estimated as explained in the Sub-section 5.2.2.

(3) The Confirmation of Village Households

It is necessary to confirm the number of households in the target villages in order to estimate the demand of the villages. SEILA database is useful to acquire the information.

(4) Estimation of the Demand

Please refer to the Sub-section 5.2.1 for the details of demand estimation.

(5) Comparison of Power and Demand

Please refer to the Sub-section 5.2.3 for the comparison of power and demand.

The result of above study is summarized in the format as shown in the Table 5.2.1. By this study, the possibility of village electrification by micro hydropower is confirmed. The further study is required in order to confirm the feasibility of the scheme taking into consideration the project cost.

Table 5.2.1 Target Villages to Each MHP Schemes (Sample)

No.	Scheme Name	Sub No.	Province	District	Commune	Village	SEILA ID	Potential Dry Season Power (kW)	Length of MV Lines (km)	Total HHs	HHs to be Electrified	Total Demand (kW)	Back up capacity (kW)
1	**Bay Srok**	1	Ratanak Kiri	Lumphat	Ka Laeng	Bay Srok	16050204	**65**	**3**	**560**	**448**	**58**	**0**
		2	Ratanak Kiri	Lumphat	Ka Laeng	New Ka Laeng	16050205						
		3	Ratanak Kiri	Lumphat	Ka Laeng	New Sayos	16050206						
2	**Bu Sra**	1	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Muoy	11040401	**91**	**25**	**899**	**719**	**93**	**2**
		2	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Pir	11040402						
		3	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Bei	11040403						
		4	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Buon	11040404						
		5	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Pram	11040405						
		6	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Prammuoy	11040406						
		7	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Prampir	11040407						
		8	Mondul Kiri	Pech Chenda	Srae Ampum	Phum Lekh Muoy	11040301						
		9	Mondul Kiri	Pech Chenda	Srae Ampum	Phum Lekh Pir	11040302						
		10	Mondul Kiri	Pech Chenda	Srae Ampum	Phum Lekh Bei	11040303						

Source: JICA Study Team

5.3 RIVER GAUGING

5.3.1 Install Gauging Staff of River Water Level

(1) Purpose of Water Level Recording

The river discharges are likely to decrease significantly in the dry season in Cambodia as compared with those in the rainy season. It is, accordingly, essential to investigate discharges, especially in the dry season, for the planning of a micro hydro power station with an isolated grid system to supply stable energy throughout a year. It is desirable to observe the river water levels throughout the year once the candidate hydropower site is identified and selected.


WL Gauging Staff at St.Sanke River, Battambang Province

It is also required to observe the flood water levels during the rainy season in order to know the possible maximum water level of floods and to protect the intake and waterway facilities from the floods accordingly.

If a river water level gauging staff was installed and the daily water level records/ several times of river discharge were observed, it is able to estimate the daily discharge by using prepared correlation rating curve between the gauge height (H) and the flow (Q) as shown in Figure 5.3.1.

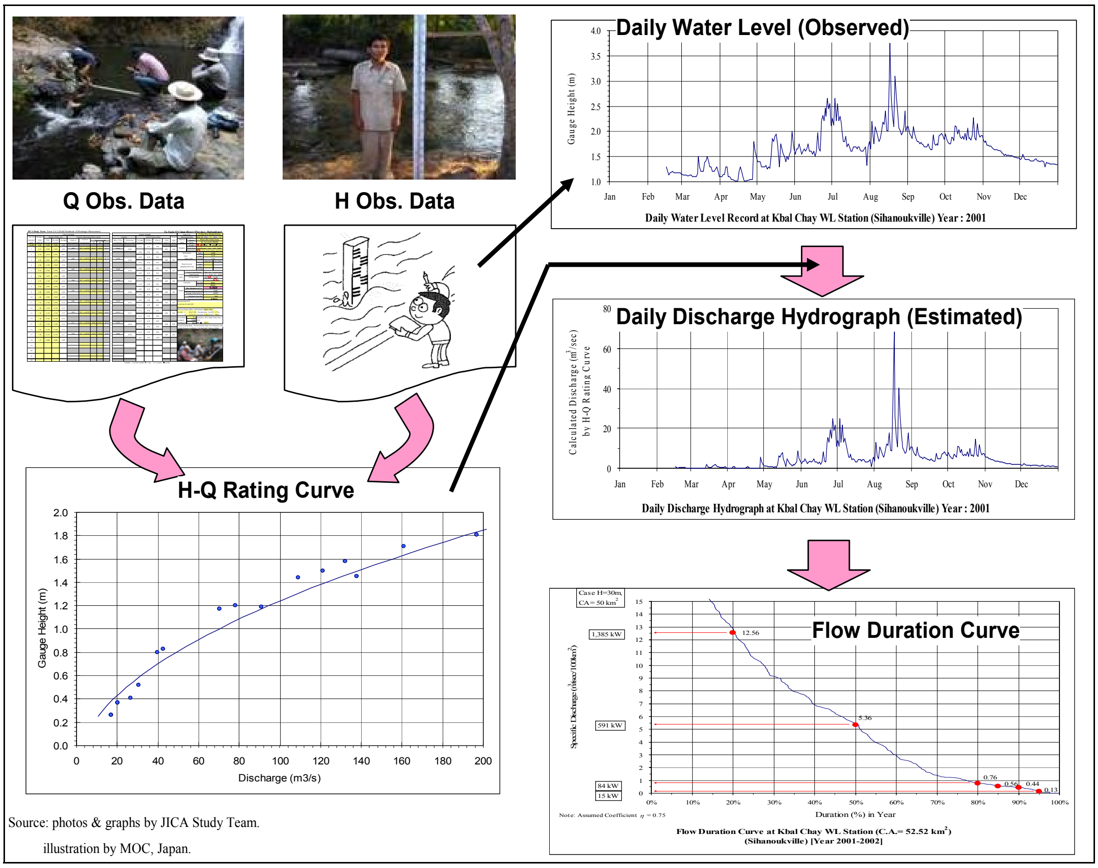


Figure 5.3.1 Procedure of Estimated Daily Discharge by using H-Q Rating Curve

(2) Candidate Site for Installation of Water Level Gauging Staff Gauge

The site for discharge measurement and water level observation shall be selected on a accessible straight river stretch where water depth is uniform and flow conditions are stable. Also, the site should be on a uniform slope section of the river to avoid being affected by the change in riverbed level and river width due to scouring or sedimentation. It should be referred to bench marks entirely removed from the gauge so that, if disturbed, it may be replaced to same datum.

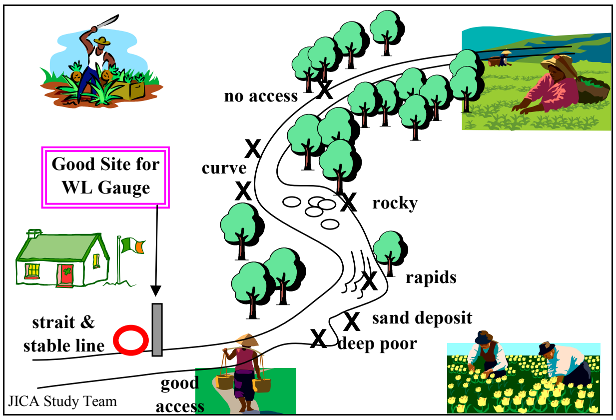


Figure 5.3.2 Candidate Site for WL Gauge

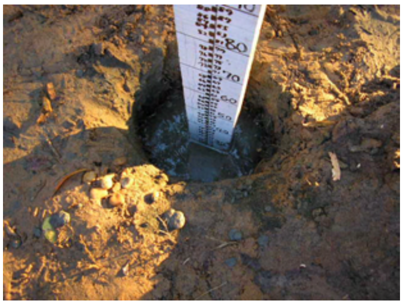
Attention is needed to protect the gauge from damage by floods and flowing debris. It is also possible to place a graduated staff on the rigid rock surface under the water upon each measurement. In this case, the position to place the gauge shall be clearly marked for its easy identification at the next measurement.

(3) Install Gauging Staff of River Water Level

A wooden staff with graduation preferably at 1 cm intervals shall be prepared and firmly placed vertically by concreting its bottom end deep into the ground at least 50 cm in depth. The zero level on the gauge shall be below the lowest water level expected in the dry season. To this end the gauge should be installed in the dry season. The graduated surface shall be faced in such as way so that the gauge reader easily read the water level on the gauge or clean the gauge surface.

The staff gauges shall be installed vertically. Staff gages shall be set in a location where readings can be readily made from the river bank. Furthermore, markings for one meter intervals shall be clearly painted onto the existing pair in large white letters. Figure 5.3.3 shows a schematic of the staff gage installation. After the installation, the exact coordinates and elevation of the local "zero" setting of the gage shall be recommended.


Preparation of water level gauging staff


Foundation by concrete

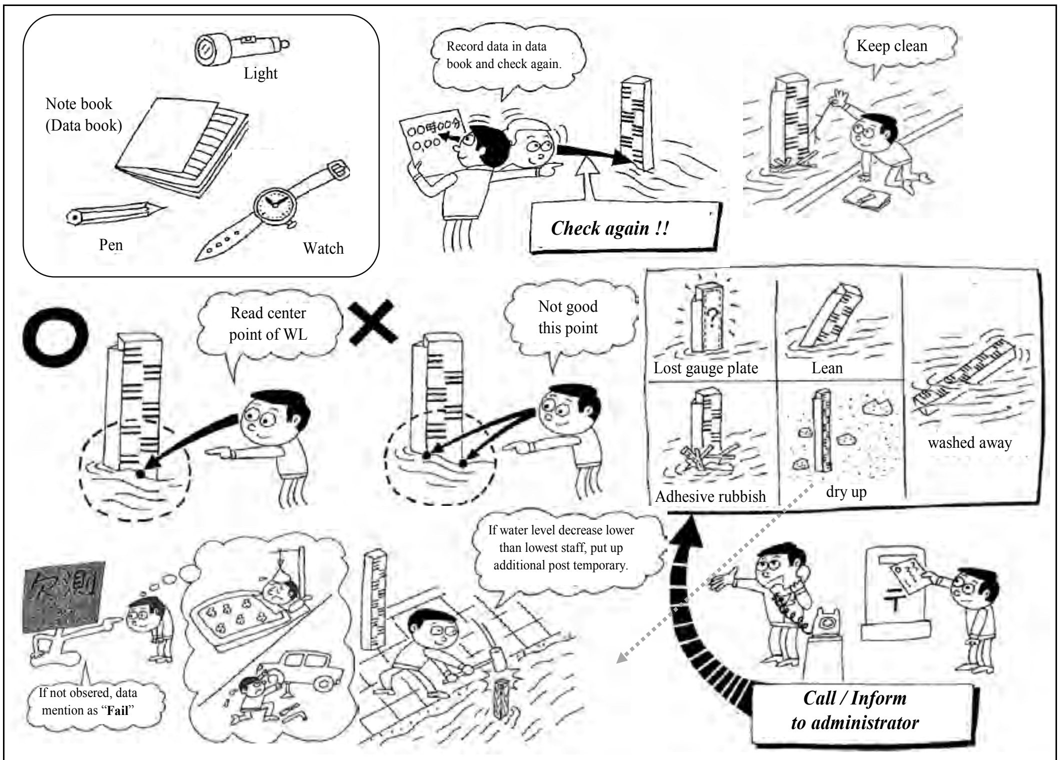

Installed Water Level Gauging Staff

Source: JICA Study Team.

Figure 5.3.3 Installation of Water Level Gauging Staff

5.3.2 Gauge Reading

The water level observation should be made once a day (at 7:00 a.m.) of twice a day (6:00 a.m. and 18:00 p.m.) for example. Attention is needed to read water level carefully and faithfully. If observer could not to read by some reason, the data should be recorded as blank or mention as "fail" etc, (do not estimate data). For matters to be attended to read water level are shown in Figure 5.3.4.



Source: Hydrologiocal Observation, Ministry of Consrtuction, Japan, 1979.

Figure 5.3.4 Guide to Water Level Gauge Observation

5.3.3 Water Level Logging

Sample format for the water level recording is attached in Table 5.3.1.

5.3.4 Preparation of Stage - Discharge Rating Curve (H-Q Curve)

For the planning of micro hydro schemes, dry season discharge is one of the most important values to know. It is necessary to measure the driest discharge at the end of dry season. Water level should also be measured.

To know more precisely about characteristics of the flow regime, observation of discharge and gauge height shown in Figure 5.3.5 is desirable. The followings are the points for observation:

1) Discharge measurement more than 10 times within a proper range that enable establishment of the stage-discharge rating curve at the intake site. The water level gauging staff reading should be conducted at the same time of discharge measurement.

2) Using observed discharge (Q) and the water level (H) data, the relation between H and Q can be expressed by a quadratic equation. This equation can be calculated by using Table 5.3.2. The relation curve called the "Stage-Discharge Rating Curve (H-Q Curve)". It is noted that the stage-discharge rating curve should be reviewed periodically for calibration, especially after the flood season that may result in erosion or sedimentation on the riverbed.

Table 5.3.1 Form of Daily Water Level Record (Monthly Table)

JICA Study Team

Form of Daily Water Level Record (Monthly Table)

Province	:	River Name	:
District	:	W.L. Station	:
Commune	:	Coordinates	: N ° ' ", E ° ' "
Village	:	Observer	:
Year	:		

Month	Morning 6:00 a.m.				Evening 18:00 a.m.				Notes
	Time	Weather	Water Level		Time	Weather	Water Level		
Date			m	cm			m	cm	
1	:	○			:	○			
2	:	○			:	○			
3	:	○			:	○			
4	:	○			:	○			
5	:	○			:	○			
6	:	○			:	○			
7	:	○			:	○			
8	:	○			:	○			
9	:	○			:	○			
10	:	○			:	○			
11	:	○			:	○			
12	:	○			:	○			
13	:	○			:	○			
14	:	○			:	○			
15	:	○			:	○			
16	:	○			:	○			
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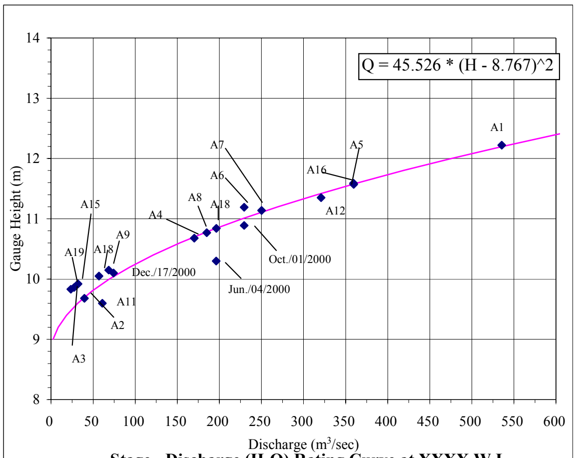
27	:	○			:	○			
28	:	○			:	○			
29	:	○			:	○			
30	:	○			:	○			
31	:	○			:	○			

Weather : ○=clear weather, ⦶=fair, ◎=cloudy, ●=rain

Sample of Discharge and Gauge Height Observation Data

Measured by JICA Study Team

River Name	Station	No.	Obs. Date (Y/M/D)	Time	Weather	Q Obs. Discharge (m^3/s)	Gauge Hight (m)	Q Obs. Method
YYYY	XXXX	A-1	1998/9/2	13:10	fine	535.35	12.22	Current meter
		A-2	1998/12/8	15:30	cloudy	39.68	9.68	
		A-3	1999/2/9	12:52	cloudy	23.44	9.83	
		A-4	1999/5/29	11:15	cloudy	170.13	10.68	
		A-5	1999/6/25	14:20	cloudy	359.56	11.57	
		A-6	1999/8/3	9:25	cloudy	229.45	11.19	
		A-7	1999/9/5	11:15	cloudy	250.15	11.14	
		A-8	1999/10/9	9:57	cloudy	184.96	10.77	
		A-9	1999/11/28	13:00	fine	68.53	10.15	
		A-10	2000/1/27	15:20	fine	60.75	9.60	
		A-11	2000/6/4	9:33	cloudy	196.18	10.30	
		A-12	2000/7/30	9:59	cloudy	320.77	11.35	
		A-13	2000/10/1	9:15	cloudy	229.41	10.89	
		A-14	2000/12/17	9:37	cloudy	74.18	10.10	
		A-15	2001/2/17	13:17	cloudy	32.12	9.92	
		A-16	2001/7/4	10:49	rainy	359.29	11.59	
		A-17	2001/9/29	17:28	fine	196.52	10.84	
		A-18	2002/1/9	11:35	fine	56.87	10.05	
		A-19	2002/3/27	9:45	fine	27.35	9.86	



Stage - Discharge (H-Q) Rating Curve at XXXX W.L. Station

(YYYY River) [JICA Study Team]

Source: JICA Study Team

Figure 5.3.5 Sample of Stage-Discharge Rating Curve (H-Q Curve)

Table 5.3.2 Sample of Calculation Sheet of H-Q Rating Curve

Calculation Sheet of H - Q Rating Curve (1/2)

Rating Curve (I) from 02-Sep-1998 to 17-Feb-2001

Gauge Height for Using : 9.60 m ～ 12.22 m

Q= a^2 *(H ± b/a)^2

Q= 45.526 8.767) ^2

Basin	MMMM		River	YYYY		Station	XXXX
No.	Date	Time	H	H2	Q	√Q	H√Q
1	1998/9/2	13:10	12.22	149.33	535.35	23.14	282.74
2	1998/12/8	15:30	9.68	93.70	39.68	6.30	60.98
3	1999/2/9	12:52	9.83	96.63	23.44	4.84	47.59
4	1999/5/29	11:15	10.68	114.06	170.13	13.04	139.30
5	1999/6/25	14:20	11.57	133.86	359.56	18.96	219.39
6	1999/8/3	9:25	11.19	125.22	229.45	15.15	169.50
7	1999/9/5	11:15	11.14	124.10	250.15	15.82	176.19
8	1999/10/9	9:57	10.77	115.99	184.96	13.60	146.47
9	1999/11/28	13:00	10.15	103.02	68.53	8.28	84.02
10	2000/1/27	15:20	9.60	92.16	60.75	7.79	74.82
11	2000/6/4	9:33	10.30	106.09	196.18	14.01	144.27
12	2000/7/30	9:59	11.35	128.82	320.77	17.91	203.28
13	2000/10/1	9:15	10.89	118.59	229.41	15.15	164.94
14	2000/12/17	9:37	10.10	102.01	74.18	8.61	86.99
15	2001/2/17	13:17	9.92	98.41	32.12	5.67	56.22
16	2001.7.4	10:49	11.59	134.33	359.29	18.95	219.69
Total			170.98	1,836.33	3,133.95	207.22	2,276.41

Calculation Sheet of H - Q Rating Curve (2/2)

