5. PRESENT USES, DEVELOPMENT POTENTIAL AND ISSUES OF RENEWABLE ENERGY

5.1 MICRO HYDRO POWER

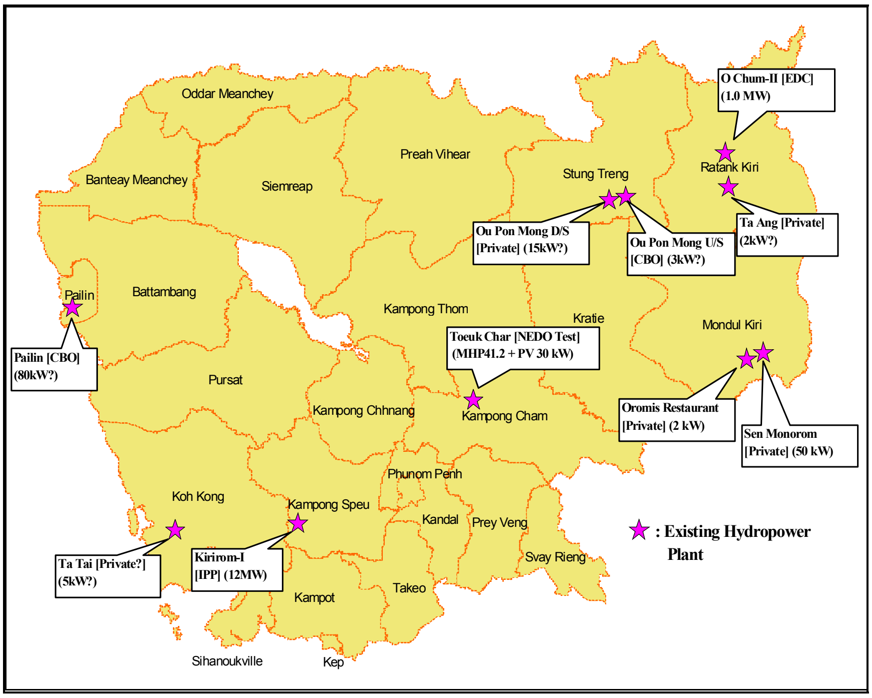
5.1.1 Present Uses of Micro Hydro

The classification of hydropower is categorized as follows in Cambodia:

- Large Hydro : > 50 MW
- Medium Hydro : 10 MW ~ 50 MW
- Small Hydro : 5 MW ~ 10 MW
- Mini Hydro : 500 kW ~ 5 MW
- Micro Hydro : < 500 kW

In addition, hydropower smaller than 1 kW may be called as pico hydro.

Of the 15,000 MW hydropower potential of Cambodia, only 1.0 MW at the O Chum-II hydropower station (Ratanak Kiri) and 12 MW at the Kirirom-I station (Kampong Speu)[18] have been developed as of 2004[19]. Some micro/pico hydros are in operation or proposed as shown in Figure 5.1.1 below:



Source: Team elaboration based on the information from MIME, etc.

Figure 5.1.1 Location Map of Existing and Proposed Hydropower Project Sites in Cambodia

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18 Rehabilitation works of the Kirirom Power Station and Dam by "CETIC International Hydropower Development Co., Ltd.", and new construction of transmission line (115 kV) by EDC in May 2002.

19 Details are given in Appendix-A.

As of February 2005, two sites of mini hydro and seven sites of micro hydro power (MHP) plants exist in Cambodia. The following hydropower projects are under implementation or planning:

- Sen Monourom MHP project (200 kW in total installed capacity) in Mondul Kiri province is under basic design (February 2005) by JICA towards implementation with Japan grant.
- Kamchay HEPP project (180 MW) at Kampot province will be constructed as an IPP scheme. As of February 2005, the project was under tendering to select an IPP contractor. The construction of dam is planned to be started in 2006.
- The study of the O Katieng micro hydro power project in Ratank Kiri province (proposed installed capacity of 1,076 kW or 224 kW) would be started in early 2005 by UNIDO to supply power to a rubber processing factory.
- A community MHP on the Stueng Kronnung River in the Samlot district of Battambang province is under construction by the Ta Sang Commune people and monks. The installed capacity was planned to be 50-100 kW. However, due to poor design and construction technologies, the estimated generation capacity will be only 4 to 23 kW.

In Cambodia, most of the micro hydro plants implemented or under construction by community or private sector are facing technical problems such as low power outputs especially in the dry season due to poor planning and design of facilities and equipments (i.e. waterway, turbine, etc.). Technical support and capacity building by government/donors/NGOs are essentially needed.

5.1.2 Potential of Micro Hydro

(1) General

Cambodia depends on small diesel generates for electricity supply in rural areas. This results in high power tariff for domestic consumers as well as for cottage industries, water supply pumps, irrigated agriculture, telecommunications and hotels. Therefore, MIME has formulated a short- and long-term plan to develop hydropower of 358 MW in total installed capacity. MIME further seeks a long-term development of an additional 2,785 MW. In addition, multi-purpose water resources development projects including hydropower are planned by MOWRAM, such as the Prek Thnot multi-purpose project.

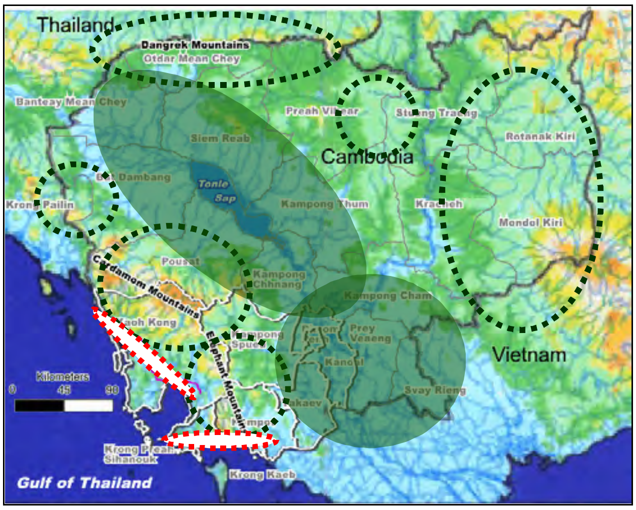
(2) Characteristics of Natural Conditions of Cambodia

(i) Geographical Characteristics

Cambodia covers an area of 181,035 km^2. The country is hilly along its international boundaries, but the dominant feature of landscape is the extensive flood plains of the Mekong River and the Tonle Sap Lake (the Great Lake). The geographical characteristics of Cambodia can be summarized as follows:

Central Plain

The central region is a low-lying alluvial plain surrounding the Tonle Sap (Great Lake) and the head of the Mekong River delta that lies in the southeast of the Plain. Extending outward from this region are transitional plains, thinly forested with prevailing elevations no higher than around 50 m above sea level.



Source: IDI-Japan, GIS for Mekong River Basin 1999

Figure 5.1.2 Landscape of Cambodia

Northern Mountains

On the north along the border with Thailand, the Cambodian plain abuts a sandstone escarpment that marks the southern limit of the "*Dangrek Mountains*".