Rating Curve (I) fro 02-Sep-1998 to 17-Feb-2001

n * [H√Q] = 16 * 2,276.406 = 36,422

[H] * [√Q] = 170.98 * 207.218 = 35,430

n * [H^2] = 16 * 1,836.327 = 29,381

[H^2] = 170.98 ^{2} = 29,234

[H^2]*[√Q] = 1,836.327 * 207.218 = 380,520

[H]*[H√Q] = 170.98 * 2276.405519 = 389,220

a = (n*[H]*[H√Q]-[H][√Q]) / (n[H^2]-[H]^2) = (36,422 - 35,430) / (29,381 - 29,234) = 6.747

b = ([H^2][√Q]-[H][H√Q]) / (n*[H^2]-[H]^2) = (380,520 - 389,220) / (470,100 - 29,234) = -59.152

a^2= 6.747 ^{2} = 45.526

b/a = -59.152 ／ 6.747 = -8.767

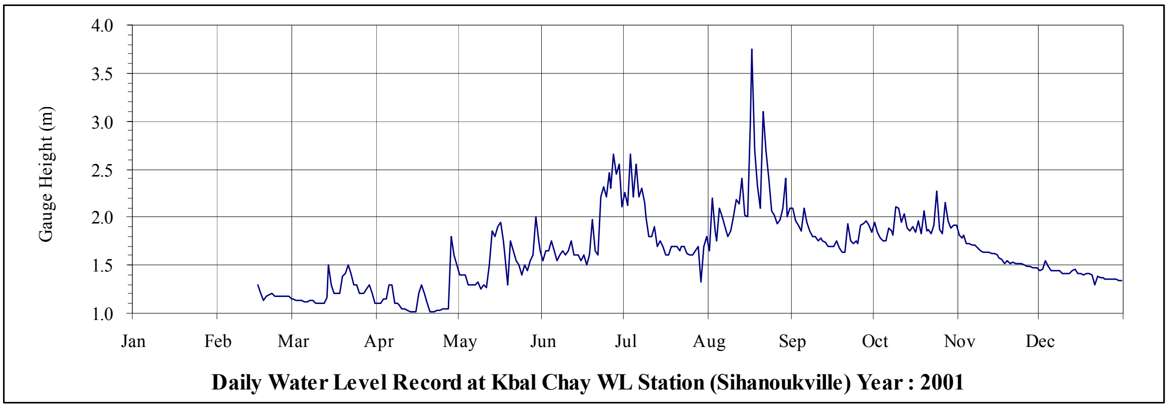
Q = a^2* (H ± b/a)^2 = 45.526 (H -8.767) ^{2}

Source: JICA Study Team

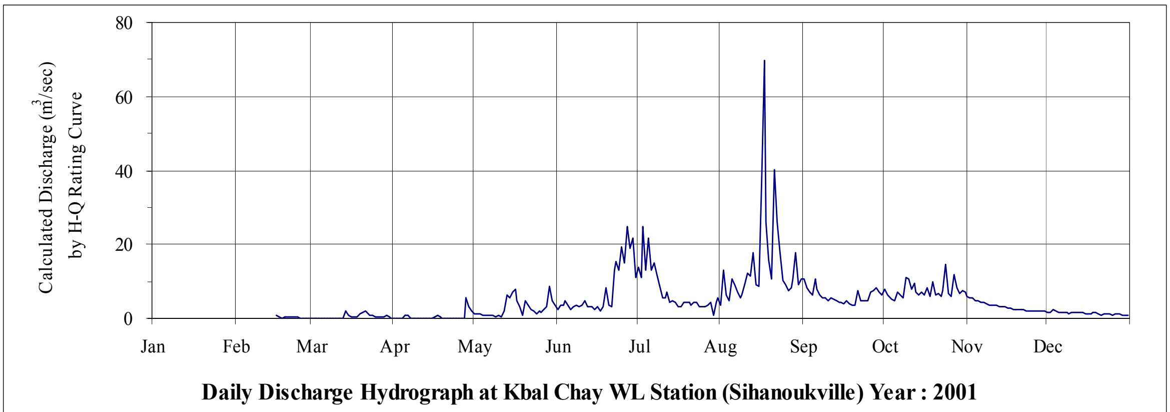
5.3.5 Estimation of Minimum Plant Discharge at Proposed Intake Site

(1) Preparation of Daily Discharge Hydrograph

Daily discharge hydrograph can be developed based on observed daily water level records and H-Q rating curve as shown below (Figure 5.3.6):



Source: DOWRAM, Sihanoukville.

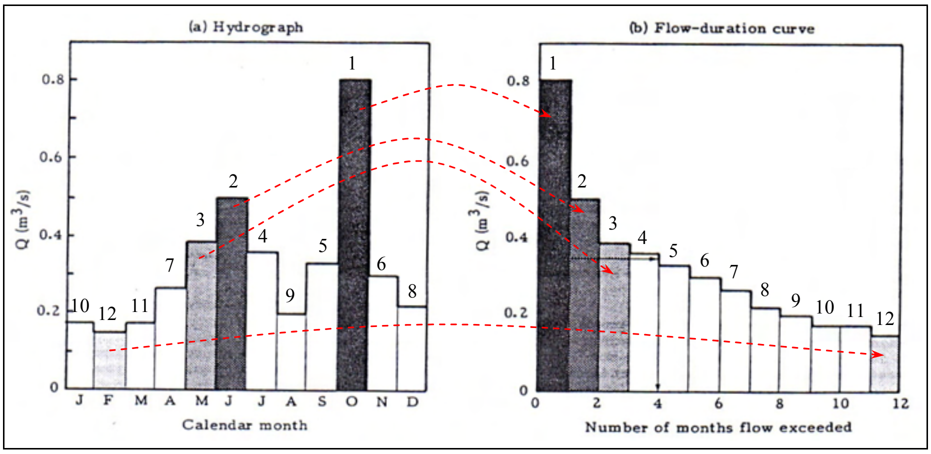


Source: Q-hydrograph was prepared by JICA Study Team for The Study on Regional Development of the Phnom Penh.- Sihanoukville Growth Corridor in the Kingdom of Cambodia, JICA 2003.

Figure 5.3.6 Sample of Observed Daily Water Level and Estimated Daily Discharge Hydrograph at Kbal Chay WL Station (Sihanoukville)

(2) Preparation of Flow Duration Curve

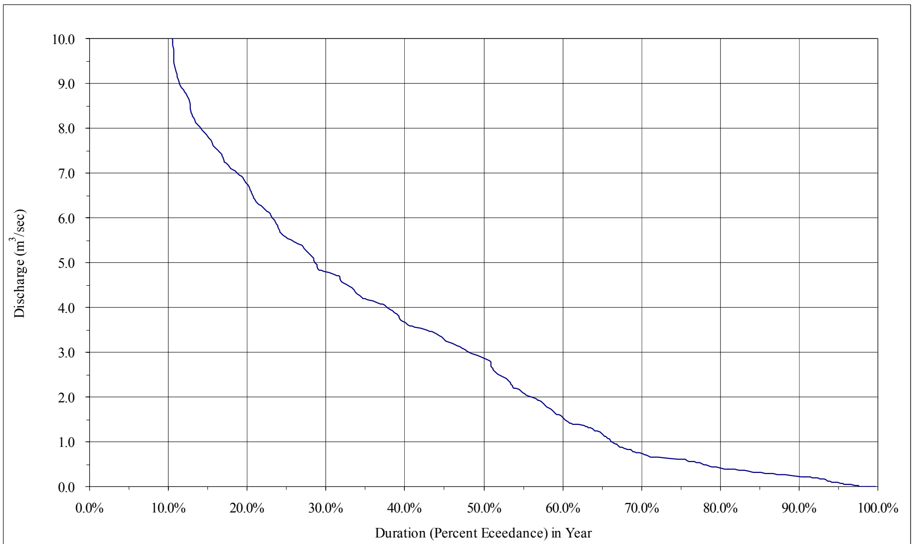
Flow duration curve is useful for sizing a turbine and predicting a site's annual energy potential. It is obtained from a hydrograph by organizing each flow measurement by size, from the largest measurement to the smallest, rather than in chronological order. If, for the sake of simplicity, a stream with constant monthly flow as shown in Figure 5.3.7(a) is assumed, the corresponding flow-duration curve would be as shown in Figure 5.3.7 (b). Note that the flows which are reorganized and sequenced on the flow-duration curve b the relative magnitude of each month's flow. Also note that the scale on the abscissa (horizontal axis) of the flow-duration curve is the number of month that the corresponding flow is equaled or exceed during that year. For example, a flow of 0.35 m^3/s (note this figure is just assumed sample value not actual data)is equaled or exceeded for four month of the year .



Source: "Micro-Hydropower Sourcebook", by Allen R. Inversin, NRECA,

Figure 5.3.7 Relationship of Hydrograph with Flow-Duration Curve

In reality, stream flow varies continually, and the associated hydrograph would be more than like that shown in Figure 5.3.6 before. This hydrograph might be essentially a bar graph as in Figure 5.3.7 (a) above, but with bars a "day" wide rather than a "month" wide bars would be sequenced not by date but by relative magnitude, as in Figure 5.3.7 (b). These day-wise bars are so narrow, however, that the result would essentially be a smooth curve (Figure 5.3.8).



Source: Q-hydrograph was prepared by JICA Study Team for The Study on Regional Development of the Phnom Penh.- Sihanoukville Growth Corridor in the Kingdom of Cambodia, JICA 2003.

Figure 5.3.8 Flow-Duration Curve at Kbal Chay WL Station (Sihanoukville)

Also, rather than calibrating the abscissa as the number of days per year that a flow is equaled or exceeded, a more common and useful scale is calibrated in terms of the percentage of the year that a flow is equaled or exceeded during the year, often shortened to "percent of time" or "percent exceedance". For example, from above flow-duration curve at Kbal Chay WL station (catchment area of 52.25 km^2) in Sihanoukville (2001-2002), the percent exceedance for flow of 0.13 m^3/s is 95% of year (or, equivalently, 347 days per year) as shown in the Table below (Table 5.3.3).

Table 5.3.3 Sample of Flow-Duration at Kbal Chay WL Station (Sihanoukville)

Duration (%) of Year	No.Days per Year	Discharge (m^3/sec)	Sepecific Discharge (m^3/sec/100 km^2)	P (kW) (H=30m, η=0.7)
20%	73	6.60	12.56	1,454
50%	183	2.81	5.36	620
80%	292	0.40	0.76	88
85%	310	0.29	0.56	64
90%	329	0.23	0.44	51
95%	347	0.07	0.13	15
100%	365	0.0002	0.00029	-

Source: JICA Study Team

(3) Estimation of Minimum Plant Discharge at Proposed Intake Site

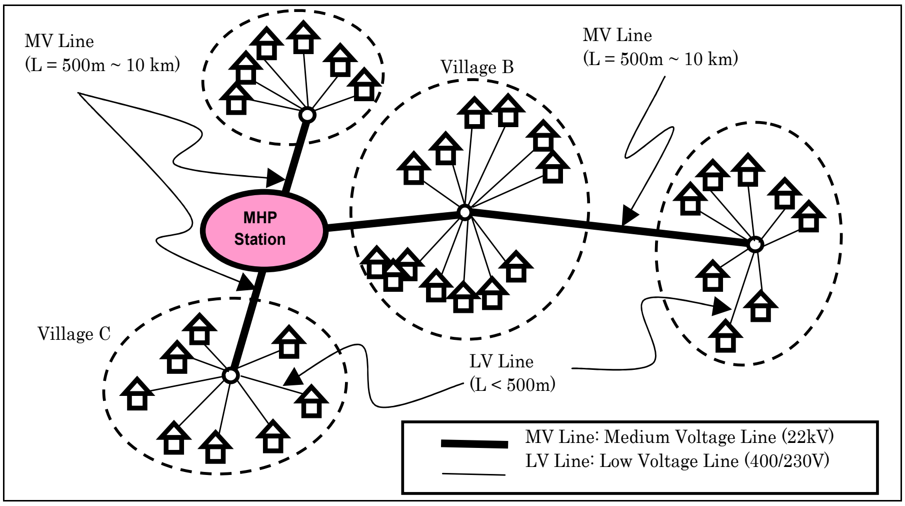
A flow-duration curve also provides information in a better digested and more directly useful form. Calculating a plant's energy output or the percentage of time that a specific power output can be generated can be made directory from a flow-duration curve.

For the planning of a micro hydro power station with an isolated grid system to supply stable energy throughout a year the percent exceedance of discharge should be apply approximately 95% of year. If there is a head of 30m at the Kbal Chay Waterfall, the 95% dependable of year power out will be at 15kW.

5.4 CONCEPTUAL PLANNING OF MINI-GRID BY MICRO HYDRO

5.4.1 Conceptual Planning of Mini-Grid

For mini-grid by micro hydro, in most cases, target villages for electrification are at least 0.5 to 1 km away from powerhouse site. Therefore, typical mini-grid layout will be as illustrated in the figure below.



Source: JICA Study Team

Figure 5.4.1 Schematic Diagram of Mini-Grid by Micro Hydro

From micro hydro power station, medium voltage (MV) lines will be extended to the target villages. At the target village, low voltage (LV) lines will further be extended from MV lines to distribute electricity to each household. Branch points from MV line to LV line will be located at the center of each target village to minimize length of LV lines. For preparation of conceptual plan, general sketch of the target village should be prepared as shown in Figure 4.2.1 above.

5.4.2 Measurement of MV Line Length

The route of MV lines should be selected to connect power station site and target villages with the minimum distance but along road in principle for inspection and maintenance purposes. The required length of MV line can be measured on topographic maps of 1:100,000 or 1:50,000.

5.4.3 Measurement of LV lines

The required length of LV lines shall be estimated as follows:

1) Routes of LV lines shall be selected along main streets in the village to connect households located along the roads. Length of one LV line should preferably be within 500 m. It may be extended up to 1,000 m at the maximum if the load on such line is limited.
2) Measure length of all the routes with tape measure or by pacing (number of walking steps times 0.7 to 0.8 m per step depending on the height of surveyor);
3) For households located on the rear side of the road, estimate length of required lines for respective houses.

5.5 COST ESTIMATE OF MINI-GRID BY MICRO HYDRO

5.5.1 Cost estimate of Generating Facilities and Equipment

Cost estimate of generating facilities and equipment at conceptual planning stage may be made as described below:

To estimate cost for a micro hydro scheme, it is necessary first to calculate quantities of construction works.

Major structures of micro hydro scheme are:

1) Intake,
2) De-sander,
3) Waterway, and
4) Penstock.

In addition to the four items above, costs for 5) generating equipment, 6) distribution lines, and 7) contingency should also be estimated.

For item Nos. 1) to 4), quantity can be calculated as follows:

(1) Intake Structure

To calculate quantities of intake weir, crest length is calculated first. Crest length is calculated based on intake weir height. For micro hydro scheme, intake height is normally taken at 3 to 5 m to minimize sedimentation upsteam of the wier. By reading counter lines near intake site on the topographic map, crest length can be estimated.

After getting crest length, the excavation volume, concrete volume, weight of reinforcement bars, and weight of gates are calculated by empirical equation presented in "Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Project, New Energy Foundation (NEF) Japan (hereinafter called as NEF Manual)" as follows:

Excavation volume (m^3): $Ve = 8.69 \times (Hd \times L)^{1.14}$ (m)

Concrete volume (m^3): $Vc = 16.1 \times (Hd2 \times L)^{0.695}$

Weight of reinforcement bar (ton): $Wr = 0.274 \times Vc^{0.830}$

Weight of gate (ton): $Wg = 0.910 \times Qf^{0.692}$

where,

Hd: Intake Weir Height (m)

L: Crest Length of Intake Weir (m)

Qf: Design Flood Discharge (m^3/sec)

(2) De-sander

From empirical equation presented in NEF Manual, quantities are calculated as follows:

Excavation volume (m^3) : $Ve = 515 \times Q^{1.07}$

Concrete volume(m^3) : $Vc = 169 \times Q^{0.936}$

Weight of reinforcement bar (ton) : $Wr = 0.120 \times Vc^{0.847}$

Weight of gate (ton) : $Wg = 0.910 \times Q^{0.613}$

Weight of screen (ton) : $Ws = 0.879 \times Q^{0.785}$

(3) Waterway

As master plan level, assumed or measured dry season discharge can be regarded as maximum plant discharge Q (m^3/sec). Quantities for waterway are calculated from length of waterway (L) and maximum plant discharge (Q). Dimensions of waterway (width: B(m) and height: H(m)) can be also calculated using Q.

The following empirical equation from NEF Manual can estimate the quantities.

$sqrt(BH) = 1.09 \times Q^{0.379}$

Excavation volume (m^3) : $Ve = 6.22 \times (sqrt(BH))^{1.04} \times L$

Concrete volume(m^3) : $Vc = H \times t \times 2 + (B + 2t) \times t$

Weight of reinforcement bar (ton) : $Wr = 0.577 \times (Vc/L)^{0.888} \times L$

where,

Q : Maximum Plant Discharge (m^3/sec)

L : Total Length of Waterway Channel (m)

B : Width of Open Channel (m)

t : Concrete Thickness (m)

H : Height of Open Channel (m)

Water channel is calculated as open type. in case of embedded or if cover is necessary, concrete volume (Vc) should be multiplied by 4/3 to obtain quantities for box culvert type structure.

If waterway with different dimensions or different material like PVC pipe, separate calculation should be made for quantity estimation.

(4) Penstock

Assuming velocity at 3 m/sec and by applying the maximum plant discharge, diameter of penstock is calculated and rounded. For more than 30 cm diameter, steel penstock is applied. For equal to or less than 30cm diameter penstock, PVC is applied.

(5) Generating Equipment

Cost for generating equipment is estimated by installed capacity. In the master plan, a unit cost of $525/kW is assumed.

(6) Distribution Line

Cost for distribution line is estimated for MV lines and LV lines. Details are given in the next section.

(7) Contingency

For master plan level, a 30 % of the total construction cost is provided as physical contingency.

(8) Unit Cost

For cost estimate of the seven items above, the following unit prices were applied:

Table 5.5.1 Unit Prices Applied for Cost Estimation of MHP Scheme

Item	Unit	Unit Price ($/unit)
Excavation	m^3	5
Concrete	m^3	80
Re-bar	ton	800
Gate & Screen	ton	1,200
PVC	ton	1,000
Steel Pipe	ton	1,200
Generating Equipment	kW	525

Source: JICA Study Team

When applying the unit prices above, the following points should be taken care of:

1) The above unit prices can be used only for conceptual planning stage.
2) The actual unit prices will be affected by various site conditions like distance from town, existence of access roads, scale of the scheme.
3) Material costs above may change reflecting the market demand and supply balance. It is advised to check market prices nearby.

5.5.2 Cost estimate of Power Transmission Facilities

Power transmission facility cost can be estimated by summing up costs of 1) MV (medium voltage) line cost, 2) LV (low voltage) line cost, 3) transformer cost, and 4) house-connection cost.

(1) MV lines

After measurement of MV lines (refer to previous section of “5.4.2 Measurement of MV lines”), cost can be estimated with the following equation:

Cost for MV lines ($) = Length of MV lines (km) x Unit cost of MV lines ($/km)

In the master plan, unit cost of MV line cost is assumed at $14,000/km.

(2) LV lines

After measurement of LV lines (refer to previous section of “5.4.3 Measurement of LV lines”), cost can be estimated with the following equation:

Cost for LV lines ($) = Length of LV lines (km) x Unit cost of LV lines ($/km)

In the master plan, unit cost of LV line cost is tentatively set at $10,000/km.

(3) Transformer cost

Transformer will be installed at the power station site and each branching point from MV lines to LV lines. The step down voltage is from 22 kV to 400/230 V. Capacity of transformer is determined by total demand at respective points. However, transformer with applicable standard capacity is normally used for convenience and cost saving purpose.

In the master plan, 22/0.23 kV, 25 kVA, single-phase transformer is commonly considered for the village electrification. The actual type (single-phase or 3-phase) and capacity of transformer will depend on the type (whether requiring three phase power) and size of the demand.

In case the layout details of the distribution lines and transformers exist, the cost can be estimated using the following table.

No	Item	Unit	Unit Cost	
			Under 500 households	Over 500 households
1	22 kV MV line	$/km	5,100 (35mm^2)	6,000 (50mm^2)
2	22 kV MV line and LV line	$/km	9,800	10,700
3	LV line*	$/km	6,500 (50mm^2)	7,100 (70mm^2)
4	Transformer 15kVA Single-phase (at end of village)	$/set	6,200	
5	Transformer 25kVA Single-phase (at end of village)	$/set	6,600	
6	Transformer 25kVA Three-phase (at center of village)	$/set	7,300	
7	Transformer 50kVA Three-phase (at center of village)	$/set	8,100	

*: Weighted average between 3-phase 4-wire (50%) and single-phase 2 wire (50%)
Source: JICA Study Team

(4) House-connection cost

Connection cost includes the costs for a) meter and its installation onto support pole, b) service wire from meter to house, and c) in-house wiring including breaker and fuse. For reference, in the World Bank's Rural Electrification and Transmission Line project, connection cost is estimated at $150 per connection. (For the cost comparison in this master plan, connection cost was not specifically counted but was assumed to be included in the LV line cost.

5.5.3 Operation and Maintenance Costs

One example of annual cost estimate for operation and maintenance works is shown below:

1)	Dispatch of 2 engineers for technical inspection (including transportation and accommodation):	500$/time x 1 time/year =	$500
2)	Salary for five operators:	$40 x 5 x 12 months =	$2,400
3)	Workers for maintenance of civil structures:	$60 x 12 months =	$720
			$3,620

5.5.4 Depreciation Costs for Future Replacement

Cost for depreciation and future replacement is estimated by structures/component of micro hydro scheme as follows:

Table 5.5.2 Depreciation Costs for Future Replacement Applied for MHP Planning

	Depreciation Period	Initial Cost	Monthly Depreciation Cost
Civil Structures	20 year	A	A/(20*12)
Turbine	10 year	B	B/(10*12)
Generator	20 year	C	C/(20*12)
Distribution Line	30 year	D	D/(30*12)
Total		Total Initial Cost	Total Monthly Depreciation Cost

Source: JICA Study Team

Major overhaul of turbines and metal structures should be made preferably every 5 years.

5.6 GENERAL TECHNICAL STANDARDS FOR MICRO HYDRO POWER SCHEMES

In general, the following technical standards are required for the planning of micro hydro power schemes. In the areas targeted in this rural electrification Master Plan, most of the small villages will be electrified with off-grid systems. Therefore, the principal criteria and standards will be applied to the micro hydropower projects.

For more detailed information on designing and planning of micro hydro power, following guidebooks or manuals are available in public (see also REFERENCES of Part-2).

1) “Micro-hydropower Sourcebook”, a Practical Guide to Design and Implementation in Developing Countries, by Allen R. Inversin, NRECA, 1994, NRECA (National Rural Electric Cooperative Association) International Foundation, Washington, D.C., U.S.A. (http://www.nreca.org) [Paperback only, $25 + shipping]

2) “Micro-Hydro Design Manual, A Guide to Small-Scale Water Power Schemes”, Adam Harvey, Intermediate Technology Publications, United Kingdom, 1993, ITDG (http://www.itdg.org/) (http://www.developmentbookshop.com/), [Paperback only, $57.49 + shipping, order available from www.amazon.com]

3) “Layman’s Guidebook on how to develop a small hydro site”, Commission of the European Communities, Celso Penche, Directorate-General for Energy by European Small Hydropower Association (ESHA), 1997, (http://microhydropower.net/) [Available online PDF from web. Site, free of charge.

Table 5.6.1 General Technical Standards for Micro Hydropower Plants (for Civil Engineering Structures)

	Structures	Applied Criteria and Ideas
1	Intake Weir/Dam	・ The construction site where the riverbed is stable and firm is to be selected. ・ The intake weir/dam is to be a concrete structure. ・ Supply a pipe screen on the opening of the intake to prevent ingress of stones/rocks. ・ Standardize the structure, considering design, construction and maintenance.
2	Sand Settling Basin	・ Build a sand settling basin near the intake weir/dam. ・ Build a sand flush facilities (scouring gate) at the end of the sand settling basin. ・ The average velocity in the basin is 0.2m/sec, the average depth is 1 m, and the length is to be determined. ・ Standardize the structure.
3	Canal (Channel)	・ Open channel type in principle. ・ Manning’s formula is to be used in the hydraulic calculation of the flow discharge. ・ Adopt the optimum section of channel that allows the maximum hydraulic radius at the same cross-sectional area of flow. ・ The maximum average velocity is to be not more than the allowable velocity (1 m/sec), which will not erode the inner surface of the channel.
4	Head Tank (Fore bay)	・ Install a head tank at the entrance of the penstock. ・ The capacity of the head tank is to be adequate to supply the maximum water consumption for more than 30 seconds. ・ No outlet gate is to be installed but an inlet valve is to be set up at the power plant end of the penstock pipe instead. ・ Set up the over flow type spillway at the side of head tank. ・ Install a sand trap (scoring) gate for sediments, which is to be a spindle gate for manual operation. ・ Reinforced concrete structure.
5	Penstock	・The common water pipe with flange is to be adopted for the penstock pipe. ・To be laid underground for protection. ・The design maximum velocity in the pipe is 3.5 m/sec, and the pipe diameter is to be standardized.
6	Power House	・ Retain space for inspection and dismantling of equipments and disassemblies etc. ・ Power house building is to have concrete walls 1 m from the foundation. ・ Structured to prevent flood/sediment influx and damage by rock falls. ・ Generators and equipments are to be installed inside the building. ・ Consider ventilation by setting up air vents with insect screens.
7	Tailrace	・Design to keep the necessary water depth in the bottom outlet for the uniform flow without vortices of the outflow from turbine.

Source: JICA Study Team

Table 5.6.2 General Technical Standards for Micro Hydropower Plants (for Electrical Utilities)

	Equipments	Applied Criteria and Idea
1	Hydraulic Turbine	・ For moderate head or small discharge, the cross flow type hydraulic turbine is to be adopted, which has a simple structure for maintenance and is economical. ・ In the case of around 50 kW output, the method below is to be adopted due to using a automatic guide-vane servomotor makes the mechanism complicated and maintenance hard, and eventually not economical. ➢ Flow regulation: Control the guide-vane manually by the load. ➢ Governor : Use an electronic servo less governor (speed adjusting device), a static governor that sets up dummy loads to stabilize the frequency to meet the load and control the rotating speed. ➢ Inlet valve: Manual gate valve To be designed so as not to suffer mechanical damage under unrestrained rotating speed in case of the failure of the governor.
2	Generator	・The plant is under unmanned control and to be designed for proper operation with one check up a day. ➢ Control method: by automatic voltage regulator (AVR). [Generator] • Type: 3-phase alternating current (AC) brushless synchronous generator • Frequency: 50 Hz • Voltage: AC400V • Connection: Pentagram, 3 phases 4 line conductors ・The generator is to be connected directly to the turbines (to prevent a decrease in the connection efficiency and complication in maintenance by belt connection type). ・Turbine efficiency 71%, generator efficiency 85%, and combined efficiency 60% are used in general.

Source: JICA Study Team

6. PLANNING OF SOLAR POWER SYSTEM

6.1 ISSUES OF SOLAR POWER

According to the questionnaire survey made by the JICA Study Team in January 2005 to the DIME, battery users for home lighting is around 871,593 households in total or 38.1%. A large percentage of the people are using battery without any other choice. People are charging their batteries without knowing the actual characteristic of diesel BCS and battery.

6.1.1 Issues of SHS

(1) Ownership if Provided under Grant

There are some examples around the world when SHS is provided under a grant, after few years due to high replacement cost of storage batteries the system is abandoned/not functioning. People understand the need to replace the consumable such as fuse, lamp or battery. However, in some cases such consumable are not available locally.

(2) Low Sustainability when ATP for Battery is Insufficient

After installation of SHS the most costly component that need replacement in few years is a storage battery. A shallow cycle lead acid battery is designed for providing large current for very short time period. Its life is very short comparing to deep cycle battery. But if a deep cycle battery having a longer life is chosen, initial system cost become high. If ability to pay for replacement of battery is low, such SHS would sooner or later fail. It is totally subject to ATP of the users.

(3) Introduction on Private/Personal Basis

Around the world SHS diffusion is left to market efforts by suppliers and crediting agency. Standardization of systems and providing training of suppliers are required for securing quality and sustainability. The government needs to provide appropriate incentives/subsidy to promote village electrification by solar power. In this M/P it is recommended that SHS be introduced on individual basis.

6.1.2 Issues of Solar Mini-Grid

(1) High Capital Cost Compared to Other Energy Sources

In rural electrification electricity requirement is limited to early morning and evening. But power generation by solar system is only at daytime. Therefore, the system needs to store energy for night tike supply. To supply power through mini-grid, distribution network is also needed. So, the capital cost of solar mini-grid becomes high comparing to the other energy sources. Furthermore, storage battery needs replacement after a few years.

(2) Users Tend to Use More Power Compared to SHS and BCS

Solar powered mini-grid is deigned to provide design power every day. On this design power the capacity of PV and storage battery is decided. If users consume more power, it exceeds the system capacity. Being a centralized system, it is difficult to control the utilization pattern of each individual user unlike SHS or BCS. If demand and supply is unbalanced from initial deign, there will be power interruption or may lead to black out. In M/P solar powered mini-grid is not recommended in view of its high cost and difficulty in demand management.

6.1.3 Issues of Existing Diesel BCS

(1) Charging System

At present in almost all cases, diesel generators (DG) used for BCS are second or even third hand with three phase AC generator. To charge the batteries it is converted to DC using simple hand made rectifier. Batteries are arranged in series to match to the output voltage of DG. Batteries with different condition (new or old), discharge level and capacity are connected in the same serial circuit. For effective charging current and voltage should be different depending upon state of charge of each battery. At existing diesel BCS, this points is neglected, which will directly affect the life time cycle of battery. BCS should adopt parallel charging.

(2) Detection Device for Charging Completion

As there is no device at diesel BCS to detect completion of charging, it is difficult to know the charge state of battery. If battery is charged heavily it will spoil batter plate and effect battery life. People are paying charging fee without knowing such situation. To protect battery from over charging and to achieve full charging, a detecting device is essential.

(3) Device at Home to Detect Timing of Charging

It is essential to install a device to alert user for a time of charging. Another option is to estimate the time of charging manually. Capacity of appliances and hours of uses should be recorded. For example if capacity of battery is 100Ah, with a maximum discharge depth of 50% the possible current to use is 50Ah. The total available capacity is 12V x 50Ah = 600 Watt-hour. Therefore, if 10 Watt-hour is used a day, battery is required to charge after every five days. To increase the days of use, either power consumption rate or hours of use should be reduced.

(4) Need of Charging Records of Battery

At present no record is taken on the utilization and charging date of battery. Such record will help understanding power consumption, amount of money paid for charging services, number of batteries charged a month and so on. It will help to understand ability to pay, total demand and area covered. Such recording can be made at BCS without much effort.

6.2 REMOTE ELECTRIFICATION AND SOCIAL ELECTRIFICATION

6.2.1 What is *Remote Electrification* by Solar BCS?

According to a hearing survey conducted by the JICA Study Team in December 2004 and January 2005 through each DIME, the diffusion level of battery lighting was 38.1% on an average of Cambodia. The highest was 98.3% in Takeo Province and the lowest 0.7% in Battambang and Ratnak Kiri Provinces and the third lowest at 3.2% of Siem Reap. The diffusion level is relatively low in the northeast and northern provinces; Ratnak Kiri, Modol Kiri, Stung Treng, Prea Vhiheal, Odar Meanchey, Siem Reap, and Kampong Thom. These provinces will be given priority in selecting candidate villages for installation of solar BCS.

Remote Electrification is proposed in the Master Plan as a tool to achieve the 100% level of village electrification. It will install solar BCS in villages that have no diesel BCS within the village or villages nearby. The capital costs will be 100% covered by grant on condition that:

1) the villagers will at their own expense prepare land and housing for BCS
2) the villagers will buy own batteries at their costs every 2-3 years, which cost about $25-30 per 50 Ah battery;
3) the villagers will pay battery charging fee at about Riel 1,200 per charging to cover operation and maintenance of BCS;
4) the villagers will undertake operation and management of the BCS installed;
5) the ownership of BCS will rest with RGC;
6) Upon realization of electrification by mini-grids or grid connection, the BCS may be removed and shifted to the other villages that do not have BCS yet.

The required operation and management works by the villagers at their costs will be:

1) daily battery charging operation including logging in a form;
2) daily cleaning of PV panel, BCS, and compound;
3) accounting of charging fee;
4) procurement and storage of consumables such as eletrolyte;
5) monthly report of accounting and charging operation to DIME;
6) maintenance of BCS building.

6.2.2 What is *Social Electrification* by PV Systems for Public Facilities?

In accordance with the similar conditions, PV systems will be installed in public facilities that are not electrified yet. This is dedicated to very poor villages where people cannot buy own battery for their home use. Unlike solar BCS of *Remote Electrification*, batteries will also be provided as part of the PV system with 100% grant on condition that:

1) the villagers will buy consumables such as lamp, electrolyte, etc. at their own costs;
2) the villagers will buy storage batteries upon expiry of lifetime. To secure this, monthly deposit of certain amount will be required;
3) the ownership of PV systems will rest with RGC;

4) Upon realization of electrification by mini-grids or grid connection, the PV system may be removed and shifted to the other villages.

The required operation and management works by the villagers at their costs will be:

1) periodical cleaning of PV panel and filling electrolyte to batteries;
2) collection of deposits for future replacement of batteries;
3) procurement and storage of consumables such as lamps and eletrolyte;

6.3 PLANNING OF REMOTE ELECTRIFICATION

(1) Identify Villages to Electrify

It is essential to conform from village survey that the diffusion level of battery is very low (<10% to 20), and villagers have difficulty in transporting their batteries to BCS over a long distance.

(2) Assess the Battery Charging Demand

To assess the battery charging demand below points need to consider

- Even though there is no diesel BSC in the village or nearby village, if some households have the battery and travel over long distance to charge their battery, then demand on BCS is high. If the charging is available on reasonable cost at BCS inside village then it may be affordable to other households too.
- If diffusion level of battery is zero but people are using dry cell batteries for radio, search light, or using kerosene at night, it will be suitable for solar BCS. However, battery and lamps might be expensive to them.
- In most of the village there are certain diffusion of small 6 Volt batteries. But load is very small and varies day by day. If daily demand is unpredictable, it should not be counted as demand on BCS. Small demand of 6 Volt batteries can be covered by BCS deigned for 12 Volt batteries.

(3) Determine Design Irradiation

To design the system it is required to determine the design irradiation for that site. For reference national average is 5.1 kWh/m^2/day and minimum average is 4.6 kWh/m^2/day. Design may be made on the basis of country annual average. But to provide the service especially in the rainy season months from July to September, it needs to deign at lower irradiation level. If system is deigned at lower irradiation level, there will be excess power in other dry months. Therefore, in those areas where annual average solar irradiation is lower than the country average then it is recommended that the system be deigned at annual average of the minimum monthly solar irradiation.

Beside the solar irradiation, inclined installation angle of PV module is also important to maximize the power generation of system. For this PV array is faced to south (in northern hemisphere) at an angle of site latitude. It is recommended to choose such angle that the system will generate maximum power even in the low irradiation months. Table 6.3.1 shows the solar irradiation level, recommended inclined angle for respective province. The detail data of solar irradiation level is given in **Appendix-B.**

Table 6.3.1 Group of Province, Solar Irradiation and Recommended inclined Angle

Group	Provinces	Solar Irradiation (kWh/m^2/day)	Inclined angle (degree)
1	Kampot, Koh Kong, Pursat and Takeo	4.6	5
2	Remaining province	5.1	10

Source: JICA Study Team

(4) System Configuration

The main components of solar BCS are:

i) PV Module

PV module generates power when exposed to direct sunlight. When ambient temperature raises the output voltage of PV module goes down. Therefore, it needs to select such a module which can generate enough voltage to charge even at higher ambient temperature above 30 degree Celsius. For example if it is assumed that there will be 2 volt loss in the system, the module needs to generate at least 15 Vmp (Voltage at maximum power point) even at higher temperature.

ii) Charge Controller (with reverse pole protection and current meter)

For effective charging, it is required to charge according to the state of charge of battery. A charge controller needs to have a function to adjust charging current according to the voltage of battery to protect from over/forced charging. To avoid accidental connection of reverse polarity, the charge controller needs to have built-in protection. To measure actual charge current either separate or built-in current meter on charge control is required.

iii) Wirings

The PV module will be connected in parallel to supply enough current to charge the battery within a day. Wires from PV array will be connected to the charge controller and from charge controller it is connected to each battery to charge effectively.

(5) Standard Units

Table 6.3.2 shows standard deigns parameters of solar BSC.

Table 6.3.2 Design Parameters of Solar BCS

Item	Parameters	Value	Unit	Remarks
1	Horizontal solar irradiation	5.1	kWh/m^2/d	Country average
2	Horizontal solar irradiation	4.6	kWh/m^2/d	Minimum average for lower irradiation region
3	Module derating factor	10	%	Decrease of output due to dirt, years of uses and so on.
4	Columbic efficiency	90	%	To charge battery effectively.
5	Charge controller (C/C) consumption	10	mA/day	Depends on manufacturer
6	Depth of discharge (DOD) of battery	50	%	for shallow cycle lead acid battery
7	Charging interval	5	days	To avoid deep discharge
8	Voltage output from charge controller (C/C)	13.5	V	Minimum voltage to charge battery effectively
9	C/C capacity	12	Amp	To charge battery effectively
10	Battery to be charged	50, 70 & 100	Ah	Present battery size charged at DG BCS

Source: JICA Study Team

(6) Selection of Units Suitable for Village

From the parameters in the Table 6.3.4 a shallow cycle battery can be discharged up to 50%:

- 100Ah battery can discharge 50 Ah
- 70 Ah battery can discharge 35 Ah
- 50 Ah battery can discharge 25 Ah

<u>Grouping of households</u>

It is required to decide the number of battery to be charged in a day or total number of households to be cover by each BCS. The number of battery or households differs from village by village. To provide services even in small or remote villages, it is better to have many adequate systems than having one large system. To cover even small villages the systems are categorized as follows:

- BCS Model 25 for up to 25 households
- BCS Model 50 for 26 to 50 households
- BCS Model 75 for 51 to 75 households
- BCS Model 100 for 76 to 100 households

If a village has more than 100 households, a combination of above mentioned Models can be applied.

(7) Capacity of System

To determine the capacity of system below point need to be considered.

<u>Total current required to charge each battery</u>

Beside the household number it is required to know the number of batteries by capacity to decide the required capacity of BCS. For example it is assumed as shown below:

- 50 Ah battery 30% of total households
- 70 Ah battery 50%

- 100 Ah battery 20%

A total current to be charged for each battery is calculated as:

$$\textit{Total current } T_{Imp}\,(Ah) = \frac{\text{Max. Discharge Capacity of Batt. (Ah) } B_{Ah}}{\text{Module derating factor } (M_{kf}) \times \text{ Columbic eff. } (C_{eff})} + \text{C/C consumption}$$

As there will be many batteries to be charged in a day, it should be summed up to get a total required current. Table below shows number of batteries to be charged:

Capacity of battery	BCS Model 25 (No. of Batt)	BCS Model 50 (No. of Batt)	BCS Model 75 (No. of Batt)	BCS Model 100 (No. of Batt)
100 Ah	5	10	15	20
75 Ah	12.5	25	37.5	50
50 Ah	7.5	15	22.5	30

Source: JICA Study Team

To determine the capacity of PV

After determining the required capacity to be charged, required DC current and power are calculated as:

Total required DC current (Ah/day) =

Total Current (T_{Imp}) x No. of Battery / Charge Interval (day)

Required power (kWh/day) =

Total required DC current (Ah/day) x Required voltage to charge / 1000

To calculate the capacity of PV, it is required to know the output current of PV module. Therefore, if each PV module can generate 50 Wp (Watt peak) and 3.00 Imp (current at maximum power point) then,

Total current generation by each PV module (total current) =

PV module current x Solar irradiation / Module derating factor

Required no. of PV module =

Required Total DC current / (Columbic eff. x Total current generation by each PV module)

From the above required PV capacity for the system will be:

For BCS Model 25 : 1 kWp

For BCS Model 50 : 2 kWp

For BCS Model 75 : 3 kWp

For BCS Model 100 : 4kWp

The number of PV Module is round to a digit.

(8) Land Area Required

The required land for installation of PV module is around 11 m^2 for 1 kWp. This will vary a little depending on the shape of land and type of PV module used. For battery charging shade/house, a 1 kWp system requires around 3 m^2. Considering also the working space, the total land requirement will be not less than 15 m^2 for a 1 kWp system.

(9) Selection of Site

To select the solar BCS site the following points should be considered:

- It should be accessible around the year.
- Convenient location to all households.
- Shadow should not fall on PV array at least from 8 AM to 4 PM
- Far from any garbage dumping area or fire place.
- No security issue.