A southward-facing cliff, stretching for more than 300 km from west to east, rises abruptly from the Plain to the heights ranging from 180 to 550 meters.

Eastern Highlands

East of the Mekong, the transitional plains gradually merge with the eastern highlands, a region of forested mountains and high plateaus that extend into Laos and Vietnam.

Southwestern Mountains

In southwestern Cambodia two distinct upland blocks, comprising the "*Cardamom Mountains*" and the "*Elephant Mountains*", form another highland region that covers much of the land area between the Tonle Sap and the Gulf of Thailand. In this remote and largely uninhabited area, there is "*Mount Aoral*" (1,813 meters), Cambodia's highest peak.

Southern Coastal Region

The southern coastal region facing the Gulf of Thailand is a narrow lowland strip, heavily wooded and sparsely populated. This area is isolated from the central plain with the southwestern highlands in between.

(ii) Meteorological Characteristics

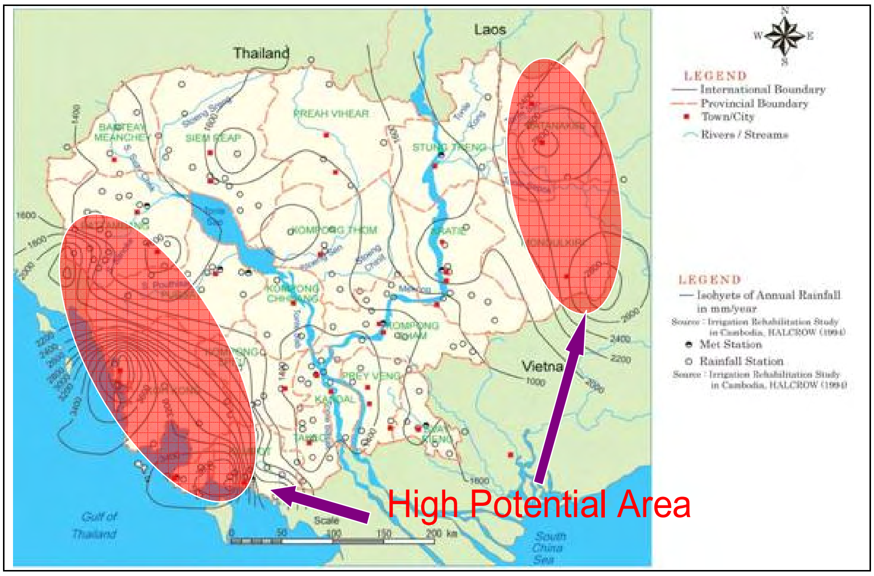
The temperature across the country ranges from a mean daily minimum of 19°C in January to a mean daily maximum of 35°C in April. There is very little spatial variation in the temperature across the region only in an order of 1°C. The mean annual temperature is 27.7°C in Phnom Penh. Wind speed data indicate a variation in the mean wind speed across the country. The wind speed is much low in the inland region compared to the coastal regions. Mean wind speeds range from 82 km/day (= 0.95 m/s) in the inland region to 179 km/day (= 2.1 m/s) in Kampot. The maximum wind speed occurs in January when the northeast monsoon prevails. Mean annual evaporation varies from 1,020 mm/year in Siemreap to

1,450 mm/year in Kompong Cham[20].

(iii) Rainfall Characteristics

Cambodia's climate is dominated by the monsoon. In the period from May to November, the southwest monsoon prevails and brings some 90% of the annual rainfall while the northeast monsoon brings the dry season in the period from December to April.

The mean annual rainfall varies from 1,200 mm/year in the northwestern part of the country to over 4,000 mm/year in the southeastern coastal area with an overall country mean of about 2,000 mm/year. The mean annual rainfall in the central plains, where most irrigation schemes are practiced, varies from 1,200 to 1,600 mm/year. An isohyetal map of mean annual rainfall in Cambodia is shown in Figure 5.1.3. According to the map, southwestern coastal area and eastern part of Cambodia should have high potential for micro hydro, depending on the topography.



Source: Irrigation Rehabilitation Study in Cambodia, Halkrow, 1994

Figure 5.1.3 Isohyetal Map of Mean Annual Rainfall in Cambodia

Mean monthly rainfall at representative rainfall stations is shown in Figure 5.1.4. The monthly rainfall distribution pattern shows a distinct rainy season from May to November with a peak in August/September. Approximately 85~90% of the annual rainfall are observed during the rainy season. The period from December to April is the dry season, January being the driest month. The rainfall pattern shows a single peak in many years. However, it is reported that there is often a short dry period up to two weeks even in the rainy season. The timing of this dry period is unpredictable and makes rain-fed rice farming risky and requires supplementary irrigation water in such time.

20 Irrigation Rehabilitation Study in Cambodia, Mekong Secretariat, Halcrow, June 1994.

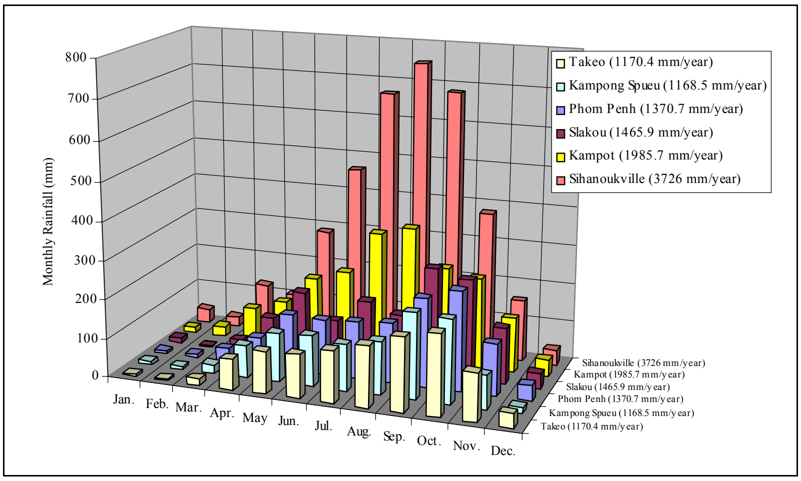
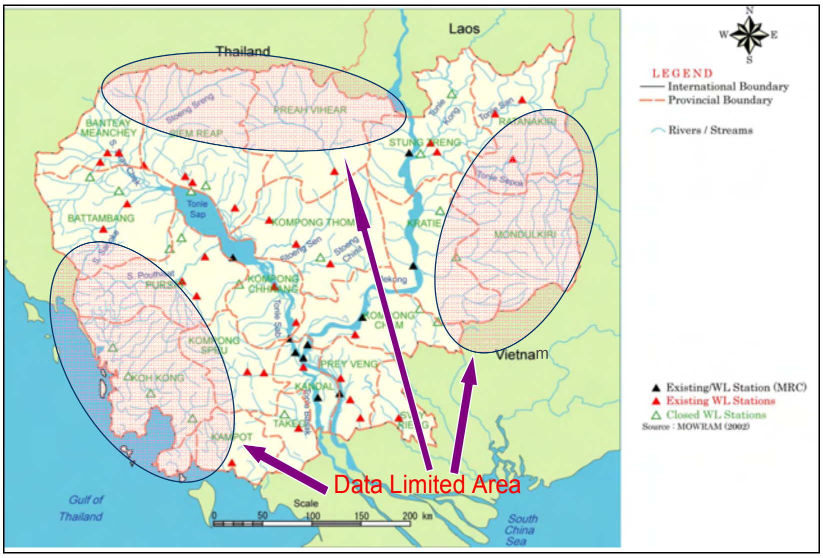