6.4 PLANNING OF SOCIAL ELECTRIFICATION

(1) Selection of Public Facilities to Electrify

PV system for public facility is applicable to those villages where public facilities like health post, night school or community hall are not yet electrified.

(2) Electricity Demand of Public Facilities

The power consumption of each appliances and hour of utilization needs to be estimated first to assess the electricity demand of public facilities. These includes floor area of respective rooms, number of rooms, purposes/uses of electricity to determine deign illumination

(3) Battery Charging Demand of Villagers

The battery charging demand of villagers should be assessed in accordance with the same procedure as mentioned in Chapter 6.3 for solar BCS if there is such demand and if villagers can afford to buy batteries and pay charging fee.

(4) Determine Design Irradiation

The design irradiation value shall be same as for solar BSC.

(5) System Configuration

Main components of PV system for public facilities are:

<u>PV module</u>

The power generated by PV module is stored in battery to be placed inside the public facilities can be used directly during day time.

<u>Charge/discharge controller</u>

Generated power by PV is charged through the controller for effective charging and controlling overcharging. The power is supplied directly to load if battery is full. At the time of bad weather or nighttime, power is supplied via controller which will control the over-discharge to protect the battery.

<u>Storage battery</u>

The storage battery will supply power at the time of bad weather and nighttime. The battery is needed to supply power even at no sunshine day. The number of day is determined on the basis of no sunshine days. The no sunshine days is set at 3 on an average in the country. The detail data is attached as **Appendix-B**.

(6) Standard Units

Standard units of PV system for public facilities are shown in Table 6.4.1.

Table 6.4.1 Design Parameters of PV Systems for Social Electrification

Item	Parameters	Value	Unit	Remarks
1	Horizontal solar irradiation	5.1	$kWh/m^2/d$	Country average
2	Horizontal solar irradiation	4.6	$kWh/m^2/d$	Minimum average for lower irradiation region
3	Module derating factor	10	%	Decrease of output due to dust, years of uses and so on
4	Columbic efficiency	90	%	To charge battery effectively
5	Depth of discharge (DOD) of battery	80	%	for deep cycle battery
6	Days of autonomy	3	days	for no sun days
7	Charging interval	5	days	for battery charging option
8	Voltage output from charge controller (C/C)	13.5	V	Voltage to charge battery effectively
9	System voltage (DC)	12	V	

Source: JICA Study Team

(7) System Sizing

The capacity of PV and storage battery is determined by the following:

(i) DC load (Wh/day) = Load capacity (Watt) x Quantity (no.) x hours of uses (hour/day)

(ii) Total DC load = {DC load (Wh/day) / Columbic efficiency (%)} + {C/C Consumption (Ah/day) / System voltage (V)}

(iii) Total DC load current (Ah/day) = DC load (Wh/day) / System voltage (V)

(iv) Total current generation by each PV module (Total current) = PV module current x Solar Irradiation / Module derating factor

(v) Required capacity of storage battery = Total DC load current (Ah/day) x Days of Autonomy (days) / Battery depth of discharge (DOD)

(vi) Total current generation by each PV module (Total current) = PV module current (Imp) x Solar Irradiation / Module derating factor

(vii) Required no. of PV module = Required total DC current / (Columbic eff. x Total current generation by each PV module)

The outcome number needs to be rounded up to a digit.

(viii) Total PV capacity = Required no. of PV module x capacity of each PV module

(ix) Capacity of charge controller =

Total current generation by each PV module x No. of PV module

(8) Land Area Required Nearby Public Facilities

The land area required for public facility is the same as for solar BSC which is around 11 m^2 for 1 kWp. This will vary a little depending on the shape of land and type of PV module used. In the case of PV system for public facilities, it requires space with good ventilation to keep storage battery. The space requirement depends upon the capacity. To keep one 100Ah deep cycle battery, it requires around 120 cm^2 (30cm x 40cm) of area.

6.5 COST ESTIMATE

(1) Arrangement of Land

To install the PV array it may require a little leveling works to install the system depending upon ground conditions. It would require around 8 US$ for leveling 1m^2 of land.

(2) Building for BCS/PV System for Public Facilities

Cost of model BSC depends on the household numbers to be covered. The house cost for solar is around 20 US$/HH on an average. PV system for public facilities requires no specific house.

(3) Equipment Cost of Solar BCS/PV System for Public Facilities

The equipment cost for standard solar BCS is summarized in Table 6.5.1.

Table 6.5.1 Equipment of Solar BCS

No.	Item	Cost	Unit
1	PV module	3.7	US$/Wp
2	Charge controller with Amp hour meter	265	US$/unit
3	Accessories cost (Frame structure for PV, breaker, wires, switch etc.)	15	% (of total cost excluding Charge house)

Source: JICA Study Team

The cost of the component is based on present international market price and does not include customs and taxes

The components price of PV system for public facilities is presented in Table 6.5.2. The percentage of accessory cost is higher than solar BSC with two reasons:

- The facility is already exists but requires new wirings.
- Land for installation of PV array may need more cost because of its location close to public facility.

Table 6.5.2 Equipment Cost of PV System for Public Facilities

No.	Item	Cost	Unit
1	PV module	3.7	US$/Wp
2	Charge controller (C/C) 12 V DC - 5 Amp 12 Amp 20 Amp 30 Amp 40 Amp	30 95 115 170 220	US$/pcs.
3	Deep cycle battery	1.47	US$/Ah
4	Lamp set (12V DC) 5 to 7 W (CFL) 8 to 11 W (CFL) 20 W (FL) 40 W (FL)	4 5 15 30	US$/set
5	Accessories cost (Frame structure for PV, breaker, wires, switch etc.)	20	% (of total cost)

Source: JICA Study Team

(4) Operation and Maintenance Costs

PV systems need minimum O/M comparing to the other systems. Even though it requires some works regularly such as refilling of electrolyte daily to batteries at solar BCS and periodically at PV system for public facility. Change of fuses, lamps and cleaning of PV module one required. On an average around 2% of the total system cost may be required for O/M.

7. IMPROVEMENT OF EXISTING MINI-GRIDS AND CONNECTION TO EDC GRID

7.1 IMPROVEMENT OF EXISTING MINI-GRIDS

7.1.1 Distribution Facilities

Distribution facilities of licensees of EAC except for EDC are far from the technical standards of Cambodia and very poor except for some licensees who supply electric energy to their customers in the province towns and/or district towns. There are many distribution facilities of which LV lines are hung on poor wooden and/or bamboo poles without insulators.

For the licensees registered by DIME before 2001 and non-licensees, situations of their distribution facilities are similar to ones of licensees of EAC or more poor.

7.1.2 Energy Losses of Power Suppliers

No reliable records on energy losses of power suppliers are available except EDC and licensees of EAC whom detail information by suppliers are published periodically in their annual reports.

Energy losses of suppliers by group are given in Table 7.1.1. Energy losses by supply area are situated in wide range, i.e. from 3.7 % of Baveth system of Svay Rieng (import from Vietnam) to 22.3 % of Siem Reap system of EDC, from 10.7 % of Licensee #036L of Svay Rieng to 40.3 % of Licensee #015L of Takeo of consolidated licensees and from 4.0 % of Licensee #009L of Pailin (import from Thai) to 25.3 % of Licensee #089 of Pilin. The table shows that averaged energy losses of licensed suppliers is 20.4 % of generated and purchased energy in the country. Among suppliers groups, averaged energy losses of distribution licensees is the lowest and one of consolidated licensees are highest. In general the averaged scale of supply of the former is about 20 times of the later, most of their supply areas are province towns and district towns, and situations of their distribution facilities are better than that of the later.

Table 7.1.1 Energy Losses of Power Suppliers

Unit: MWh

Group	Generation/Purchased	Sold	Losses	%
EDC	744,252	589,010	155,242	20.9
Consolidated Licensees	18,095	12,865	5,230	28.9
Distribution Licensees	53,204	47,475	5,728	10.8
Total	815,550	649,350	166,200	20.4

Source: Annual report 2004 of EAC

Energy losses of licensees of DIME and non-licensees are estimated at similar level to the above-mentioned losses of consolidated licensees or higher.

7.1.3 Technical Standard Applicable to Mini-Grid

Design condition of structures, electrical and mechanical requirements of materials and minimum technical requirements for selecting materials shall not be principally changed to keep safety of people, even applying to mini-grid. However, applicable range of some electrical requirements like "rated short time current" which will be decided by the scale of power supply system and kind and/or size of materials such as poles and conductor can be widen to apply to mini-grid for cost saving.

The following are applied to the MV and LV system under the Province Power Supply Project (ADB) by EDC.

(1) Design Conditions

Altitude	Up to 1,000m
Ambient air temperature	
Average	+ 27.5 ^{o}C
Minimum	+ 13.3 ^{o}C
Maximum	+ 40.5 ^{o}C
Design wind pressure (design wind speed of 25 m/sec)	
Conductor	35 kg/m^2
Poles	45 kg/m^2
Other equipment	36 kg/m^2

(2) Design Data of MV System

Nominal voltage U_n	22 kV
Highest system voltage U_{max}	24 kV
Design voltage U_m	24 kV
Standard frequency	50 Hz
System configuration	3-phase, 3-wire
Earthing	Solidly earthed
Isolation co-ordination	IEC 60071-2
Rated impulse withstand (peak)	125 kV
Rated 1 min power frequency withstand (peak)	50 kV
Rated short time current	25 kA/1 sec
Min. phase-to-earth clearance	220 mm
Creepage distance outdoor	20 mm/kV
Transformer vector group	Dyn11

(3) Design Data of LV System

Nominal voltage U_n	400/230 V
Highest system voltage U_{max}	440/245 V
Design voltage U_m	1.0/0.6 kV

Voltage variation	± 5%
Standard frequency	50 Hz
System configuration	3-Ø, 4-wire; 1- Ø, 2 or 3-wire
Earthing	Solidly earthed
Isolation co-ordination	IEC 60071-2
Rated impulse withstand (peak)	6 kV
Rated 1 min power frequency withstand (peak)	2 kV
Rated short time current	25 kA/1 sec

(4) MV Conductor

1) AAC (All Aluminium Conductor)

AACs are required for MV overhead distribution line and its construction shall be to IEC 60889 and IEC 61089

Nominal Area	Code Name	Stranding (mm)
150 mm^2	Cricket	7/5.36
70 mm^2	Earwig	7/3.78
35 mm^2	Mosquito	7/2.59

2) AAAC (All Aluminium Alloy Conductor) XLPE Covered Conductor

AAAC covered conductor (partially insulated) is required for overhead lines where there is a likelihood of tree contact that may cause transient supply interruption.

Nominal Area	Code Name	Tranding (mm)
150 mm^2	Krypton	19/3.25
35 mm^2	Mosquito	7/2.59

(5) LV Aerial Bundled Conductor (ABC)

Three-core plus neutral aerial bundled conductor cable is required for low voltage distribution lines.

Cable Type	Cable	Construction
ABC(1)	3x150+70 mm^2	Distribution line without street
ABC(2)	3x70+70 mm^2	Lighting pilot wires
ABC(3)	3x150+70+2x16mm^2	Distribution lines with street
ABC(4)	3x70+70+2x16mm^2	lighting pilot wires

(6) Galvanized Steel Guy Wire

Galvanized steel guywire (staywire) is required for the guying of distribution poles.

Nominal size	50 mm^2
Composition	7x3.25
Weight of zinc coating	0.24 kg/m^2
Ultimate tensile strength	68 kN

(7) MV & LV Cables

1) MV Three-core XLPE Insulated Cables

Three-core 12.7/22 (24) kV 150 mm^2 and 35 mm^2 aluminium conductor, cross-linked polyethylene (XLPE) insulated, screened, PVC underground cable shall be used for 22 kV circuits.

2) MV Single Core XLPE Insulated Cables

Single core 12.7/22 (24) kV 70 mm^2 aluminium conductor, cross-linked polyethylene (XLPE) insulated, screened, PVC underground cable shall be used for installation from the distribution transformer primary bushing to the indoor 22 kV fuse switch of ringmain unit (RTU).

3) LV Cables

Four-core XLPE insulated cable, 3x150 mm^2 AAC phase conductor and 1x70 mm^2 AAC neutral conductor, will be used for underground connection between the LV distribution cabinet (if any) and overhead bundled conductor and LV road crossing, if required.

(8) Support Poles

The poles shall be prestressed concrete of rectangular or circlar cross-section. Pole length, shape and design loading are as follow.

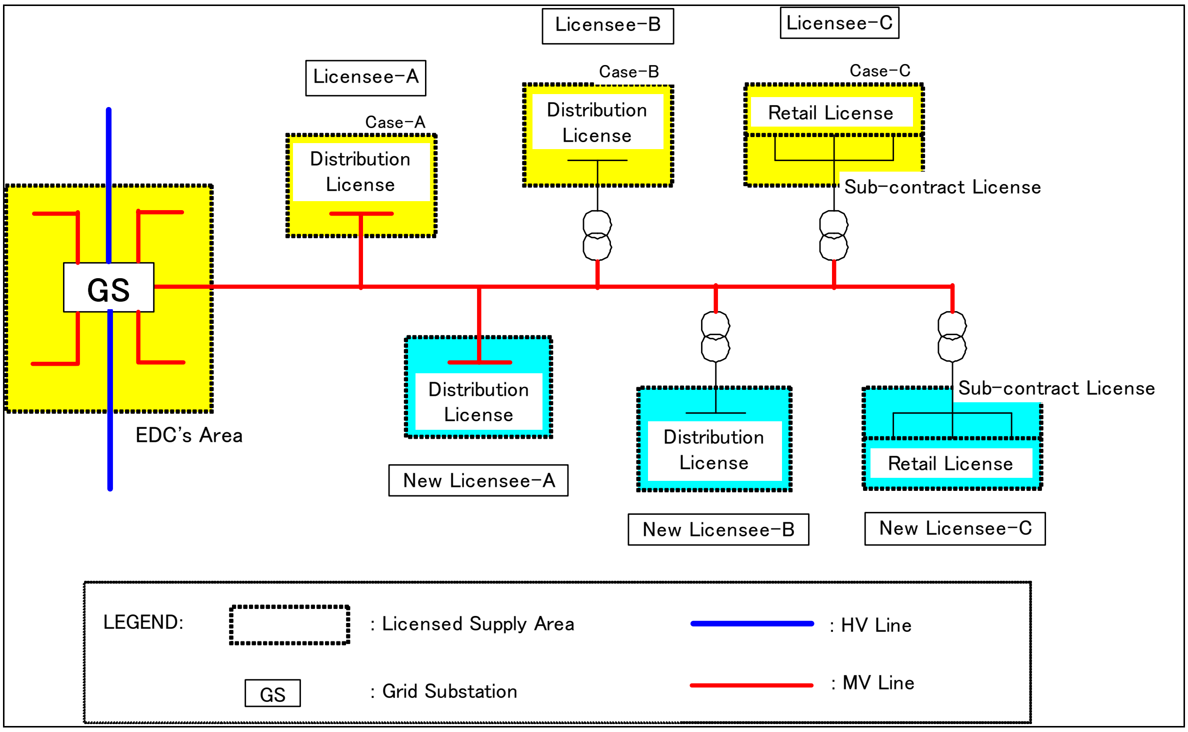
Table 7.1.2 Pole Length, Shape and Design Loading

Length	Type	Design Load Applied Pole		Design Bending Moment at GL	
		Traverse kN	Longitud. kN	Traverse kN.m	Longitu. kN.m
9m	Type T	3.0	1.0	22.5	7.5
9m	Type A	5.0	1.7	35.0	13.0
9m	Type S	8.0	2.7	60.0	20.0
12m	Type T	5.0	1.7	50.0	15.0
12m	Type A	8.0	2.7	80.0	24.0
12m	Type S	12.0	4.0	120.0	36.0
14m	Type T	4.3	1.4	50.0	16.0
14m	Type A	6.8	2.1	80.0	24.0
14m	Type S	10.2	3.4	120.0	40.0

Source: JICA Study Team

7.2 CONSIDERATION FOR FUTURE GRID CONNECTION

Typical cases for integrating mini-grids of existing (licensed and non-licensed) suppliers and/or non-electrified villages into the national grid by the extension of sub-transmission line are given in Figure 7.2.1. For further details, refer to section 2.1.3 of Part 2 of this report.



Source: JICA Study Team

Figure 7.2.1 Extension of Sub-transmission Grid and Integration of REEs

8. ORGANIZATION FOR IMPLEMENTATION AND MANAGEMENT

8.1 INTRODUCTION

8.1.1 Pros and Cons of Business Entities

There are three players for implementing rural electrification in rural area. These are EdC, REE and CEC:

- EdC is responsible for national grid operation and some peri-urban mini grid operation.
- REEs are responsible for mini grid systems and solar-based standalone systems
- CECs are responsible for mini grid systems and solar-based standalone systems which REEs will not go for.

The pros and cons of each business entity are described in the following table.

Table 8.1.1 Pros and Cons of Each Business Entity

Model/Description	Advantages	Disadvantages
1. National Utility (EdC) Model Government-owned electricity utility extends its grid to rural areas and augments its generating capacity as required. May operate peri-urban mini grids as well, with own generation or cross-border supplies.	• Well proven model internationally • Can cross-subsidies costs of electrification from urban consumers and industries (this can also be a disadvantage). • Depending on government financial policy, may benefit from lower cost of capital than private companies. • Large utility size means less likely to require outside technical support and can benefit from economies of scale. • Internalizes planning process so that decisions on location of generation, grid expansion and electrification opportunities can be easily coordinated.	• Government ownership tends to lead to greater inefficiencies in operation and investment. • Does not provide access to new sources of funds for electrification. (The REF support mechanism is not applicable to EdC.) • Tendency to focus on urban consumers at expense of rural areas due to greater political influence of former. • Difficult to set tariffs that discriminate by location – requiring urban consumers to cross-subsidies rural consumers or meaning connecting additional rural consumers involves making a loss. • Subsidies will tend to benefit both richer urban and poorer rural consumers rather than being targeted on the latter.
2. Rural Electricity Enterprises (REEs) Private companies or individuals construct small networks (mainly at low voltage), install generators (mostly diesel) and supply electricity. The term generally refers to the Cambodian model.	• Generally greater capacity and higher quality of supply than individual household systems • Generally private sector has greater incentives to improve efficiency, access to new technology and expertise and freedom from public sector controls. • Introduces new sources of funding for investments.	• Service quality and capacity generally less than EdC grid supply and costs generally higher (depending on distance from grid) • Lack of technical capability and absence of regulation/competition can lead to poor service quality. • Can be high-cost due to monopoly position, and therefore supplies tend to be restricted to richest households (it may be possible to address this through regulation and subsidies, but these will increase costs and reduce interest). • In absence of subsidies, no incentive to

Model/Description	Advantages	Disadvantages
		expand services to poorer households. (This will be addressed by the REF subsidy facility.) • Can be difficult to attract private financing in absence of established legal and regulatory framework. (This will be addressed by the REF support facility.)
4-1 Community Ownership (CECs) Local communities (communes/villages), either separately or in combination with each other, undertake the construction and operation of electrical systems. In the RE context, this often includes RET-based local generation. Consumer cooperatives owned by consumers are included in CEC model.	• Allows greater consumer participation in design and operation helps to improve sustainability • Cooperative nature assists in reducing non-technical losses and improving collection of billing • In principle, cooperatives are self-financing • Absence of profits (non-profit making nature) reduces costs of financing	• Cooperatives often have difficulty persuading members to pay tariffs at levels sufficient to fund necessary maintenance and rehabilitation. • Pressure to use surplus funds for other purposes (e.g. agriculture) rather than to retain these for future rehabilitation and investment • Often financial controls are inadequate • Lack of scrutiny of management due to dispersed ownership and absence of clear measures of performance in absence of profits targets leads to inefficiencies and higher costs • Lack of expertise among cooperative members means frequent need for external support and monitoring • Cooperatives may be unwilling to expand service to new members where this will raise costs for existing members. • Difficulties in apportioning responsibility between asset owner and cooperative for maintenance (cooperative) and investments (owner)

Source: JICA Study Team

8.1.2 Demarcation between EdC and REE

Division of roles between EdC and REE is set out as follows:

- EdC is responsible for: (i) HV extension and MV extension to priority supply areas of PAGE; and (ii) MV extension to high demand areas within PAGE.
- REE is responsible for: (i) upgrading of existing REE grids to MV system to be connected to the national grids; and (ii) extension of existing mini grids to connect new customers.

There are observed some areas within PAGE where REEs face competition from EdC and crowding out and/or taking-over of existing REEs by EdC with progress of the latter system expansion are taking place. Under the RGC policy of prioritizing REEs, EdC's extension should not be allowed to push out the REEs unless EdC has previously announced firmly their plans and these were known to REEs and taken into account by EAC in the license. It is desirable the services provided by REEs and EdC should be viewed as complementary and clear boundaries should be drawn between EdC and REEs by EAC. The EdC's owned and REE-leasing or –operating options or distribution/supply by REEs purchasing bulk power from EdC should be pursued wherever possible.

With expansion of EdC grid areas the REE grid areas are also expected to expand since most REEs are willing to be in peri-urban and rural town areas and close enough to EdC's operations, so that the interface between activities of EdC and REEs should be coordinated and adjusted properly

8.1.3 Demarcation between REE and CEC

REEs are private businesses which are driven to do business by private interests. Things which are vital in attracting REEs' interests are: (i) household density, (ii) strong local economy (high demand and affordability to pay), and (iii) availability of cheap and stable energy sources. Therefore the demarcation between REEs and CECs is generally made as follows:

- REE mini grid areas will cover the areas attracting the private interests and the medium/high income areas with the number of customers above a certain threshold, say 200 or more.

- CEC mini grid areas will be lower income areas with lack of REEs' interests, but with high possibility of formation of cooperatives or association of communities or customers benefiting electrification. These conditions include:

  (i) willing to provide free labors to help with installation of plants and equipment and erection of lines as well as own construction of access roads, etc.

  (ii) able to manage operation, collect revenues from sales and organize maintenance of the system

Preliminary results of socio-economic surveys revealed the following areas are seen as likely for those community-ownership options:

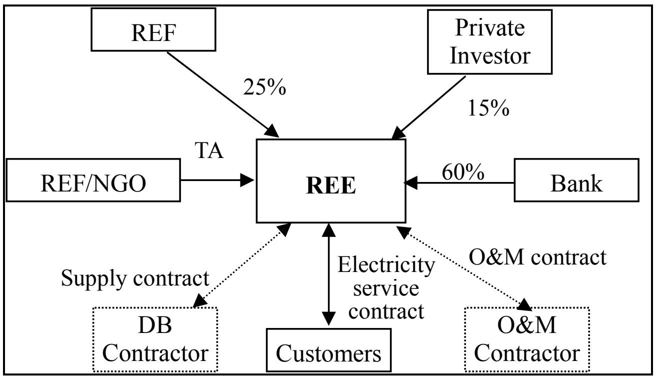
- South-western area including Pusat, Koh Kong and parts of Kampot and Battambang provinces
- Northern area including parts of Siem Reap and Preah Vihear provinces
- Eastern area including Ratana Kiri, Stung Treng and Modul Kiri province

For stand-alone systems (solar BCS/PV systems), there is an observation that making distinction between REE and CEC is not practical. Pure private business-minded REEs entering off-grid remote villages are very few. Many targeted REEs are essentially CECs with features similar to NGO.

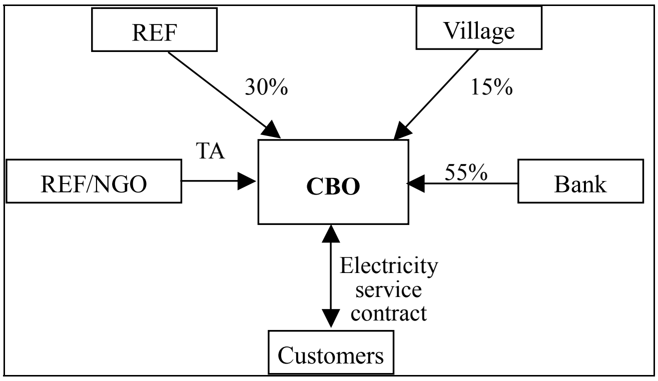
Meanwhile, there are opposite opinions that potentially business-minded REEs are many and NGO-facilitated CECs are few. The proponents believe the cooperative structure in Cambodia featured by independent (landed) farmers is neither universal nor strong. The electricity service provision is business to be put in the hands of professional business entities like REEs. Most of RGC officials and WB are likely to take this view.

8.1.4 Typical Organization of REEs Business Models

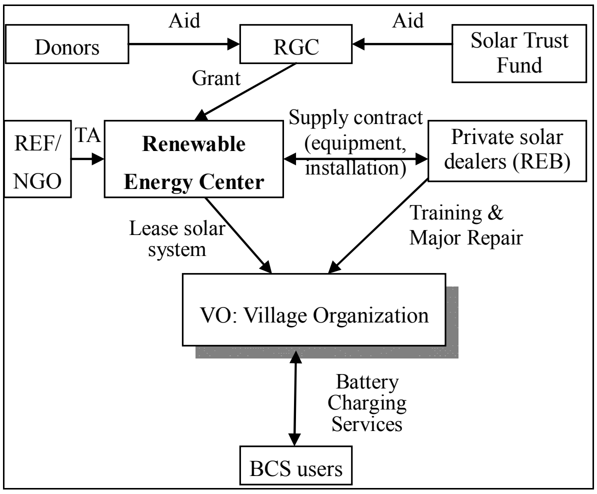
REE business models are classified into three models: (i) private-owned REE model, (ii) community-owned REE model (CEC model), and (iii) Government-owned REE model (Renewable Energy Center for remote and social electrification by solar PV system. Implementation structures for each model are shown below.



(a) Private-owned REE Model



(b) Community-owned REE Model (CEC Model)



(c) Government-owned BCS Model

Source: JICA Study Team

Figure 8.1.1 Typical Organization of REEs Business Models

8.2 REE FOR MINI-GRIDS

8.2.1 Introduction

REEs usually provide electricity services for the area with densely populated, medium/high incomes and the number of customers with a threshold of say 200 or more. Here we will present a business case of model REE-owned biomass-based mini-grid systems with following features:

- Production capacity: 20 – 100 kW or more
- Number of customer: 200 – 500 households, or more
- Service continuity: 5 hour or longer per day

8.2.2 Tariff Setting and Expected Level of Tariff

The tariff calculation by REEs must start with calculation of cost of service since the cost must be recovered by the tariff and the subsidy. The cost shall be calculated in accordance with the Sub-Decree on Business Principles for Tariff Setting, which specifies the licensee's reasonable costs shall consist of the following components:

(a) operation and maintenance costs;
(b) costs of fuel purchases;
(c) administrative and general management costs;
(d) power purchase costs;
(e) depreciation costs;
(f) profit and cost of loan employed; and
(g) other specific costs as considered reasonable by the EAC

Basic calculation methods of each component are specified by the Sub-Decree. Detailed methodologies for calculation and quantification of the reasonable costs are specified in the Regulations and Procedures drafted by EAC subsequent to the Sub-Decree.

In the calculating capital costs (items (e) and (f)) the subsidy and the smart loan available for the project shall be considered referring to the following financial support facilities provide by REF/CFR.

Table 8.2.1 Financing Framework for Rural Electrification by Types and Operators

Type of Electrification	Scope of Work	Ownership	Fund Sources of Capital Costs	
1. National grid extension	Grid extension to priority supply and high demand areas	EdC	Equity (30%), Loan (70%)	
			REE	CEC
2. Rehabilitation of REE grid	Rehabilitation of Distribution lines and Extension of an existing mini grid systems	REE	Subsidy (25%), Equity (25%), Soft Loan (50%)*	-
3. Renewable Energy new mini grid (Hydro, Biomass)	Generation and distribution	REE/CEC	Subsidy (40%), Equity (20%), Soft Loan (40%)	Subsidy (50%), Equity (10%), Soft Loan (40%)
4. Diesel new mini grid	Generation and distribution	REE/CEC	Subsidy (25%), Equity (25%), Soft Loan (50%)	Subsidy (30%), Equity (20%), Soft Loan (50%)
5. Solar system	SHS, BCS	REE/CEC	Subsidy(40%)** Equity (20%), Soft Loan (40%)	Subsidy (50%)**, Equity (10%), Soft Loan (40%)
	Remote & Social electrification by solar power	Public (Owned by a New National Agency)	Grant (100%)	

Note) Above figures are changeable by future investigation
* Expected interest rate is around 7% with guarantee of REF
** Capital cost of Solar system is very high, so subsidy rate may be raised
Source: JICA Study Team

Then the overall tariff level to be charged to the household customers shall be calculated. The electric tariff will be determined on two principles: (i) the cost-recovery principle; and (ii) the customers' accessibility and affordability principle.

First principle requires that the cost of services should be recovered by the tariff revenues. Second principle is that the customer be able to pay for connection charges[1], and then also be able to pay the service charges once they are connected. These principles conflicting each other are required to make the electricity business operationally and financially sustained.

Therefore it is important to see how to strike a balance between these conflicting interests: private interests and public interests in equitable and efficient ways.

The following table is an example of indicative tariff table likely to be applicable to the off-grid areas in Cambodia. This is a so-called "lifeline and increasing block tariff system". In this system, every household gets a guaranteed fixed supply of electricity and above the lifeline consumption (say 1 kWh per month) they pay for consumed quantity by the meter under a progressive manner.

[1] The connection charge includes costs for the line from the distribution network to the household and the tariff meter and the house wiring. The connection charge ranges from $30 to $100 in Cambodia. There are many poor customers who are unable to pay such high one-time charge. To make them accessible to the power service such support measures are needed as deferred payment using micro financing or provision of subsidy for connection payments.

Long Term Goal of Rural Tariff Table

Household Class (electricity consumed in kWh/month)	Tariff Level	
	Riel/kWh	US¢/kWh
1) 0 –10	1,400	35
2) 10 –20	1,280	32
3) over 20	1,160	29

1 US$=Riel 4,000

Source: JICA Study Team

It should be noticed that the above tariff table is presented just as an example for indicative purposes. Actual tariffs will be designed case by case based on site specific conditions and situations.

REEs shall submit their tariff proposal to EAC for approval. The EAC will appraise the tariff proposal pursuant to the Sub-Decree on Tariff Setting which stipulates the basic policy for evaluating the cost of electricity business for EAC to set the electricity tariff.

8.2.3 Terms and Conditions to be Clarified

Essential terms and conditions in contracting with REE for achieving village electrification include:

1) Limit of power use at household (for example,100 W);
2) Supply hours a day (typical one is for 6 hours from 5:00 p.m. to 11:00 p.m.);
3) Date of commissioning to start power supply;
4) Guaranteed voltage at user end;
5) Initial connection fee;
6) Tariff per kWh and penalty for delayed payment (supply cut for non-payment over 2 months, for example);
7) Interval and duration (days) for scheduled maintenance and measures during such maintenance period (for example, no supply and use battery lighting at home);
8) Penalty when power supply interruption has exceeded agreed frequency and duration per month;
9) Conditions in case of bankruptcy of REE;
10) Conditions for canceling contract between REE and the villagers.

8.2.4 Negotiation with REE

The terms and conditions listed in Sub-section 8.2.3 need negotiation between candidate REE and the villagers. The best way is to refer to example of existing cases. There are over 100 licensed REE operating diesel powered mini-grids. Main differences between diesel and biomass power are summarized below for reference:

Table 8.2.2 Main differences between diesel and biomass power

No.	Items	Diesel Mini-Grid	Biomass Mini-Grid
1.	Capital cost	Low	High
2.	Fuel cost	High	Low

Source: JICA Study Team

8.2.5 Operation and Maintenance Staff Requirements

The number of O&M staff required depends on the size and scope of supply system and customers as well as scope of works and components of the system. Indicative plans for various systems (excluding hybrid systems) are shown below.

Table 8.2.3 Number of O&M Staff and Scope of Works by Energy Source (example)

Energy source	Implementation	The generation capacity	Distribution facilities	Number of users	Staff required
Diesel	REE	varies	LV/MV	200 – 500	Manager 1 Generator operator 1 Line technician/tariff collector 1
Biomass	REE	10 – 500 kW	MV/LV	200 – 2,000	Manager 1 Accountant 1 Generator operator 3 (including biomass-fuel collectors) Line technician/tariff collector 1
Micro-hydro	REE	5 – 200 kW	MV/LV	200 – 2,000	Manager/accountant 1 Civil/mechanical engineer 1 Electrical engineer 1 Tariff collector one (1) each village/commune (part-timer)
Micro-hydro	CEC	5 – 50 kW	MV/LV	50 – 500	Manager/accountant 1 Civil/mechanical engineer 1 Electrical engineer 1 Tariff collector one (1) each village/commune (part-timer)
Solar PV	BCS	1-4 kWp		25-100	System operator/tariff collector

8.3 CEC FOR SMALL MINI-GRIDS

8.3.1 Works Required for Mini-Grid by Biomass Power

Works required for CEC particular to biomass gasification power are fuel supply. The fuel supply will need the following:

1) Contracting with tree growers and start tree planting at least one year ahead of commissioning;
2) Scheduling of monthly fuel purchase and determination of suppliers;
3) Having sufficient stock (for one month) in roofed storage space in the rainy season in particular;
4) Chipping of fuel trees.

8.4 MANAGEMENT OF REMOTE ELECTRIFICATION BY SOLAR BCS

8.4.1 Works Required

For management of solar BCS, required works are:

1) Assigning person for daily operation, record keeping and collection of service charge at BCS.
2) Record keeping of each battery.
3) Keeping stocks of battery electrolyte and use record.
4) Collection of service charge and record keeping.
5) Providing information to users on proper utilization of battery and load management at rainy seasons.
6) Providing assistance in buying and changing fuse, lamps etc. by keeping stocks at solar BCS.
7) Removing and cleaning of foreign particles such as tree leaves, bird excrement from PV surface.
8) Visual checkup of over all system and Site cleaning.
9) Hiring technical assistance if required.

8.5 MANAGEMENT OF SOCIAL ELECTRIFICATION

8.5.1 Works required

Routine check up system is required for PV system of public facilities. The required works will be as follows:

1) Record keeping of battery condition.
2) Removing and cleaning of foreign particles such as tree leaves, bird excrement from PV surface.
3) Keeping stocks of battery electrolyte and use record.
4) Visual check up of overall system.
5) Hiring technical assistance if required.

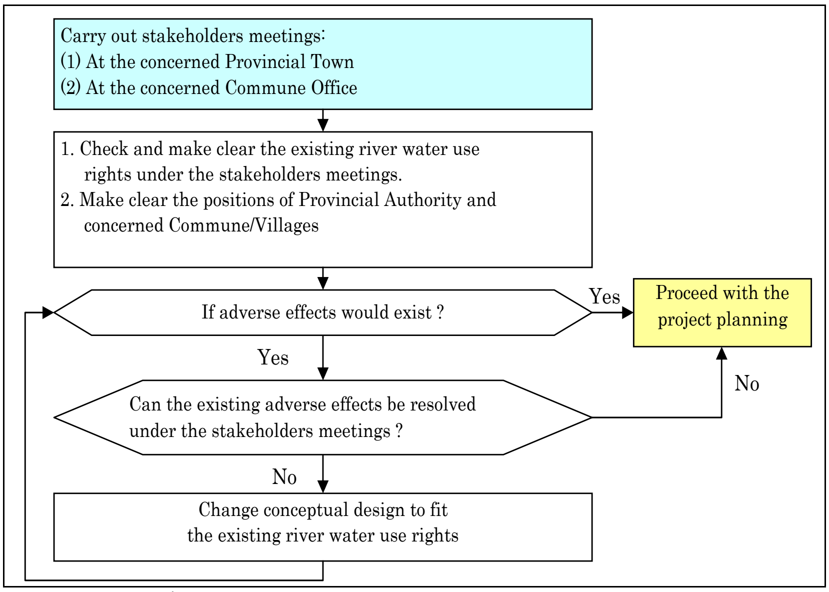
9. ENVIRONMENTAL CONSIDERATIONS

9.1 MICRO HYDRO

9.1.1 Adverse Effects to Existing Users of River Water

The following show the process of solving possible adverse effects to existing users of river water upon Conceptual Planning (see Figure 9.1.1):

1) To hold stakeholders meetings at both places as listed below:
   - i) The concerned Provincial town
   - ii) The concerned Commune Office
2) Under stakeholders meetings, conduct the following items:
   - i) Check and make clear the existing river water use rights
   - ii) Make clear the positions of concerned Provincial Authority and Commune/Villages
3) Make clear if adverse effects would exist
   - i) If "No", proceed with the project planning
   - ii) If "Yes", to see if the existing adverse effects could be resolved under the stakeholders meetings
   - If it could be resolved under the meetings, proceed with the project planning
   - If it could not be resolved under the meetings, change conceptual design to fit the existing river water use rights.
4) After making the change of conceptual design, repeat the above process.