Figure 5.1.4 Mean Monthly Rainfall in Typical Cities

(iv) Hydrological Characteristics

Past and existing hydrological gauging stations in Cambodia are shown in Figure 5.1.5. Most of the hydrological gauging stations are located on large to medium sized rivers. Many gauging stations (especially on tributaries) were closed during the long continued turbulent history. Water levels were gauged at 35 stations in Cambodia and stream flows measured at 22 stations before 1975. These hydrological network was abandoned in 1975. In the 1980s, attempts were made to rehabilitate the stations but resulted in only limited success. Since 1995, some 28 stations have been rehabilitated by MOWRAM under the contract with Mekong River Committee (MRC). It was planned to set up a network of some 40 water level/stream flow stations in Cambodia since 2001. For planning of micro hydro, stream flows in the dry season are essential. However, stream flow measurements on tributaries and small rivers are very limited in the country.



Source: MOWRAM, 2002

Figure 5.1.5 Hydrological Gauging Stations in Cambodia

On the Mekong and a few of the largest tributaries, the Sekong, Sesan and Srepok on the east bank, there remains a substantial flow even during the dry season. However, in the smaller catchments, flows depend more directly on local rainfall patterns, and fall to the minimum levels during the dry season. Figure

5.1.6 shows a flow duration curve on the Kbal Chay river in Sihanoukville. According to the isohyetal map or mean annual rainfall (Figure 5.1.3), the Sihanoukville area has a rainfall of higher than 3,400 mm/year. Even in these rainy areas, the river flows in the dry season almost dry up. Most of the small streams dry up as shown in the right hand photograph of Figure 5.1.6. This remarkable drop in the dry season flow is a common feature in Cambodia and is a great hurdle to rural electrification by micro hydro[21].

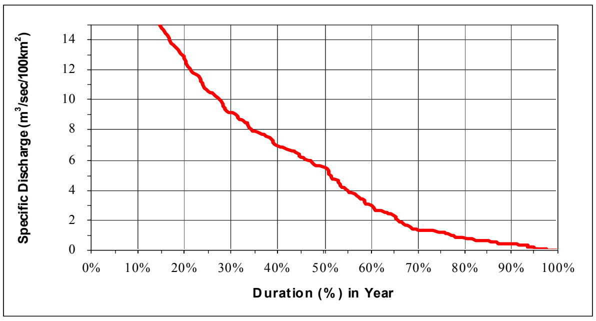


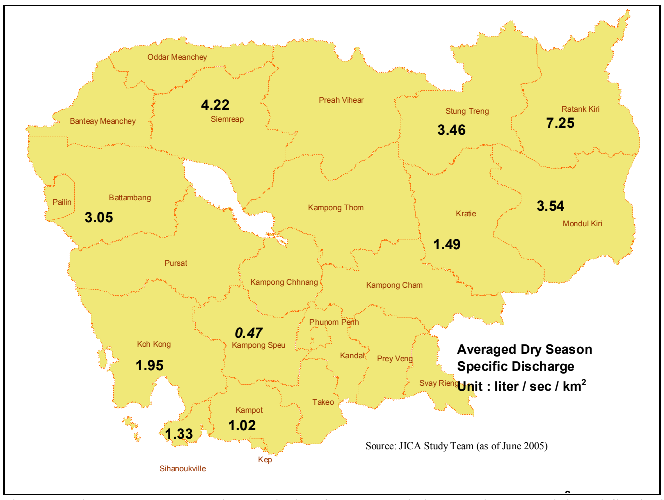
Photo: Preaek Kaoh Touch, Kampot, 6 Dec. 2004 (JICA Study Team)

Source: Flow duration curve at Kbal Chay WL station, Sihanoukville (Year 2001-2002), The Study on Regional Development of the Phnom Penh-Sihanoukville Growth Corridor in the Kingdom of Cambodia, JICA, 2003

Figure 5.1.6 Example of Flow Duration Curve

The dry season flows of in Cambodia are spatially presented in Figure 5.1.7. The figure was developed based on Table 5.1.2, which summarizes specific discharge of small rivers available in the past studies as well as those measured by the Study Team. The following observations may be made from the figure:

- Specific flows in the dry season varies from 0.47 l/s/km^2 in Kampong Speu to 7.25 l/s/km^2 in Ratanak Kiri Province with majority in a range of 1 to 4 l/s/km^2;
- The dry season specific flows are relatively high in three northeastern provinces (Ratnak Kiri, Mondol Kiri, and Stung Treng) as well as in two northwestern provinces (Siemreap and Battambang);
- The dry season specific flows in four southwestern provinces (Kampong Speu, Kampot, Shihanoukville, and Koh Kong) are low being below 2 l/s/km^2 in spite of the high annual rainfalls of about 3,000 mm.



Note: Observations were made mainly for promising schemes identified through map study. Figures for provinces are shown based on limited observed data, not covering whole province characteristics.

Figure 5.1.7 Averages of Observed Specific River Discharge in Dry Season by Province

[21] Concept of Installed Capacity Selection is given in Appendix-A for reference.

Table 5.1.1 Dry Season Flows Measured at Potential Sites of MHP

No.	Province	District	River Name	Name of MHP Scheme	C.A. (km^2)	Observed Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)	Observed Date	Specific Discharge ** (for Average) ($liter/s/km^2$)
1	Kampong Speu	Phnum Snoch	Sva Slab	Stung Sva Slab	205 [2)]	**0.096** [1)]	0.0005	2004/12/4	0.47
	Kampong Speu	Phnum Snoch	Sva Slab	Stung Sva Slab	205 [2)]	**0.200** [2)]	0.0010	2001/4/21	
Kampong Speu Province Average									**0.47**
2	Kampot	Kampot	Kaoh Touch	Preak Kaoh Touch	21.65 [4)]	**0.000** [1)]	0.0000	2004/12/6	0.00
3	Kampot	Chum Kiri	Srae Cheng	Srae Cheng	48.0 [3)]	***0.150*** [3)]	0.0031	2001/5/9	
	Kampot	Chum Kiri	Srae Cheng	Srae Cheng	36.0 [4)]	**0.017** [1)]	0.0005	2004/12/7	0.47
4	Kampot	Kampot	O Traou Trao	O Traou Trao	20.0 [2)]	***0.200*** [2)]	0.0100	2001/2/9	
	Kampot	Kampot	O Traou Trao	O Traou Trao	20.0 [2)]	**0.052** [1)]	0.0026	2004/12/8	2.60
Kampot Province Average									**1.02**
5	Battambang	Samlot	O Samrel	O Samrel (O Tek Souk)	12.0 [3)]	**0.036** [1)]	0.0030	2005/1/5	3.00
6	Battambang	Samlot	O Chum	Ta Taok	*20.5* [3)]	**0.400** [3)]	0.0195	2002/5/14	
	Battambang	Samlot	O Chum	Ta Taok	14.0 [3)]	**0.060** [1)]	0.0043	2005/1/6	4.29
7	Battambang	Samlot	Ou Daem Chek	Kampong Lpov	*15.0* [3)]	**0.100** [3)]	0.0067	2002/5/16	
	Battambang	Samlot	Ou Daem Chek	Kampong Lpov	8.0 [3)]	**0.026** [1)]	0.0033	2005/1/7	3.25
8	Battambang	Samlot	Stung Sangke	Sangke (D/S)	696.0 [1)]	**1.150** [1)]	0.0017	2005/2/5	1.65
Battambang Province Average									**3.05**
9	Pursat	Veak Veng	Tumpor	O Pramoie	75.0 [3)]	***1.000*** [3)]	0.0133	2002/12/6	
Pursat Province Average									
10	Siem Reap	Banteay Srey	Stung Siem Reap	French Weir	500.0 [A)]	**0.740** [A)]	0.0015	$Q_{95\%}$ in 1998	1.48
	Siem Reap	Banteay Srey	Stung Siem Reap	Stung Siem Reap	115.0 [2)]	**0.800** [2)]	0.0070	2001/2/16	6.96
	Siem Reap	Banteay Srey	Stung Siem Reap	Upper St.Siem Reap	86.0 [2)]	**0.600** [2)]	0.0070	2001/2/16	
Siem Reap Province Average									**4.22**
11	Ratanak Kiri	Lumphat	O Kachan	O Kachan	31.2 [4)]	**0.350** [1)]	0.0112	2005/1/19	11.22
12	Ratanak Kiri	Lumphat	O Katieng	O Katieng	42.9 [4)]	**0.410** [1)]	0.0096	2005/1/19	9.56
13	Ratanak Kiri	Lumphat	O Sien Ler (O Paling Thom)	Bay Srok	115.0 [3)]	***5.500*** [3)]	0.0478	2002/5/28	
	Ratanak Kiri	Lumphat	O Sien Ler (O Paling Thom)	Bay Srok	115.0 [3)]	**1.070** [1)]	0.0093	2005/1/20	
	Ratanak Kiri	Lumphat	O Sien Ler (O Paling Thom)	Bay Srok	115.0 [3)]	**0.410** [1)]	0.0036	2005/5/20	3.57
14	Ratanakiri	Andoung Meas	O Pyol	O Pyol	14.0 [1)]	**0.130** [1)]	0.0093	2005/1/21	9.29
15	Ratanak Kiri	Koum Mom	O Cheng	Ta Ang	19.0 [3)]	**0.050** [3)]	0.0026	2002/5/30	2.63
	Ratanak Kiri	Koum Mom	O Cheng	Ta Ang	19.0 [3)]	**0.070** [1)]	0.0037	2005/1/22	
Ratanak Kiri Province Average									**7.25**
16	Stung Treng	Sienbok	O Chrolong	O Chrolong	128.0 [1)]	**0.450** [1)]	0.0035	2005/1/23	
	Stung Treng	Sienbok	O Chrolong	O Chrolong	128.0 [1)]	**0.320** [1)]	0.0025	2005/5/22	2.50
17	Stung Treng	Se San	O Chrop	O Chrop	16.0 [1)]	**0.030** [1)]	0.0019	2005/1/24	1.88
18	Stung Treng	Siem Bouk	O Baign Kla	O Baingkla (D/S)	35.0 [1)]	**0.210** [1)]	0.0060	2005/1/24	6.00
Stung Treng Province Average									**3.46**
19	Kratie	Chhnong	O Dambal	O Dambal	115.0 [1)]	**0.050** [1)]	0.0004	2005/1/26	0.43
20	Kratie	Sunoul	O Chrei Meing	O Chrei Meing	180.0 [1)]	**0.719** [1)]	0.0040	2005/1/27	3.99
21	Kratie	Sunoul	Prek Prey	Prek Prey	165.0 [1)]	**0.007** [1)]	0.0000	2005/1/27	0.04
Kratie Province Average									**1.49**
22	Mondul Kiri	Ou Reang	O Dak Dam	O Dak Dam	4.0	**0.020**	0.0050	2005/1/26	5.00
23	Mondul Kiri	Pechr Chenda	Prek Por	Busra	198.0 [3)]	**4.400** [3)]	0.0222	2001/7/23	
	Mondul Kiri	Pechr Chenda	Prek Por	Busra	197.0 [1)]	**0.150** [1)]	0.0008	2005/1/27	0.76
24	Mondul Kiri	Pechr Chenda	O Phlai	O Phlai	302.0 [1)]	**0.330** [1)]	0.0011	2005/1/27	1.09
25	Mondul Kiri	Saen Monourom	O Romis	Prek Dak Deur / O Romis (D/S)	41.0 [3)]	**3.000**	0.0732	2001/7/19	
26	Mondul Kiri	Saen Monourom	Prek Dak Deur		98.0 [3)]	**4.000**	0.0408	2001/7/24	
	Mondul Kiri	Saen Monourom	Prek Dak Deur	Mondul Kiri MHP	53.0 [B)]	**0.290** [B)]	0.0055	$Q_{95\%}$ in 2003-2004	
27	Mondul Kiri	Saen Monourom	O' Moleng		56.0 [B)]	**0.300** [B)]	0.0054		5.36
28	Mondul Kiri	Saen Monourom	O' Romis		42.0 [B)]	**0.230** [B)]	0.0055		5.48
Mondul Kiri Province Average									**3.54**
29	Koh Kong	Thmabang	Stung Tatai	Tatai (D/S)	423.0 [1)]	**0.284** [1)]	0.0007	2005/2/11	0.67
	Koh Kong	Thmabang	Stung Tatai	Tatai (U/S)	158.0 [1)]	**0.031** [1)]	0.0002	2005/2/12	0.20
30	Koh Kong	Thmabang	Chhay Areng	Chhay Areng D/S	890.0 [1)]	**0.367** [1)]	0.0004	2005/2/13	0.41
31	Koh Kong	Sre Amble	Ou Sla	Ou Sla (D/S)	54.0 [2)]	***0.200*** [2)]	0.0037	2001/4/23	3.70
32	Koh Kong	Sre Ambel	Stung Phun Ruol	Phnum Batau D/S	105.0 [2)]	**0.500** [2)]	0.0048	2001/4/23	4.76
Koh Kong Province Average									**1.95**
33	Sihanoukville	Prey Nob	Stung Phun Ruol	Phnum Batau D/S	52.5 [C)]	**0.070** [C)]	0.0013	$Q_{95\%}$ 2001-02	1.33
Sihanoukville Province Average									**1.33**

Source *1): JICA Study Team (JST) Surveyed (observed in Dec. 2004 - Feb.2005, May.2005)
*2): "Pipeline Development Program of Small Hydropower Project in Cambodia", WB / Meritec, (2001).
*3): "Pre-Investment Study of Community-Scale Hydro Projects, Cambodia", NZ MoFA&T, Meritec (2003).
*4): MIME
*A): "The Study on Water Supply System for Siem Reap Region in Cambodia", JICA, 2000.
*B): "The Technical Work Shop on the Mondul Kiri MHP Project", JICA Study Team for Mondul Kiri MHP Project B/D Survey, Dec. 2004.
*C): "The Study on Regional Development of the Phnom Penh-Sihanoukville Growth Corridor in the Kingdom of Cambodia", JICA, 2003
Note ** : Smaller value of specific discharge was selected if there are more than two data at same site.