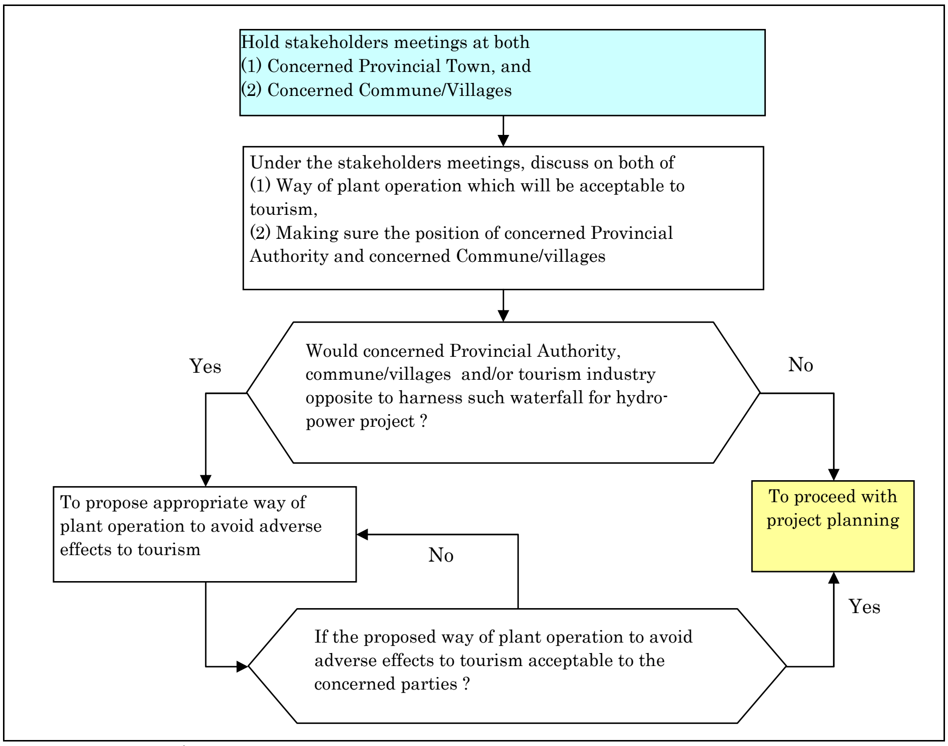
Source JICA Study Team

Figure 9.1.1 The Process of Solving Adverse Effects to Existing River Water Use Right

9.1.2 Adverse Effects to Tourism Industry When Waterfall Are Harnessed

The following show the process of solving possible adverse effects to tourism industry when waterfall will be harnessed (see Figure 9.1.2):

1) To hold stakeholders meetings at both places as listed below:
   - i) The concerned Provincial town
   - ii) The concerned Commune/Village Office(s)
2) Under stakeholders meetings, discuss the following items:
   - i) Check and make clear the acceptable way of plant operation, such as operating the power plant during night time only in dry season
   - ii) Make clear the opinions and positions of concerned Provincial Authority and Commune/Villages
3) Make clear the most acceptable way(s) of the power plant operations
4) Define power plant operation scheme



Source JICA Study Team

Figure 9.1.2 The Process of Solving Adverse Effects to Tourism Industry When Waterfalls are Harnessed

9.1.3 Potential Social Impacts on the Ethnic Minorities due to Buying up of the Land by Insider Deal

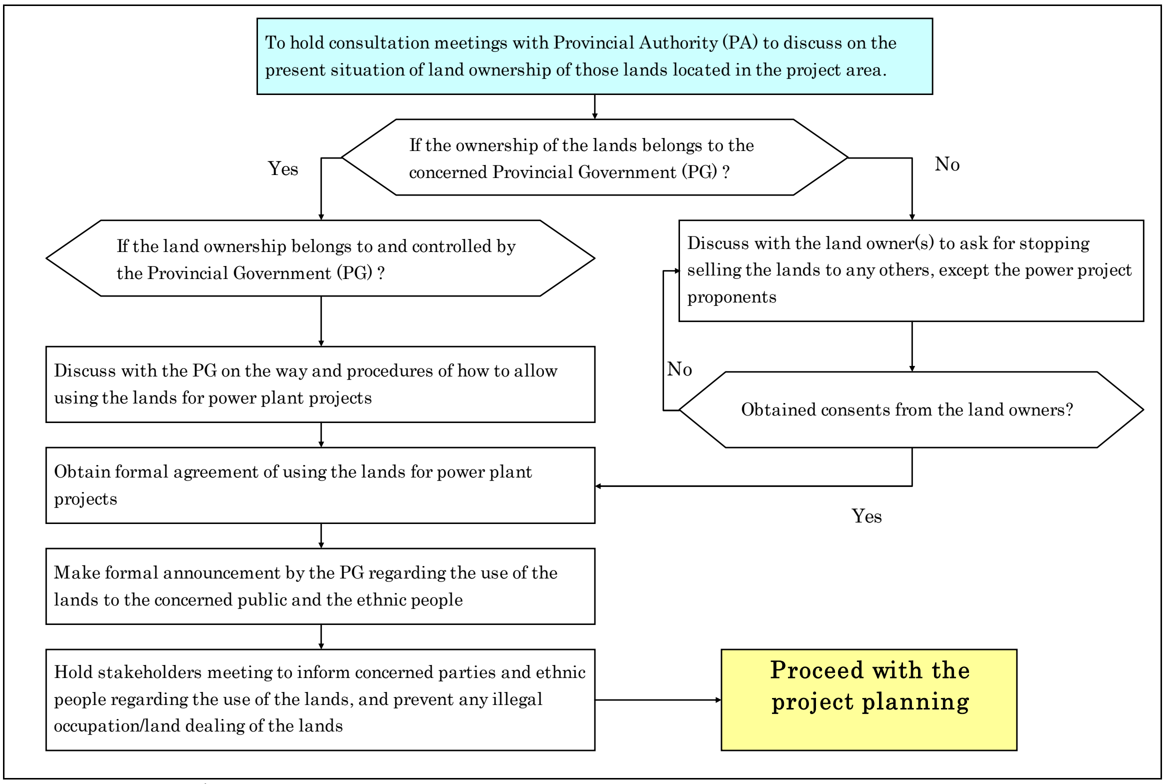
No social protection system exists for the minorities. Therefore, they tend to sell their land when approached with some cash (see Figure 9.1.3):

1) To hold consultation meetings with concerned Provincial Authority (PA) to discuss on the present situation of land ownership of those located in project site area

2) Check if the ownership of the lands belongs to the Provincial Government (PG) and acquire approval for land usage.

3) If the land ownership belongs to the ethnic minorities, ask the land owners not to sell the land to any other persons or parties, except the project proponents. And also ask for transferring the land title to the Project proponents or the PG.

4) Project proponents discuss further with the PG on the procedures and other to allow using the lands for the project as mentioned above



Source JICA Study Team

Figure 9.1.3 The Process of Solving Potential Social Impacts to the Ethnic Minorities Regarding Their Land ownership

9.2 BIOMASS GASIFICATION POWER

9.2.1 Potential Conflicts with Existing Users When Agricultural or Forest Wastes are Sources as Energy

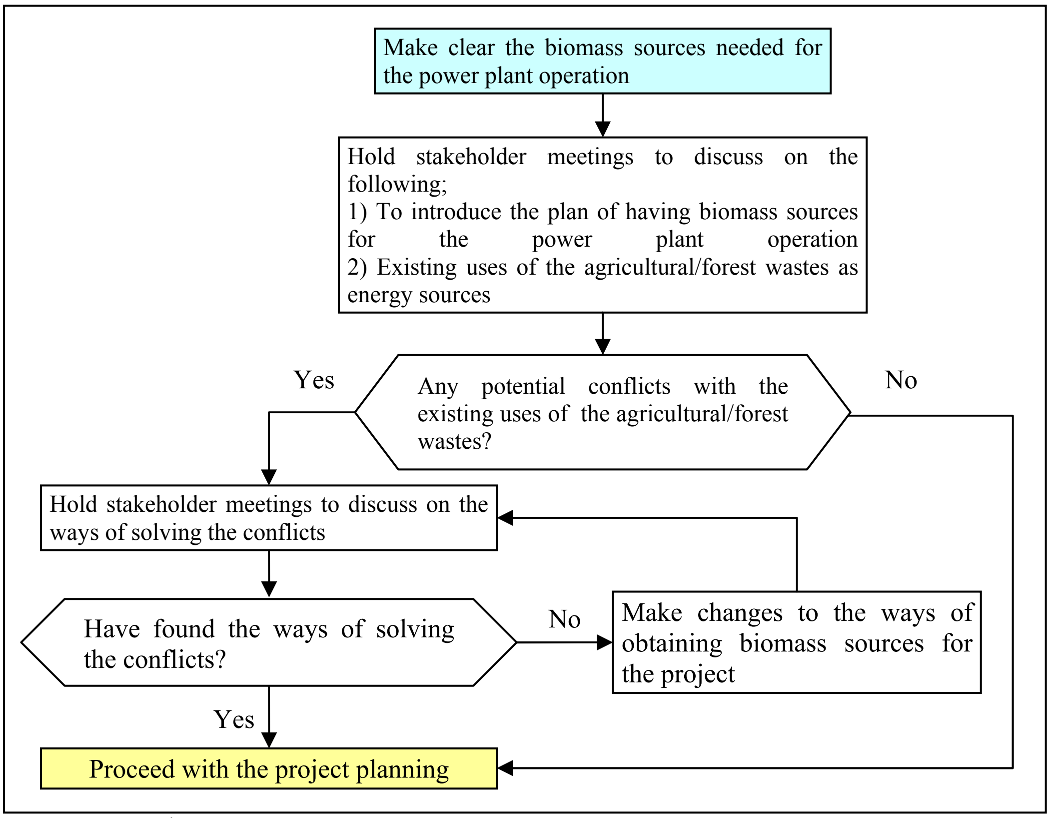
The following considerations are necessary in order to take into account potential conflicts with existing users when agricultural or forest wastes are sources as energy.

1) Hold stakeholder meetings to discus on the following
   i) To introduce the plan of having biomass sources for the project
   ii) Details of existing users of agricultural/forest wastes as energy sources
2) Check and make clear if any such potential conflicts would exist
3) If such conflicts would exist, take the following actions
   i) Hold stakeholder meetings to discuss the ways of solving the conflicts

ii) If proper ways of solving the conflicts could not be found, make change to the project plan to fit the existing user right.

4) Proceed with the project planning/operation after solving the potential conflicts

Figure 9.2.1 shows the process of above action flow for solving the potential conflicts.



Source JICA Study Team

Figure 9.2.1 The Process of Solving Potential Conflicts with Existing Users of Biomass Sources as Energy

9.2.2 Pressure to Illegal Forest Cutting

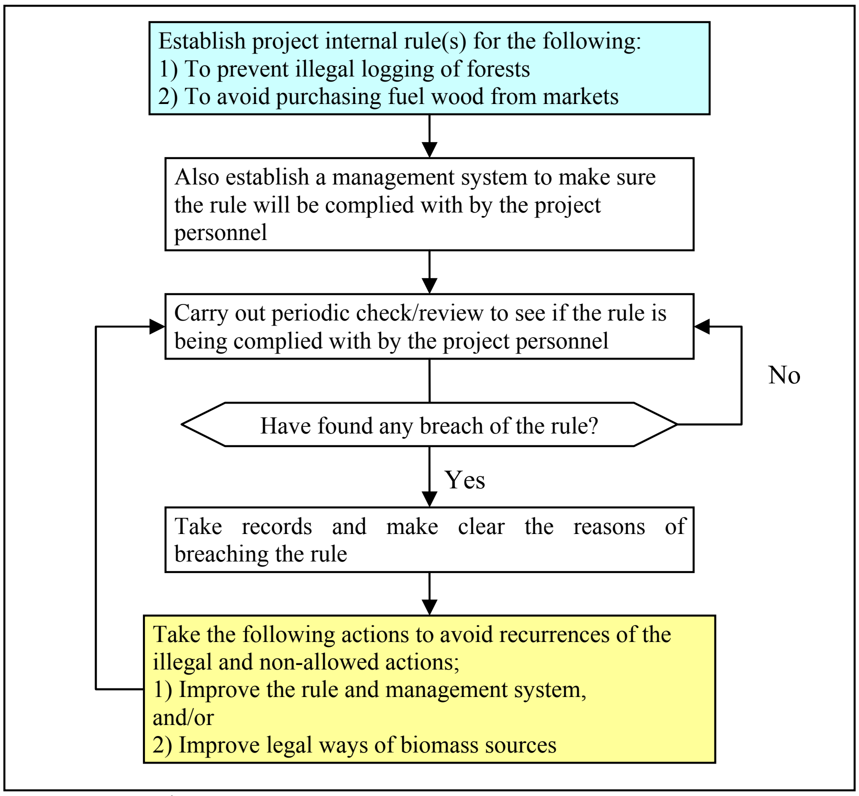
It is important to diminish the pressure to do illegal forest logging for project operation. It must be noted that fuel wood should not be purchased in the markets for being the biomass sources of a power plant operation. The following action plan will be required to avoid above issues:

1) Establish project internal rules for the following:
   - i) To prevent illegal logging of forests
   - ii) To avoid purchasing fuel wood from markets
2) Also establish a management system to assure the rules will be complied with by project personnel
3) Carry out periodic check/review to see if the rules are being complied with by the project personnel
4) Have found any breaches of the rules ?
5) If yes, take records and make clear the potential reasons of the breach
6) Take the following actions to avoid recurrence of the illegal actions:

i) Improve the rules and management system, and/or

ii) Improve legal ways of obtaining biomass sources for the plant operation

Figure 9.2.2 shows the process of solving the issue of conducting illegal logging of forests.



Source JICA Study Team

Figure 9.2.2 The Process of Solving The Issues of Illegal Logging of Forests

9.2.3 Conflicts or Robbing of Fuel Wood Planted by Farmers

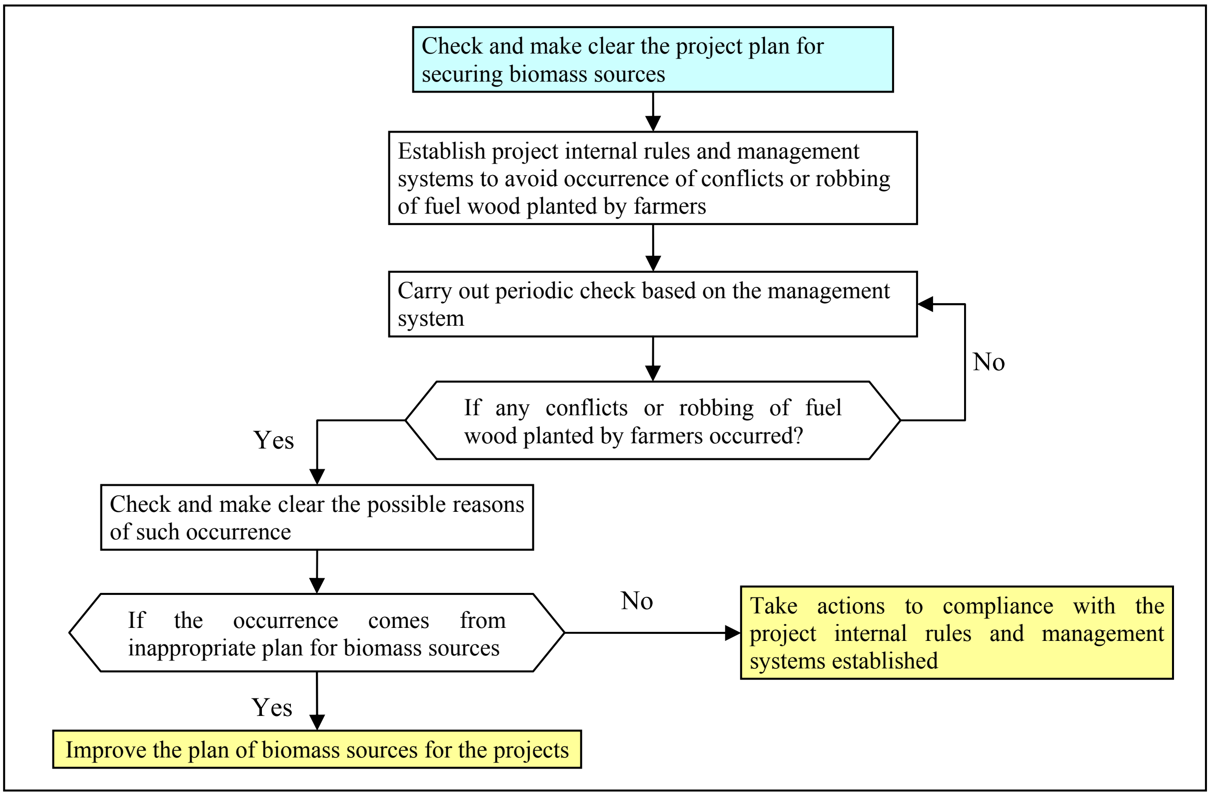
The issues of having conflicts with or robbing of fuel wood planted by farmers could cause severe social problems to the project proponents. Take the following actions to avoid such issues:

1) Check and make clear the plan of securing bio-mass sources needed for the plant operation

2) Establish project internal rules and management system to avoid occurrence of conflicts or robbing of fuel wood planted by farmers

3) If the occurrence caused by personal reasons of plant personnel, enhance the compliance with the rules established.

Figure 9.2.3 shows the process of avoiding the issues as mentioned above.



Source JICA Study Team

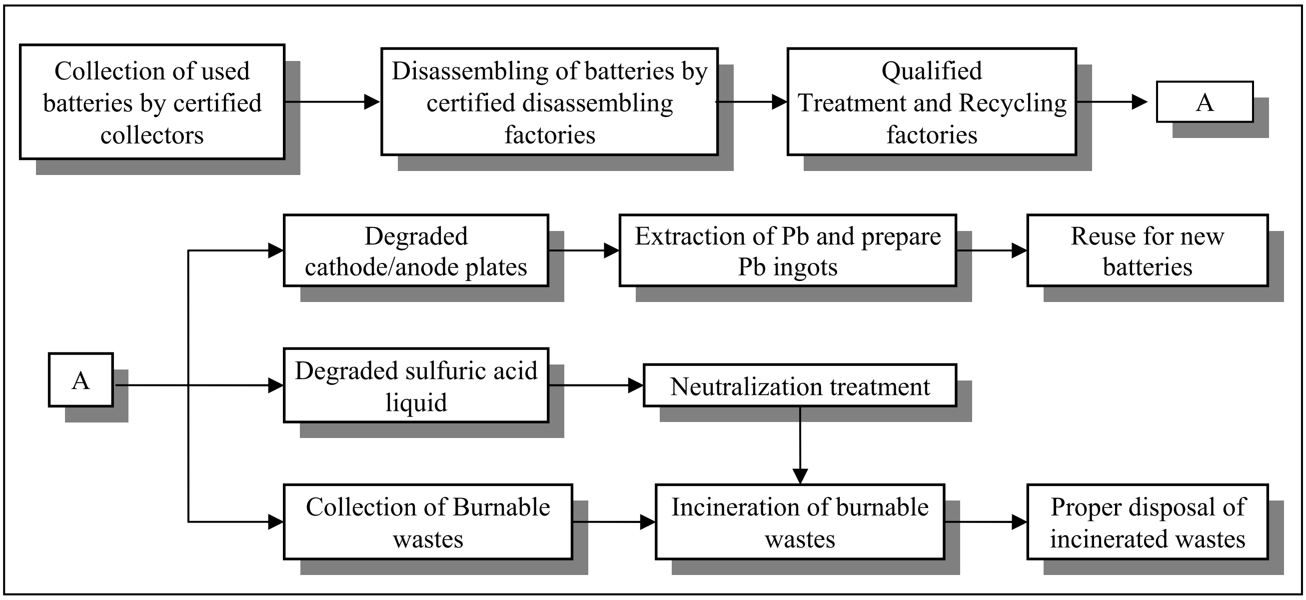
Figure 9.2.3 The Process of Avoiding Conflicts With and Prevention of Robbing Fuel Woods Planted by Farmers

9.3 SOLAR POWER

9.3.1 Disposal, Collection and Recycling of Used Batteries

The following show the process of the above for disposal, collection and recycle of used batteries.

1) Establish rules by local authorities to prevent illegal disposal of used batteries
2) Certify qualified collectors for collecting used batteries
3) Certify qualified disassembling factories for collected used batteries
4) Certify qualified incineration factories for burnable wastes
5) Certify qualified recycling treatment factories
6) Implement the recycling activities



Source JICA Study Team

Figure 9.3.1 The Process of Recycling Used Batteries to be Disposed

9.3.2 Disposal of BCS and PV Systems upon Grid Connection

1) Disassembling of BCS and PV systems to be disposed

The underlying principle of this MP is that the BCS and PV facilities are to be transferred to an alternative unelectrified village upon grid connection. However, if for some reason, BCS and PV facilities require to be disposed, the following processes are necessary.

(i) Disassembling of solar power generation sets
(ii) Consider using PV panel elsewhere
(iii) Disassembling of charging controller
(iv) Collection of batteries to be disposed
(v) Collection of disconnected electrical wiring
(vi) Disassembling of power charging house , if being use
(vii) Collection of various wastes

Figure 9.3.2 shows the details of the process flow of the above.

2) Disassembling of PV system itself to be disposed

The underlying principle of this MP is that SHS is installed by individuals through subsidy, and that when the SHS becomes unnecessary due to electrification, then the facilities will be sold in the market.

However, if for some reason, the SHS facilities require to be disposed, the following processes are necessary.