Source: JICA Study Team

(3) Map Study of Micro Hydro Potentials

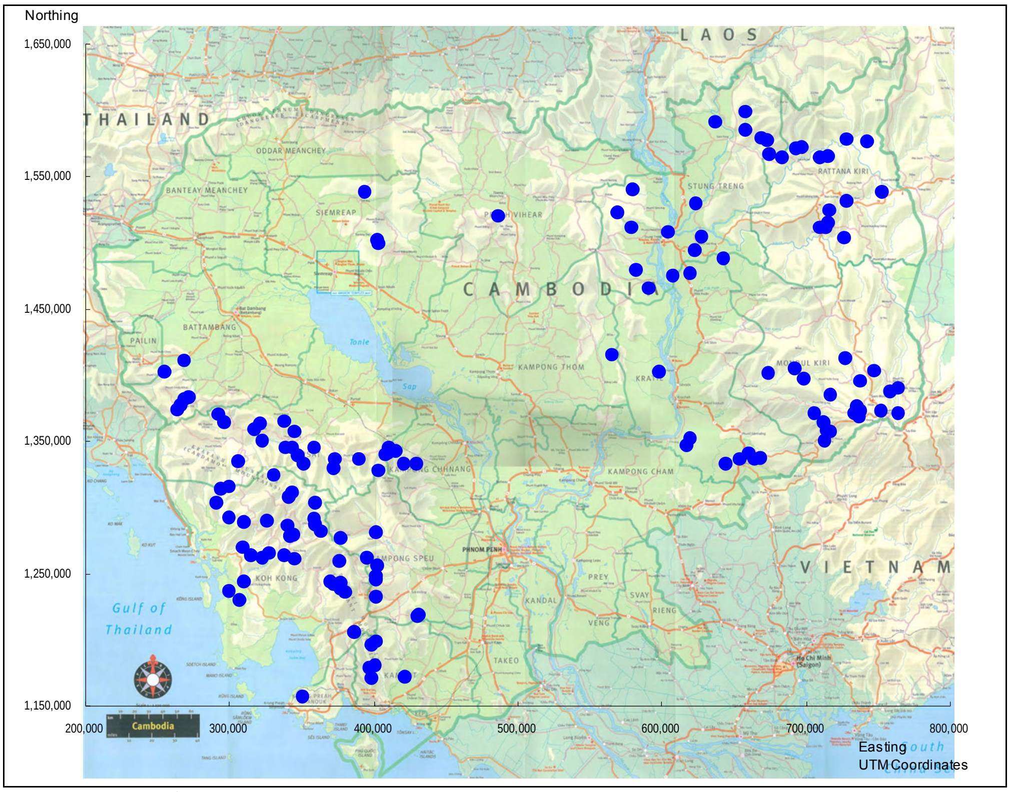
Identification of micro hydro potential requires hearing to villagers and confirmation by field reconnaissance since small head could hardly be identified on maps and flow of small catchments cannot be estimated simply by catchment area ratio. It has been found through the first field reconnaissance made in December 2004 that most of the small rivers have very low flows in the dry season as a result of the hydrologic features unique to Cambodia.

Accordingly the Study Team checked potential sites on 1:50,000 and 1:100,000 maps seeking those sites that have significant flows in the dry season (refer to Figure 5.1.12 for the location)[22]. Procedures of checking potential sites by map study are as follows:

1) Check numbers of households of villages to be electrified nearby a potential river and estimate demand assuming unit consumption of 100 W per household;
2) Check contour lines and select sites with significant head (rapid or waterfall) nearby the villages;
3) Measure catchment area to estimate an order of the dry season flow;
4) Estimate dry season flow with reference to isohyetal map and those of gauged rivers;
5) Estimate dry season power outputs on 24 hour basis by the following formula:

$$P\ (kW) = 9.8 * \eta * Q\ (m^3/s) * H\ (m)$$

$$\text{where } \eta = 0.7$$



Source: JICA Study Team

Figure 5.1.8 Location Map of MHP Sites Identified through Map Study

[22] Detailed descriptions of map study results are given in Appendix-A.

(4) Reconnaissance of Prospective MHP Sites

Reconnaissance of the prospective micro hydro sites was conducted during the 1st to 3rd field survey period (December 2004 - June 2005) jointly by the JICA Study Team and MIME staff. During the field survey, discharge measurements were carried out near the intake site using current meter, and leveling survey using hand level between intake site and power house site. A total of 30 sites were inspected as shown in Table 5.1.5.

Table 5.1.2 Survey Results of Potential MHP Sites

No.	Name of MHP Scheme	Province	District	River Name	Q Obs. Site (UTM: Indian-Thai) GPS X (E)	GPS Y (N)	C.A. (km^2)	100% Observed Discharge (m^3/s)	Specific Discharge ($m^3/s/km^2$)	Date	Time of Q.Obs	Gross Head (m)	(η = 0.7) Potential Power Gen. (kW)	No. of Househol (HH)	(0.10 kW/HH) Demand (Peak) *a) (kW)		Name of Villages (Target Area)	Remarks
1	Stung Sva Slab	Kampong Speu	Phnum Snoch	Sva Slab	*03 95 710*	*12 61 360*	205 [2]	**0.096** [1]	0.0005	2004/12/4	13:52	***85.0*** [2]	**56**	665 [5]	**69**	X	Chambak, Kreng Chek, Beng, Thmei	Meritec Study (2001) [3.80MW] *2)
2	Preak Kaoh Touch	Kampot	Kampot	Kaoh Touch	03 99 035	11 71 179	21.65 [4]	**0.000** [1]	-	2004/12/6	15:17	***60.0*** [4]	**0**	546 [5]	**57**	X	Kilou Dabpir village + Kaou Touch (Preak Chek)	MIME List [317kW] (River dried up)
3	Srae Cheng (Srat Cheng)	Kampot	Chum Kiri	Srae Cheng (Srat Cheng)	04 31 151	12 18 070	36.0 [4]	**0.017** [1]	0.0005	2004/12/7	14:55	**55.0** [1]	**6.4**	284 [5]	**30**	X	Pong Tuek village	Height measurement by Altimeter
4	O Traou Trao	Kampot	Kampot	O Traou Trao	04 01 427	11 80 460	20.0 [2]	**0.052** [1]	0.0026	2004/12/8	10:30	**154.3** [1]	**55**	352 [5]	**37**	OK	Mortpeam, Bat Kbal damrei	Meritec Study (2001) [1.12MW] *2)
5	O Samrel	Battambang	Samlot	O Samrel	02 68 866	13 81 692	12.0 [3]	**0.036** [1]	0.0030	2005/1/5	16:25	**28.0** [1]	**6.9**	*110*	**11**	X	O Kroch (old name: Samrel) Village	Meritec Study (2003) [33kW] *3)
6	Ta Taok	Battambang	Samlot	O Chum	02 65 898	13 76 917	14.0 [3]	**0.060** [1]	0.0043	2005/1/6	14:22	**71.4** [1]	**29**	*50*	**5**	OK	Veal Roling village (Ta Taok Commume)	Meritec Study (2003) [37.5kW] *3)
7	Kampong Lpov	Battambang	Samlot	Ou Daem Chek	02 71 928	13 83 174	8.0 [3]	**0.026** [1]	0.0033	2005/1/7	14:15	**78.7** [1]	**14**	127 [1]	**13**	OK	Ou Daem Chek village (Kampong Lpov Commune)	Meritec Study (2003) [31kW] *3)
8	O Chum I (exisiting dam)	Ratanak Kiri	O Chum	O Chum	07 16 437	15 24 726	22.7 [2]	***1.500*** [6]	0.0661	2005/1/18	16:00	**9.0** [2]	**92**	274 [5]	**28**	OK	Ta Long (Tharang Chong), Ou Chum, Svay	Meritec Study (2001) [74kW] *2)
9	O Kachan	Ratanak Kiri	Lumphat	O Kachan	07 15 659	15 14 518	31.2 [4]	**0.350** [1]	0.0112	2005/1/19	9:40	**13.2** [1]	**32**	98 [5]	**10**	OK	Phum Pir	MIME List [82kW] *2)
10	O Katieng	Ratanak Kiri	Lumphat	O Katieng	07 14 128	15 11 427	42.9 [4]	**0.410** [1]	0.0096	2005/1/19	12:00	**14.1** [1]	**40**	295 [5]	**31**	OK	Katieng I & II (Ka Tueng, Banlung town?)	Meritec Study (2001) [1076kW] *2), MIME List [224kW]
11	O Katieng (D/S)	Ratanak Kiri	Lumphat	O Katieng (D/S)	07 14 128	15 11 427	42.9 [1]	**0.410** [1]	0.0096	2005/1/19	12:00	**44.7** [1]	**126**	368 [1]	**38**	OK	Katieng I & II, Kam Pleng, Kateng	New Proposed Scheme by JICA Study Team
12	Bay Srok (O Sien Ler)	Ratanak Kiri	Lumphat	O Sien Ler (O Paling Thom)	07 26 215	15 03 449	115.0 [3]	**1.070** [1]	0.0093	2005/1/20	13:00	**23.2** [1]	**170**	560 [1]	**58**	OK	Bay Srok, New Kalaeng, New Sayos	Meritec Study (2003) [78kW] *3)
	Bay Srok (O Sien Ler)	Ratanak Kiri	Lumphat	O Sien Ler (O Paling Thom)	07 26 215	15 03 449	115.0 [3]	**0.410** [1]	0.0036	2005/5/20	-	**23.3** [8]	**65**	560 [1]	**58**	OK	Ditto	Ditto
13	O Pyol	Ratanak Kiri	Andoung Meas	O Pyol	07 52 917	15 38 257	14.0 [1]	**0.130** [1]	0.0093	2005/1/21	13:45	**12.57** [1]	**11**	91 [5]	**9**	OK	Ka Chut	-
14	Ta Ang	Ratanak Kiri	Koum Mom	O Cheng	07 09 708	15 11 423	19.0 [3]	**0.070** [1]	0.0037	2005/1/22	10:00	**25.0** [3]	**12**	98 [3]	**10**	OK	Sek	Meritec Study (2003) [10kW] *3)
15	O Chrolong	Stung Treng	Sienbok	O Chrolong	06 19 514	14 76 863	128.0 [1]	**0.450** [1]	0.0035	2005/1/23	16:20	**4.8** [1]	**15**	103 [5]	**11**	OK	O Resey Kadal	Proposed by DIME, Survey by JST (2005)
	O Chrolong	Stung Treng	Sienbok	O Chrolong	06 19 514	14 76 863	128.0 [1]	**0.320** [1]	0.0025	2005/5/22	-	**4.8** [1]	**10.4**	103 [5]	**11**	X	Ditto	Ditto
16	O Chrop	Stung Treng	Se San	O Chrop	06 42 492	14 88 053	16.0 [1]	**0.030** [1]	0.0019	2005/1/24	13:00	***5.0*** [7]	**1.0**	116 [1]	**12**	X	O Crop	Proposed by DIME, Survey by JST (2005), Low Potential
17	O Baingkla (D/S)	Stung Treng	Siem Bouk	O Baign Kla	06 07 817	14 75 073	35.0 [1]	**0.210** [1]	0.0060	2005/1/24	14:00	***5.0*** [7]	**7**	270 [1]	**28**	X	Srae Krasan (Phnom Dei Krahom)	Proposed by DIME, Survey by JST (2005)
18	O Dambal	Kratie	Chhnong	O Dambal	06 19 706	13 52 202	115.0 [1]	**0.050** [1]	0.0004	2005/1/26	17:15	**3.6** [1]	**1.2**	*175* [1]	**18**	X	Pralay Trick, Kroch	JST (2005), x 6 time avairable if peak
19	O Chrei Meing	Kratie	Sunoul	O Chrei Meing	06 64 149	13 35 908	180.0 [1]	**0.719** [1]	0.0040	2005/1/27	11:45	***5.0*** [7]	**25**	114 [5]	**12**	OK	Cheung Khle	JST (2005), Dam (H=10m, DCL=400m) and Large flood protection will be
20	Prek Prey	Kratie	Sunoul	Prek Prey	06 68 328	13 37 375	165.0 [1]	**0.007** [1]	0.0000	2005/1/27	15:30	**5.0** [7]	**0.2**	4 [1]	**0**	OK	Prek Prey (4 Army camp' families only)	JST (2005) Low possibility
21	O Dak Dam	Mondul Kiri	Ou Reang	O Dak Dam	07 51 859	13 72 642	4.0	**0.020** [1]	0.0050	2005/1/26	11:00	**17.0** [1]	**2.3**	117 [1]	**12**	X	-	-
22	Busra	Mondul Kiri	Pechr Chenda	Prek Por	*07 64 312*	*13 90 088*	197.0 [1]	**0.150** [1]	0.0008	2005/1/27	11:00	***65.0*** [1]	**67**	899 [5]	**93**	X	Busra Commune	Meritec (2003) [54kW] *3), 23m & 42m for 1st & 2nd fall. Supply to Busra Commune
	Busra	Mondul Kiri	Pechr Chenda	Prek Por	*07 64 312*	*13 90 088*	197.0 [1]	**2.050** [1]	0.0104	2005/5/20	11:30	***68.2*** [8]*	**959**	899 [1]	**93**	OK	Ditto	8)* Partly hand level applied
23	O Phlai	Mondul Kiri	Pechr Chenda	O Phlai	*07 58 800*	*13 87 700*	302.0 [1]	**0.330** [1]	0.0011	2005/1/27	16:00	***40.0*** [7]	**91**	899 [1]	**93**	X	Busra Commune and surrounding areas	Supply to Busra Commune
	O Phlai	Mondul Kiri	Pechr Chenda	O Phlai	*07 58 800*	*13 87 700*	302.0 [1]	**0.470** [1]	0.0016	2005/5/21	11:45	***23.5*** [8]**	**76**	899 [1]	**93**	X	Ditto	8)* Head will be developed more. Levelling was interrupted by time limitation
24	Sangke (D/S)	Battambang	Samlot	Stung Sangke	*02 68 875*	*14 11 162*	696.0 [1]	**1.150** [1]	0.0017	2005/2/5	11:00	***15.0*** [6]	**118**	6786 [5]	**706**	X	Ratanak Mondul District, Samlout District, etc.	Mine clearing is required for further survey
	Sangke (D/S)	Battambang	Samlot	Stung Sangke	*02 68 875*	*14 11 162*	696.0 [1]	**2.830** [1]	0.0041	2005/5/14	10:30	***7.5*** [8]	**145**	6786 [5]	**706**	X	Ditto	Ditto
	Sangke (D/S)	Battambang	Samlot	Stung Sangke	*02 68 875*	*14 11 162*	696.0 [1]	**2.880** [1]	0.0041	2005/5/15	12:15	***7.5*** [8]	**147**	6786 [5]	**706**	X	Ditto	Ditto
25	Sangke (U/S)	Battambang	Samlot	Stung Sangke	*02 55 200*	*14 02 400*	499.0 [1]	***0.824*** [6]	0.0017	2005/2/5	-	***15.0*** [6]	**85**	6786 [5]	**706**	X	Ditto	Ditto
26	Tatai (D/S)	Koh Kong	Thmabang	Stung Tatai	03 25 927	12 89 335	423.0 [1]	**0.284** [1]	0.0007	2005/2/11	11:00	**32.0** [1]	**62**	155 [5]	**16**	OK	Kokir Chrum, Trapeang Chuetrav Villages	Auto W.L. gauge was installed by ADB (2004).
	Tatai (D/S)	Koh Kong	Thmabang	Stung Tatai	03 25 927	12 89 335	423.0 [1]	**No measu -rement**	-	2005/6/1	-	**30.2** [8]	**62**	155 [5]	**16**	OK	Ditto	Ditto
27	Tatai (U/S)	Koh Kong	Thmabang	Stung Tatai	03 40 963	13 07 608	158.0 [1]	**0.031** [1]	0.0002	2005/2/12	11:40	**28.0** [1]	**6**	92 [1]	**10**	X	Kandal, Trapeang Khna, Spean Kdar Villages	-
28	Chhay Areng D/S	Koh Kong	Thmabang	Chhay Areng	034 0171	12 85 782	890.0 [1]	**0.367** [1]	0.0004	2005/2/13	11:15	**6.0** [1]	**15**	96 [5]	**10**	OK	Tuek L'ak	Access is only by Motor Bike