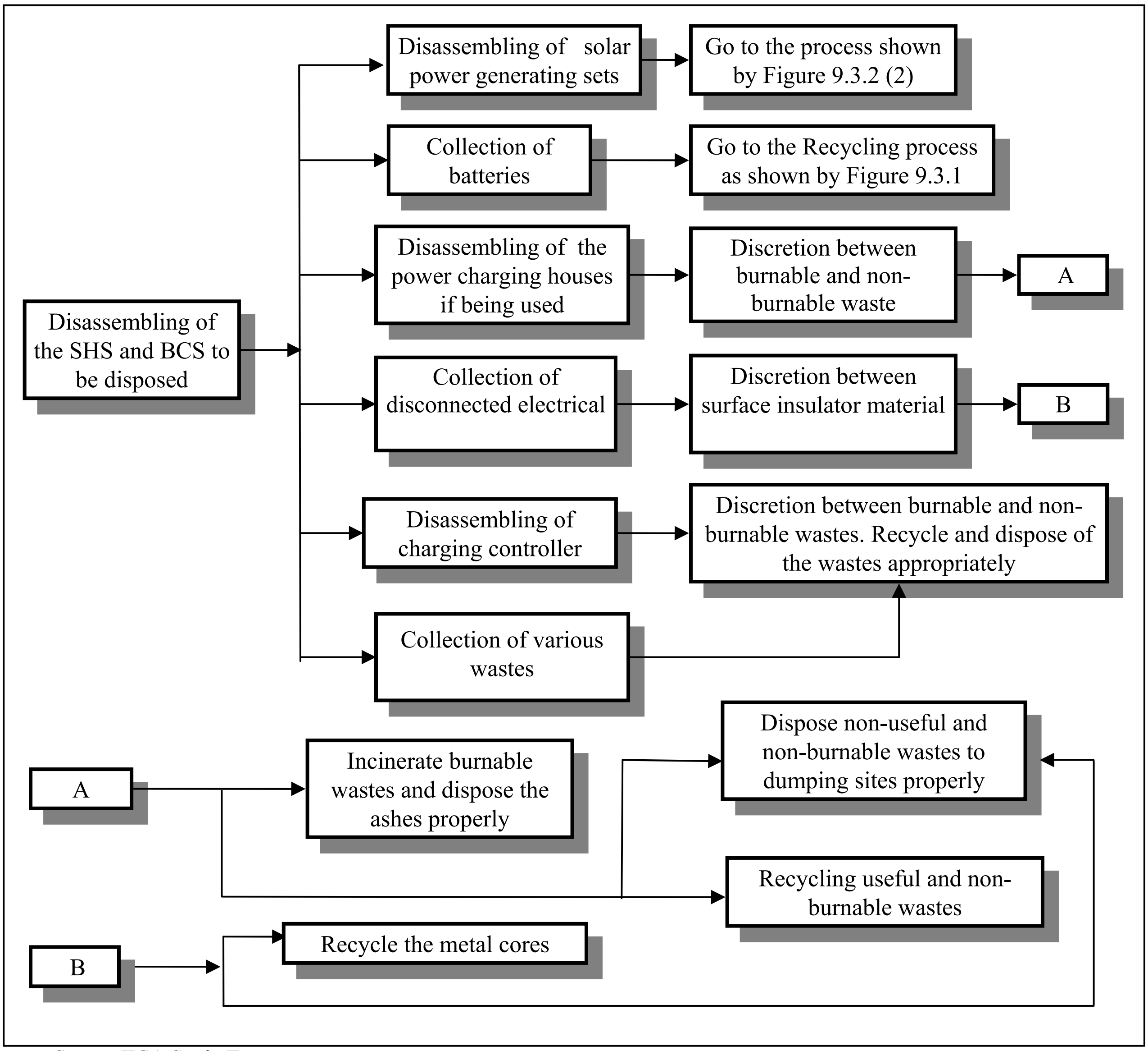
(i) Disassemble the solar panels
- Recycle the solar panels still useful
- Dispose non-useful solar panels to disposal sites

(ii) Recycle the poles if being used

(iii) Collection of disconnected electrical wiring

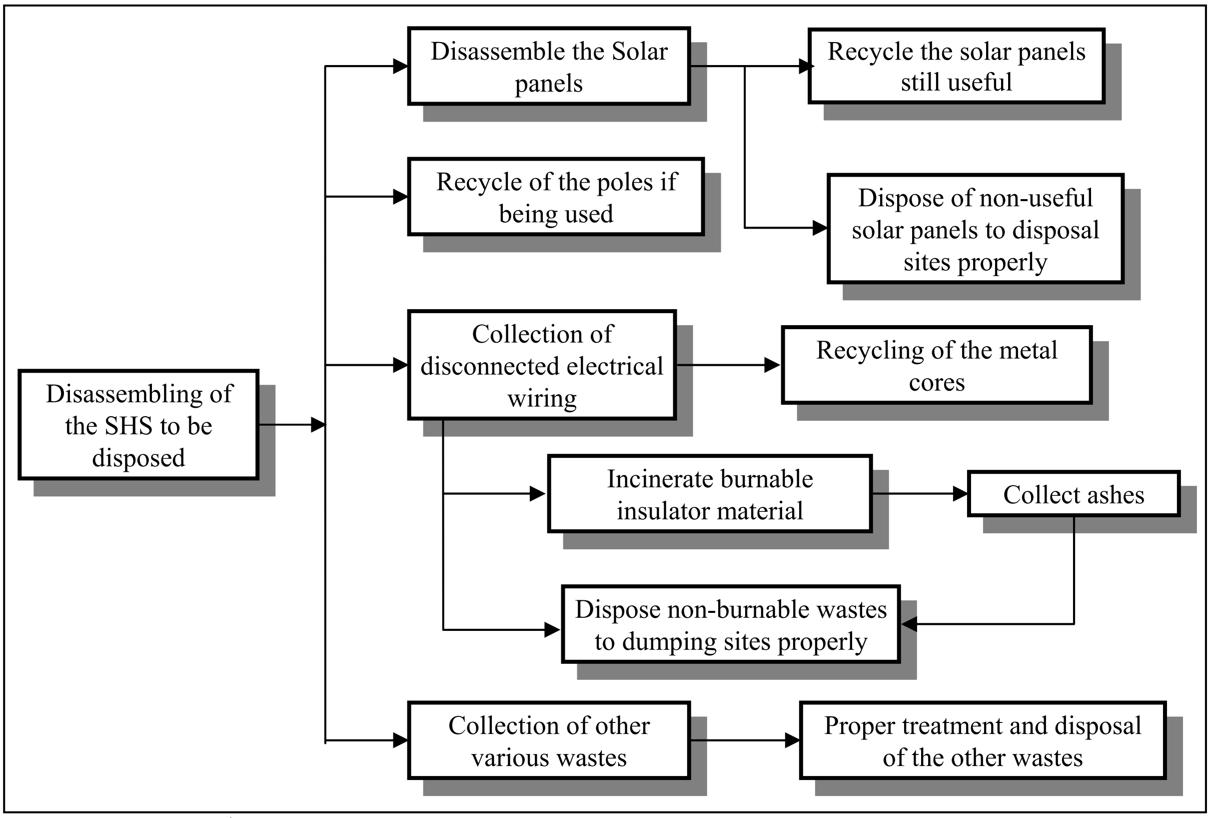
(iv) Collection of other various wastes for proper treatment and disposal

Figure 9.3.3 shows the details of the process flow of the above.



Source JICA Study Team

Figure 9.3.2 The Process of Treatment and Disposal of BCS and PV Systems



Source JICA Study Team

Figure 9.3.3 The Process of Treatment and Disposal of PV Systems to be Disposed

10. APPLICATION TO REC AND SUPPORTS AVAILABLE

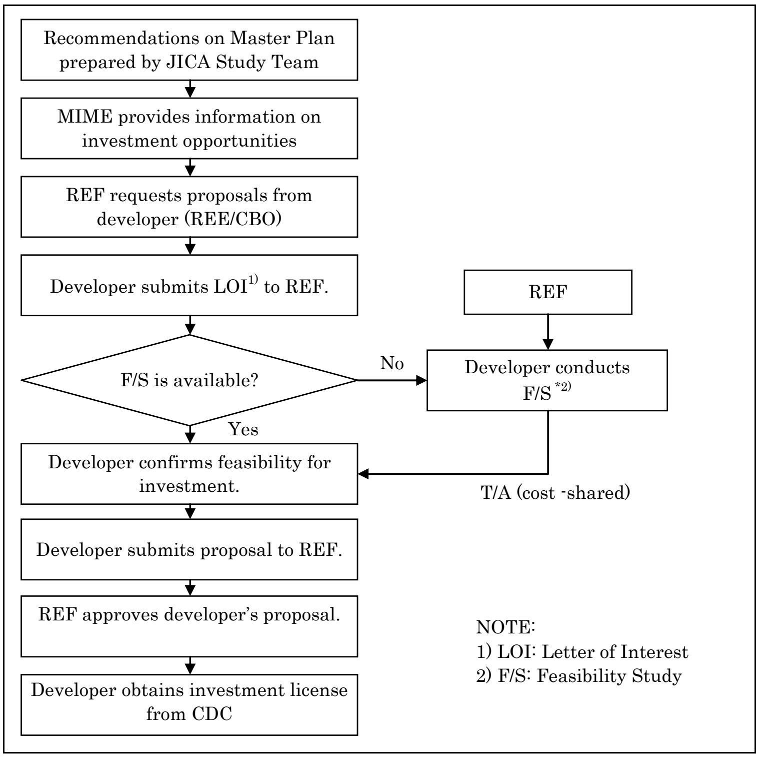
10.1 INVESTMENT PROCESSES FOR PRIVATE INVESTORS (REES AND CECS)

There are two processes available for private developers (REE, CEC and NGOs); one is for REEs who apply for REF procedures and the other is for CECs who apply the priority action plan (PAP) scheme.

10.1.1 Process of REF Scheme

The REF procedure is summarized in Figure 10.1.1. The detailed project cycle and application form for REF support are presented in Appendix F. The developers (REEs, CECs and NGOs) can invest in the rural electrification pursuant to MIME/REF program mechanism under the following steps:

1) REF announcement of proposal
2) Private developers initiating investment
3) Approval of REF investment subsidy
4) REF subsidy application and disbursement process
5) EAC licensing procedures
6) EdC's power purchase agreement process



Source JICA Study Team

Figure 10.1.1 Flowchart of Investment Process of Rural Electrification Development According to REF Scheme

(1) REF announcement of proposal

The REF, in coordination with EAC, will issue request for proposals (RfPs) from the private developers to implement the rural electrification project in particular nominated areas. Candidate projects and the nominated areas will be selected by MIME based on the recommendations made by the JICA Master Plan Study on Rural Electrification by Renewable Energy.

The REF Secretariat will align applications forms with the forms used by the EAC in the license application to minimize the transaction costs for developers and for the REF-EAC appraisal process.

(2) Private developers initiating investment

The developers interested in investing rural electrification projects announced by REF shall initiate the investment according to the following steps:

1) The developer submits a letter of interest (LoI) to the REF Secretariat.
2) In case of feasibility study[2] not conducted the developer obtains permission for conducting feasibility study.
3) The developer conducts the feasibility study and confirms the feasibility for the investment.
4) The developer applies to relevant financial institutions for project loans.
5) The investor applies to MIME/DIME for registration of REEs depending on the generating capacity: (i)125 kVA or more at MIME offices in Phnom Penh; and (ii) less than 125 kVA at DIMEs.
6) The investor applies to EAC for appropriate types of license (generation or distribution or consolidate).
7) The developer submit the proposal with application form to REF fully filled out, a copy of the feasibility report attached, copies of all relevant approval documents attached; or if, not yet processed, of the applications for approval.

It should be noted that private investment projects in general require processing and approval through the CDC (local CDC in case of investment cost of 20,000 M$ or less), but electricity-related investment projects do no require approval of the CDC, but can be processed directly through MIME (or DIME), with exception of investment license which will be given by CIB which is the CDC's operational arm for private sector investment.

(3) Approval of REF investment subsidy

The REF subsidy will be approved for the proposal meeting the following criteria:

a) All categories of REF-supported projects

- Compliance with regulatory conditions
- Compliance with technical conditions

[2] The REF application form demands the applicant to submit a copy of the feasibility study (F/S) as shown in Appendix F. The level and contents of the F/S, however, varies from a simple business plan to a full-scale F/S for a large scale power project depending on the size and scope of the project to be studied. A simple business plan will do for most of RET-based off-grid rural electrification projects conceivable. Such simple F/S just covers such items as (i) site conditions, (ii) demand for power, (iii) supply potential and plans, (iv) cost estimates, (v) implementation, and O&M plans, (vi) economic and financial analysis, including the tariff setting, etc.

- Financial viability of the project:
- Institutional viability of the project
- Compliance with Donors (providers of original loans and grant aids) standards for social and environmental safeguards.

b) Criteria specific for distribution projects

- The tariff calculation formula used to establish the tariff schedule, submitted to EAC for approval, takes the REF-investment subsidy into account.
- Potential consumers have expressed their interest in the project by paying a deposit

c) Criteria specific for grid-connected biomass and hydro plants

- EdC has signed a PPA with a developer or a letter of intent.

d) Criteria specific to solar BCS/PV system

- Solar company (REB) is eligible for access to REF-subsidy, being on the approved dealer list for solar BCS or PV systems. Inclusion in the list is subject to confirmation by the REF that the BCS/PV systems marketed by the solar companies in Cambodia comply with REF quality standards for solar BCS/PV systems.

(4) Subsidy application and disbursement process

a) Grant rate schedule (as proposed by JICA Study Team) is shown in Table 10.1.1.

Table 10.1.1 Subsidy Rates Proposed by JICA Study Team

Type of Electrification	Scope of Work	Ownership	Funding Modality of Capital Costs	
			REE	CEC
1. Extension of REE grid	Rehabilitation of Distribution lines and Extension of an existing mini grid systems	REE	Subsidy (25%), Equity (15%), Soft Loan (60%)*	-
2. Renewable Energy new mini grid (Hydro)	Generation and distribution	REE/CEC	Subsidy (25%), Equity (15%), Soft Loan (60%)	Subsidy (50%), Equity (10%), Soft Loan (40%)
3. Renewable Energy new mini grid (Biomass)	Generation and distribution	REE/CEC	Subsidy (25%), Equity (15%), Soft Loan (60%)	Subsidy (25%), Equity (15%), Soft Loan (60%)
4. Diesel new mini grid	Generation and distribution	REE/CEC	Subsidy (25%), Equity (25%), Soft Loan (50%)	Subsidy (25%), Equity (25%), Soft Loan (50%)
5. Solar system	SHS,BCS	REE/CEC	Subsidy (25%) Equity (15%), Soft Loan (60%)	Subsidy (95%), Equity (5%), Soft Loan (0%)

Source JICA Study Team

b) Triggers for disbursement of grants

- Grid extension and mini grids
  - First payment: 40% after start of construction, based on declaration by project developer of signing of contracts amounting at least to 50% of total investment sum, written confirmation by contractors having signed the listed contracts, and declaration of project developer providing planned time schedule for completion of construction.
  - Second payment: 40% at finalization of construction, based on certification by

chartered engineer that the system is complete and complies with specification and is operational.

- Final payment: 20% after three months of operation, based on certification by chartered engineer and/or confirmation by EAC or EdC.

- Solar systems
  - Single payment: 100% upon receipt of detailed schedules in hard copy and in read-only soft copy format of REF-compliant solar system installed along with subsidy disbursement request. The solar company will also forward a declaration confirming that the schedules exactly match the information given in Customer Acceptance Receipts (CARs) and that the original CARs will be kept available for inspection by authorized personnel. Copies of custom forms for imports of solar system or its components will be provided. The solar company has signed a declaration confirming that the original custom forms will be kept for inspection.

The REF Operational Manual will establish procedures for control checks on information received from project developers, evaluations, in the event of irregularities and sanctions for breach of subsidy award contracts.

(5) EAC licensing procedures

The Electricity Law requests every developer, either government-owned, private-owned or community-owned REE, get a license and business permit from EAC. The EAC licensing and permitting procedures are straightforward and easy to follow. The most recent information available on these procedures is available on the website (http://www.eac.gov.kh).

The application process for several types of businesses has been active for one to five years and several licenses have been issued. Recent improvements have streamlined the application process.

The best source of up-to-date information on the application process is available at the website. A written document in PDF format has been prepared and is available at the following website which explains how to apply, what information will be requested and other pertinent questions. (http://www.eac.gov.kh/pdf/press-release/regulation.pdf)

(6) EdC's power purchase agreement process

The JICA Master Plan recommends MIME, REF, EdC and EAC enact and enforce a power purchase agreement for sale of surplus electricity (especially during day time) to the national grid operator (EdC) from generating plants making use of renewable energy technologies with the progress of the national grid extension.

The PPA would oblige a purchaser, most likely EdC or a provincial authority, to purchase the full output of the RET-based plant at the pre-determined fixed tariff for say, a 10 to 15 year period, after which tariffs would be market determined. The PPA provides the long-term security for the investment, which allows investors to take on the relatively expensive investment in the feasibility study and the banks to lend long-term for construction.

Developers interested in supplying surplus power to EdC would follow normal due diligence process and initiate discussions with all government agencies that will be participating in the transaction. The specific agencies depend on the type of generating facilities being proposed.

Preliminary discussions normally include representatives of MIME/REF and EdC.

The formal PPA development process begins after the developer has performed the necessary due diligence, conduct surplus power analysis, prepared a draft business proposal and accomplished the following:

1) Completed the business formation processes through CDC and acquired a business license or other proper business formation approvals.
2) Completed the formal notification and approval process with MIME or REF for electric energy projects.
3) Filed a Letter of Application to MIME or REF and EdC to provide electricity power, including the developer's proposed terms and conditions for their review and approval.
4) Obtained approval of the CDC (or provincial CDC for the case of investment cost of $ 2 million or less)

Once approved by the RGC, negotiations can begin with EdC to finalize terms and conditions, obligations and responsibilities related to the contractual arrangements necessary to ensure fulfillment of the PPA, including indemnification and mitigation procedures.

Key steps of implementing the project is summarized as follows:

1. Hire a consultant and develop a complete feasibility study of the project as per specified in the REF's RoP and relevant rules and regulations.
2. Estimate costs of the project by phase and by type of facilities
3. Study environmental issues/mitigation measures and monitoring plan pursuant to RGC environmental laws and regulations
4. Analyze operational aspects of the project (organisation, company status, financial and economic analysis)
5. Socio-economic survey (consumers structure, household incomes, collection ratios, tariff applies, etc)
6. Design of tariff structure to be applied in the service area and tariff affordability analysis
7. Analyze financial options of the project (investment costs, operational costs, tariff, subsidies mechanism, etc)
8. Present the overall project proposal (covering the items 1 to 7 above) to the relevant financial institutions and the MIME/REF/EAC for their review and comments
9. Approach the RGC to grant investment approval and business concession
10. Conduct detailed design and tendering process for rehabilitation/construction by phase and contact type
11. Conduct rehabilitation and construction activities

10.2 FINANCIAL SUPPORTS

The developers to meet the REF eligibility criteria can access to financial support facilities consisting of REF subsidy and soft loans as indicated in Section 10.1.4 above. These are reiterated as follows:

Table 10.2.1 Financial Support Mechanism Proposed by JICA Study Team

Type of Electrification	Scope of Work	Ownership	Funding Modality of Capital Costs	
			REE	CEC
1. Extension of REE grid	Rehabilitation of Distribution lines and Extension of an existing mini grid systems	REE	Subsidy (25%) Equity (25%), Soft Loan (50%)*	
2. Renewable Energy new mini grid (Hydro)	Generation and distribution	REE		
3. Renewable Energy new mini grid (Biomass)	Generation and distribution	REE		
4. Diesel new mini grid	Generation and distribution	REE		
5. Solar system	SHS,BCS	REE		

Source JICA Study Team

REF subsidy does not target biomass gasification power nor solar BCS projects, and does not recognize CECs. The 50% loan assumes commercial bank loans. In order to complement REF, the Study Team proposes a CFR with a function to service loans to off-grid rural electrification schemes by renewable energies such as biomass gasification, as well as to provide assistance on establishment and operation of CEC (refer to Volume 2 Part 2 Section 1.7.3).

For details of the financial supports, contact the REF Secretariat to be established in 2006.

10.3 TECHNICAL AND MANAGERIAL SUPPORTS

10.3.1 REF/CFR Technical Assistance

The REF/CFR will provide cost-shared technical assistance jointly with MIME, EdC and NGOs to the private sector (REEs), NGOs and CECs in order to build technical and business capacity and prepare feasibility studies for producing quality proposals for REF funding.

(1) Targeted business sector

The targeted business sectors involved in the supply side of rural electrification will include:

- Project developers (professional private investors as well as CECs)
- Renewable energy technology (RET) and rural electrification (RE) consultants, construction companies and other business involved in the production, installation, supply of equipment, O&M and other rural electrification related services;
- Financial intermediaries providing loans to rural electrification and renewable energy investments.