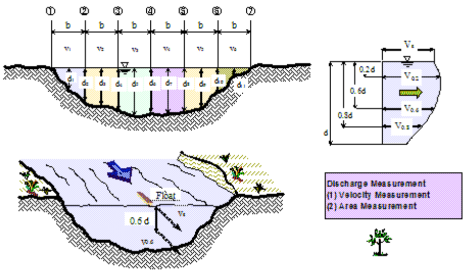
Source: *1): JICA Study Team (JST) Surveyed
*2): "Pipeline Development Program of Small Hydropower Project in Cambodia", WB / Meritec, (2001).
*3): "Pre-Investment Study of Community-Scale Hydro Projects, Cambodia", NZ MoFA&T, Meritec (2003).
*4): MIME
*5): SEILA GIS Data Base
*6): Eye measurement/Estimated figures
*7): Assumed.
*8): Measured by Auto Level
*a): Peak Demand(kW) = Total Nos of HH x 0.8 x 0.1 (kW/HH) x 1.3 for loss

To measure the stream flows, river water level gauges (staff gauges) were installed at seven sites from January to June 2005 jointly by the JICA Study Team and MIME/DIME staff. Water levels are observed twice a day by a villager nearby the gauge who is employed by the JICA Study Team for about one year period in total. Photographs of staff gage installation, discharge measurement and topographic survey are shown below:

Installation of water level gauge
(O Churolong river, Stung Treng)

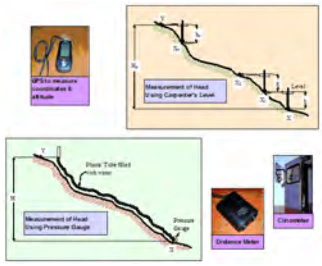
Installed staff gauge

Discharge measurement at Battambang



Method of discharge measurement

Leveling



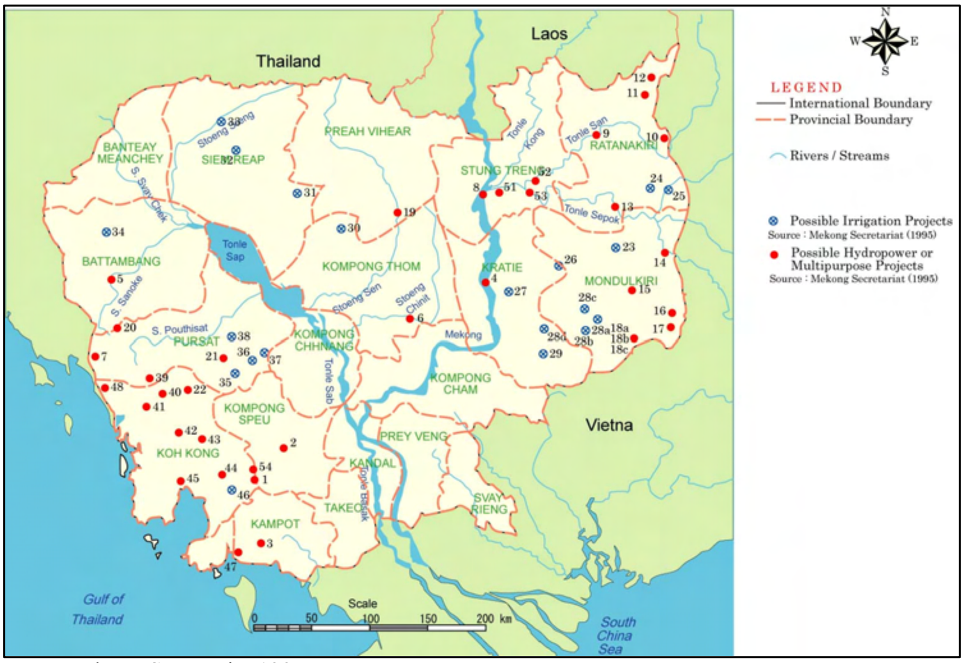
Topo. survey by hand level and GPS

Source: JICA Study Team.