(2) Scope of Supports

Support to the supply side in rural electrification covers TA at all stages – pre-investment; start up and early business and market development, business improvement and growth:

- Business Development Assistance to agents involved in the implementation of *grid based RE-projects* – project developers and small utility operators, NGOs assisting local communities in developing local electricity supply, consultants preparing feasibility studies and contractors.
- Business Development Assistance to companies involved in the commercialization of

renewable energy technologies, comprising dealers, retailers and leasers of solar home systems.

- Capacity building in the *financial sector* to banks and micro-finance institutions in the appraisal of RE and RET investment projects.
- TA in management, finance, customer relations, billing and invoicing and O&M to *community owned and small scale private RE-utilities*.
- *Promotion of productive uses of electricity* in on-farm and off-farm production. TA to small medium and enterprises on the financial feasibility of investments in electricity consuming equipment and the preparation of business plans for investments making productive use of electricity.
- *Promotion of technical norms and standards and quality control*, including the verification of the accuracy of electric meters.

As a general rule:

- *Recipients of TA to businesses in the supply side of RE* are charged a fee equal to 50% of the specific cost of the service. (The fee shared by the developer will be compensated by facilitating partners such as NGOs or bilateral donors collaborating with REF.
- *TA to businesses for enhancing their productive uses of electricity* is provided free of charge.

10.3.2 NGOs

International and national NGOs which are very helpful for preparation, implementation and operation of the electricity business in which the private developer would like to invest include the following:

(1) Small and Medium Enterprises Cambodia (SME Cambodia)

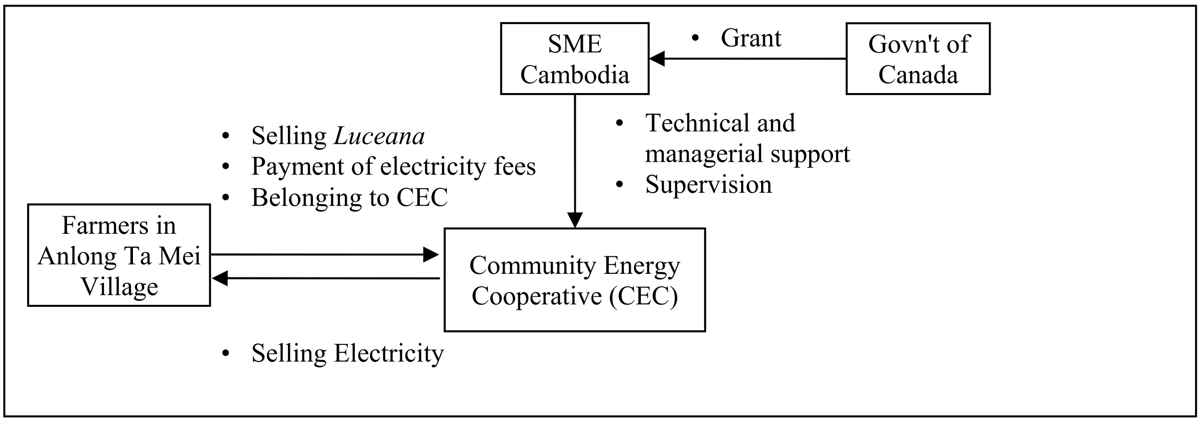
General information of the Organization:

The NGO, Small and Medium Enterprises Cambodia (SME Cambodia), was originally established as Enterprise Development Cambodia (EDC) in 1997. With financial supports from USAID, The Asia Foundation, UNDP and any other international donors, EDC has provided training programs, SME Cambodia's Private Sector Growth Program, for enforcing institutional capacities of private sector and flourishing other environmental aspects, markets, business opportunities, financial services, new production technologies, and so on. In 2002 EDC changed the name to "SME Cambodia".

Experience in rural electrification projects in Cambodia:

SME Cambodia has facilitated the establishment of 2 provincial associations of REEs owned by 70 member enterprises in the North Western provinces of Battambang and Bantey Meanchey. Currently (2005) SME Cambodia is facilitating the establishment of a third provincial association of REEs in the province of Siem Reap. In 2004 the Anlong Ta Mei Community Energy Cooperative was established as part of a biomass gasification village electrification pilot-project, whereas training on the technical as well as the operational aspect was also conducted. The structure of the project is shown below.

Project's organizational charts:



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Webpage: http://www.smecambodia.org

(2) Centre Kram Ngoy (CKN)

General information of the Organization[3,4]:

CKN is a French NGO and started the operation in Cambodia since 1998, specializing in the transfer of technology and building human resources, through technical and vocational training. Such activities are supported by Electriciens Sans Frontiéres (ESF),Agence Intergouvemementale de la Francophonie (AIF), Association d'aide pour la femme khmére (AFK) and UNESCO. As for the rural electrification development, the organization produces young electricians in their own training center in Phnom Penh as a partner of ESF programs. At the same time, it provides the mobile training programs outside Phnom Penh in order to train young people in rural or remote areas. The program consists of the following three, (i) training their technical competency specialized in electricity, electronic engineering, mechanisms, information technology and so on, (ii) strengthening their entrepreneurships and business minds in Cambodia and (iii) encouraging them to use their specialized capacities trained in the program for their promising business like selling the electricity they generate to their areas, rural or remote areas.

In the case of electrification projects, it participate in the installation of the microphone-network in the village of Banteay Chhoeu Village in Siem Reap Province. Moreover, it undertakes the generation project in Banteay Dek Village (350 families), 30 km from Phnom Penh.

Contact:

3 http://www.recambodia.org
4 http://www.ckn-cambodia.org/fr

Postal Address : # 58A Street 318, Phnom Penh 12309, Cambodia
Phone : (855-23) 987 843
E-mail : ptm.ckn@online.com.kh
Webpage: http://www.ckn-cambodia.org/fr

(3) Concern Worldwide Cambodia

General information of the Organization:

Concern World wide is a non-denominational voluntary organization, established in the Republic of Ireland in 1968 as "African Concern". The original mission of the organization is to release the severe famine from the Nigerian Civil War. Since then, the organization moved out of other areas in the world and changed the name to "Concern Worldwide".

In 1999, it started the operation in Cambodia. Concern Worldwide Cambodia has been supporting and implementing a number of programmes which contributes to improve livelihood security for poor people in rural areas. Recent main programmes are the following four;

- Community Forestry/Community-led Livelihood Improvement in Pursat, Kampong Chhnang and Kampong Cham Province
- Capacity Building for Rural Development in Siem Reap and Prusat Province
- Community-led Livelihood Improvement
- Support to Microfinance Sector Development[5]

In the Community Forestry Project, it organized the community development with the implementation of "Community Forestry Management Committees (CFMC)" through the provision of training in local action and planning processes.

Contact:

Postal Address : # 36, Street 352, Quarter Boeung Keng Kang 1, District Chamcar Morn, Phnom Penh, Cambodia.
Phone : (855-23) 214 891 Fax: (855-23) 214 879
mail : cfppenh@concerncambodia.net

(4) UTA-Cambodia, Centre for Livestock and Agriculture Development (CelAgrid)

General information of the Organization:

UTA-Cambodia, Centre for Livestock and Agriculture Development (CelAgrid), was established in 1997 in Kandal Province, aiming to develop sustainable organic farming based on livestock and to contribute training and academic activities to achieve the sustainable management of natural or local resources. Main fund resources are the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), The Swedish International Development Cooperation Agency (SIDA) and so on.

[5] AMK Co.,Ltd. is a Microfinance Institution, established by Concern. This operates in Banteay Meanchey, Pursat and Kampong Speu Province.

Experience in rural electrification activities in Cambodia:

This NGO does not facilitate any electrification project. However, through the research funded by international donors, the center enhances people to use renewable energy technologies, especially biomass gasification with food, feeds, residues and any other recyclable fuel, for their daily lives. Hereinafter, one of their activities in Kandal Province is introduced.

Contact:

Postal Address : Kandal Village, Rolous Commune, Landal Stung District, Kandal Province, Cambodia.
Phone : (855-24) 394 570 Fax: (855-23) 211 323
mail : khieu_borin@forum.org.kh
Webpage : http://www.utafoundation.org

10.3.3 Consultants

(1) JBJ-Crossroads to Development

General information of the Organization:

JBJ-Crossroads to Development is an international consulting company established in 2003. It primarily focuses on several kinds of services, social studies or assessments, economic studies, development of campaign materials and capacity building program, under the collaboration with Cambodian NGOs, international organizations, research institutions and other consulting companies. Besides, the company fosters a partnership with a Cambodian NGO, Research and Training Center for Development (RTCD), which provides community development programmes and research or training programmes. Such a partnership contributes consultancy services in research, documentation, database development, and in development-oriented facilitation work.

Contact:

Postal Address : #11A, Street 29, Sangkat Tonle Bassac, Khan Chamcar Mon, Phnom Penh, Cambodia
Phone : (855-23) 220 657 Fax: (855-23) 211 725
Mail : crossroads@online.com.kh

(2) GRET (Groupe de Recherche et d'Echanges Technologiques)-KOSAN

General information of the Organization[6]

GRET was established in 1976 as a non-profit development support organization, aiming at the economic and social development of developing countries, and has started the operation in Cambodia in the fields of rural development, including agriculture, village hydraulics, microfinance and support to higher education in agriculture since 1988. GRET has entered into an alliance with KOSAN

[6] http://www.gret.org

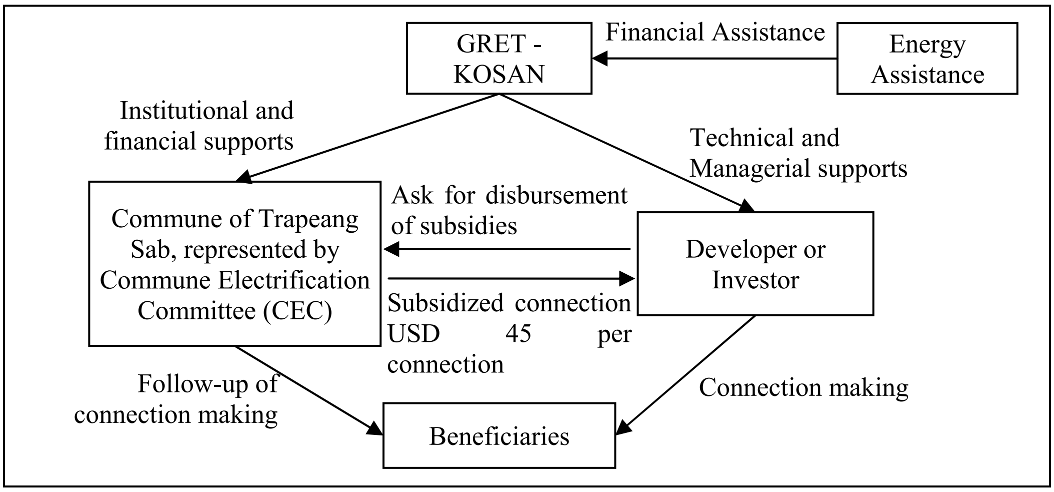
Engineering, a local consulting company, and put the name, GRET-KOSAN. The organization provides advisory services, not only of technical aspects but of socio-economical aspects.

Experience in rural electrification projects in Cambodia

Area: Smau Khnei Village, Trepang Sab Commune, Bati District, Takeo Province

Fund resource: Energy Assistance (Belgium),

Project's organizational charts:



Support from GRET-KOSAN: Originally the REE owner started the electrification supply business in 1994 and expanded the generation capacity and the service areas with the organization's supports. GRET-KOSAN has provided technical and managerial supports to the REE and financial and institutional supports to Commune Electrification Committee (CEC) with the output-based subsidy to the poorer households. As for the financial supports to the REE, it gives preference for the special loan services from Peng Heng SME Bank and ACLEDA Bank for expanding their service capacity. The loan is distributed with the preferable conditions, longer payment terms and lower interest rates than the regular conditions of the two banks.

Contact :

Postal Address : Hotel Cambodiana, Ground Floor, Office 4, Phnom Penh, Cambodia
Phone/Fax : (855-23) 212 891
E-mail : gret@camnet.com.kh
Webpage : http://www.gret.org

10.3.4 Bilateral Donors

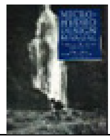
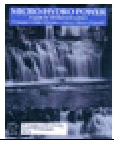
The government of Japan prepares the grand fund, Japan's Grant Assistance for Grass-Routs/Human Security Projects [7] .The Embassy of Japan in Cambodia has funded various projects, "Grassroots/Human Security Projects" since 1992 for empowering individuals and communities to

[7] Guidelines for Japan's Grant Assistance for Grass-roots/Human Security Projects (KUSANONE)

self-reliant and protecting people from any factor that threaten the lives, livelihoods and dignity of human beings. For the further information, you may refer to the Guidelines for Japan's Grant Assistance for Grass-roots/Human Security Projects (KUSANONE).

REFERENCES

The following references may also be useful for Rural Electrification by Renewable Energy in the Kingdom of Cambodia:

No.	Title	Media	Remarks
Design Manuals / Guidelines (Micro Hydro Power)			
1	" Micro-hydropower Sourcebook", a Practical Guide to Design and Implementation in Developing Countries, by Allen R. Inversin, NRECA, 1994. 	Paperback only	NRECA (National Rural Electric Cooperative Association) International Foundation, Washington, D.C., U.S.A. (http://www.nreca.org) [$25 + shipping]
2	"Micro-Hydro Design Manual, A Guide to Small-Scale Water Power Schemes", Adam Harvey, Intermediate Technology Publications, United Kingdom, 1993. 	Paperback only,	ITDG (http://www.itdg.org/) (http://www.developmentbookshop.com/) [$57.49 + shipping, available from www.amazon.com]
3	" Micro-Hydro Power, A Guide for Development Workers", Peter Fraenkel, Paish, Bokalders, Harvey, Brown, Edwards, ITDG, 1991. 	Paperback only,	Intermediate Technology Development Group (ITDG) Publications, United Kingdom, (http://www.itdg.org/) [$30 + shipping, available from www.amazon.com]
4	" Layman's Guidebook on how to develop a small hydro site", Commission of the European Communities, Celso Penche, Directorate-General for Energy by European Small Hydropower Association (ESHA), 1997.	PDF	microhydropower.net (http://microhydropower.net/) [Available online PDF from web. Site, free of charge]
5	" Small-Scale Hydro-Power Generation", Engineering Manual for Irrigation & Drainage, Japanese Institute of Irrigation and Drainage, Japan, March 1987.	Paperback only,	JIID (http://www.jiid.or.jp/e) [Currently NOT AVAILABLE]
6	" Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Project", New Energy Foundation (NEF) Japan, 1996.	Paperback only,	NEF (http://www.nef.or.jp) [Paperback only]
7	" Manual de mini y microcentrales hidráulicas", Una Guía para el Desarrollo de Proyectos, Intermediate Technology Development Group (ITDG)- Perú, PAIE/JUNAC, OLADE, BID, 1995.	PDF	ITDG(http://www.itdg.org.pe/Programas/energia/enerpub.htm) [Available online PDF from website, free of charge]
8	"The Study on Introduction of Renewable Energies in Rural Areas in Myanmar", Final Report, Main Report Volume 4, Manuals for Sustainable Small Hydros, JICA/ MEPE & MOEP, September 2003, NK/ IEEEJ.	PDF	JICA (http://lvzopac.jica.go.jp/library/) [Available online as PDF from website, free of charge]
9	" The Study for Establishment of Electric Power Technical Standards and Guidelines in Kingdom of Cambodia", Final Report, Main Report Vol. II Guidebook, JICA/MIME, February 2004, J-Power/ CEPCO.	Paperback only,	JICA (http://lvzopac.jica.go.jp/library/) [Paperback only in Library]
10	" Small HydroPower Handbook", A Guide to Understanding and Constructing Your Own Small Hydro Project, Ron Williams, Morehead Valley Hydro Inc., October 2002.	PDF	Morehead Valley Hydro Inc. (http://www.smallhydropower.com)
11	"Best Practices for Sustainable Development of Micro Hydro Power in Developing Countries", Department for International, Development, UK. & The World Bank, March 2000, Smail Khennas and Andrew Barnett, in association with London Economics / deLucia Associates USA.	PDF	ITDG:(http://www.itdg.org/docs/energy/bestpractsynthe.pdf) [Available online as PDF from website, free of charge]
12	"Small Hydropower Systems", Energy Efficiency and Renewable Energy, DOE/GO-102001-1173, FS217,	Paper	US.DOE(http://www.energy.gov/engine/content.do)

No.	Title	Media	Remarks
	U.S. Department of Energy (DOE), the National Renewable Energy Laboratory (NREL), July 2001.		
13	"Mini Centrales Hidráulicas para el desarrollo rural", PROPER - Bolivia, , Ilistración: Juan Carlos Parra,	Pamphlet	Al PROPER-Bolivia (address: Lanza No.0736, Casilla 2672, Cochabamba, Bolivia, Tel: +591-042-50327) (or Centro de Informacion en Energias Renovables :CINER: http://www.ciner.org/)
14	(Other information & links on Micro Hydro Power)	Web.	microhydropower.net (http://microhydropower.net/literature.html#Inversin)
1	Social aspects		Two case studies of community based electrification : 1. Rural electrification by mini-grid at Trapeang Sab Commune, Bati District, Takeo Province, 2 Village electrification by bio-mass at Anlong Ta mei village, Chuteal Commune, Banon District, Battambang Province
Suppliers Information			
	Equipment manufacturers of biomass gasification power		
	Equipment manufacturers of micro hydro (see Webpage Link sites)		Morehead Valley Hydro Inc. (http://www.smallhydropower.com/), microhydropower.net (http://microhydropower.net/), etc.
	Suppliers of solar power applications		
	Suppliers of materials of distribution lines		
	Concrete poles and fittings		
	Insulators and cables		
Cost Information			
	Biomass gasification power system		
	Micro hydro generator sets (see Webpage Link sites)		Morehead Valley Hydro Inc. (http://www.smallhydropower.com/), microhydropower.net (http://microhydropower.net/), etc.
	Solar BCS		
	PV systems		
	Materials of distribution lines		
Environmental Considerations (List of References re Environmental Regulations and Land Management in Cambodia)			
1	Article 59 of the Constitution of the Kingdom of Cambodia		
2	Royal Decree on the Protection of Protected Areas		
3	Royal Decree on The Establishment and Management of Tonle Sap Biosphere Reserve		
4	Law on Environmental Protection and Natural Resources Management		
5	Sub-Decree on the Organization and Function of the Ministry of Environment		
6	Sub-Decree on Environmental Impact Assessment Process		
7	Prakas (Declaration) on Guideline for Conducting Environmental Impact Assessment Report		
8	Guidelines for Conducting Environmental Impact Assessment (EIA) Report		
9	Sub-Decree on Water Pollution Control		
10	Sub-Decree on Solid Waste Management		
11	Sub-Decree on Air and Noise Pollution Control		
12	Prakas (Declaration) No. 1033 on Protected Areas		
13	Annex to Prakas No. 1033		
14	Drafted Decree on the Establishment and Management of Protected Areas		
15	Land Law (PREACH REACH KRAM),		

No.	Title	Media	Remarks
	NS/RKM/0801/14, August 13, 2001		
16	STRATEGY OF LAND POLICY FRAMWORK (Interim Paper), by Council of Land Policy, September 06, 2002		
17	POLICY PAPER ON SOCIAL LAND CONCESSIONS IN KINGDOM OF CAMBODIA, by Council of Land Policy, March 19, 2003		
18	SUB DECREE on SOCIAL LAND CONCESSIONS IN KINGDOM OF CAMBODIA,		
Clean Development Mechanism (CDM)			
1	The documents of The Ministry of Environment, GOJ : http:/www.env.go.jp/		
2	The documents of CDM-EB : http:/cdm.unfccc.int/		
3	CDM and JI in CHARTS, Version 2.1, by The Ministry of Environment, Government of Japan, March 2005		
4	List of Designated National Authorities (DNA), as of May 22, 2005		
5	List of Designated Operational Entity (DOE), as of May 22, 2005		
6	CDM Simplified PDD for Small-scale CDM Project Activities, Version 01, January 21, 2003, --- *Appendix A* to the Simplified Modalities and Procedures for Small-Scale CDM Project Activities		