Figure 5.1.9 Survey of Prospective MHP Sites

(5) Potential of MHP on Irrigation Facilities

Irrigation and multipurpose projects proposed by Mekong Secretariat are shown in Figure 5.1.14.



Source: Mekong Secretariat 1995

Figure 5.1.10 Irrigation and Multipurpose Projects

There are some possibilities to develop micro hydro harnessing potentials of existing irrigation systems. High water losses from channels and flooding around potential sites are occurring because of the long uncared "Pol Pot" irrigation schemes. Some schemes are not completed yet. Poor hydraulic design and irrigation layout stemming from the Khmer Rouge regime, together with lack of financial resources for operation and maintenance, have caused a number of irrigation schemes to deteriorate.

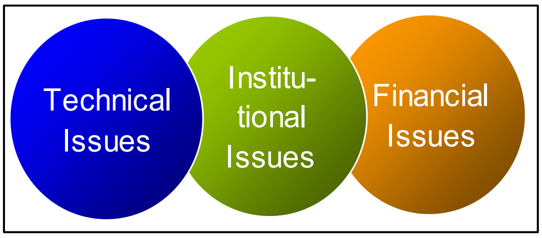
The irrigated paddy fields account only for 16.6% of the total cultivated area in Cambodia, which was 473,000 ha in 1998 of the total paddy-growing area (1.93 million ha). An area of 8% is under supplementary irrigation in the wet season and 10% under full irrigation in the dry season. Almost all the paddy area is single-cropped, resulting in low annual production. The total irrigation potential is estimated at 1,667,300 ha in Cambodia[23]. However, due to lack of infrastructure - diversion structures, dams, etc. to store the wet season water for the dry season irrigation, a great amount of water simply drains to the sea.

During the 1st and 2nd field survey period of the Study, the JICA Study Team visited and surveyed at some existing irrigation facilities. However, most of the rivers at irrigation intake facilities dried up or very limited flow was observed in the dry season. Even at irrigation schemes with reservoir function, there was no outflow from the reservoir in the dry season. The potential of micro hydro for rural electrification using existing irrigation facilities is low. These are not suitable for electrification in the off-grid area in particular because of sharp drop or stop of power outputs in the dry season.

5.1.3 Issues of Micro Hydro for Rural Electrifications

General issues of micro hydro are summarized below:

- Significant drops in the dry season flow and power outputs;
- Less availability of head (potential) for power generation due to generally gentle riverbed slope;
- Landslide, flooding and sedimentation in the rainy season;
- Organization for technical operation and maintenance;
- Access;
- Financing (especially for investment cost);
- Management of electricity business.



Principal issues of micro hydro specific to Cambodia may be as summarized below:

- Lack of hydrological records;
- Very low river flow in the dry season (Approximately 85~90% of the annual rainfall occurs during the rainy season from May to November and small rivers dry up in the dry season.)
- Little experience of micro hydro planning, construction, operation and maintenance
- Short of engineers because of the turbulent history since 1970s;
- Risk of land mines for survey and construction
- Limited power demand in rural area compared to potential
- Increase of sediment transport and flooding due to population growth, slash-and-burn agriculture in upland areas, unmanaged collection of fuel-wood, logging operations, extraction of sand, gravel, rock and other materials from riverbeds and banks of water bodies.

23 Source: MOWRAM, 2001.

5.2 BIOMASS

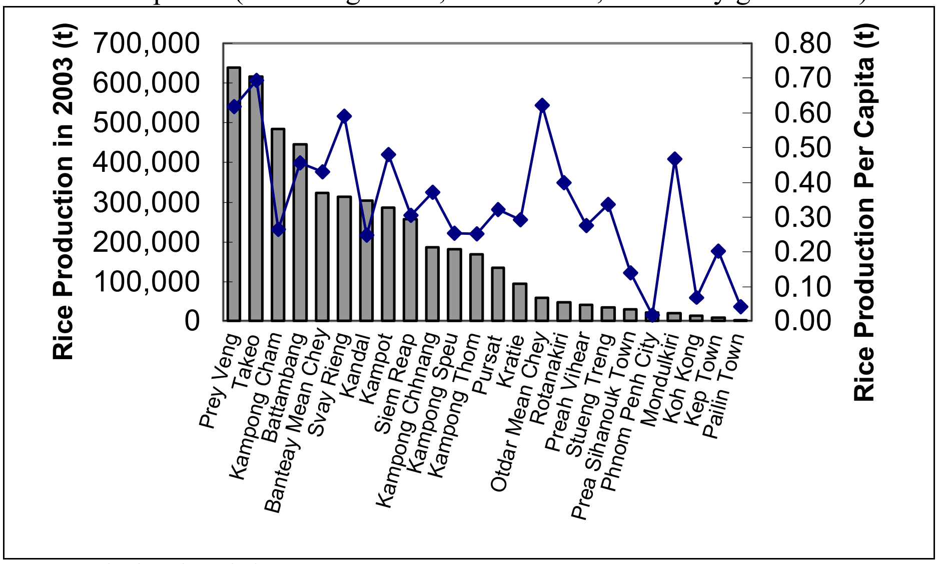
5.2.1 Biomass Resources in Cambodia[24]

Biomass resources such as wood and agricultural residues are abundant in Cambodia. It is estimated that biomass fuel accounted for some 80% of the national energy consumption (MIME 2001) but biomass fuel used for power generation is limited for a few small-scale projects and negligible amount among the total national power production. Woody biomass accounts for more than 95% of the biomass energy used in the country.

According to our initial survey, rice husk and some other agricultural residues, old rubber wood occurred as the result of new planting and forest wood from plantations and managed natural forests are high potential energy source for electricity generation. The status of those high potential biomass resources is described below:

(1) Rice Husk

The rice husk is the outer cover of the rice and on average it accounts for 20% of the paddy produced, on weight basis. The average lower heating value of the rice husk is about 13-16 MJ/kg and this is about one-third that of furnace oil, one-half that of good quality coal (Natarajan et al. 1998). Rice is by far the most important staple food of Cambodia. Rice occupies 90% (IRRI and others) of the total agricultural area and is the major agricultural item in terms of area, volume and income. In 2003, rice was cultivated in 2.3 million ha of the field and 4.7 million ton was produced (MAFF 2003). This means nearly 1 million ton of rice husk was produced in the country in 2003. One million ton of rice husk is sufficient fuel for generating 60 MW power (many small scale, 20-100 kW, electricity generation scattered around country) to over 100 MW power (a few large scale, 10-100 MW, electricity generation) for a whole year.

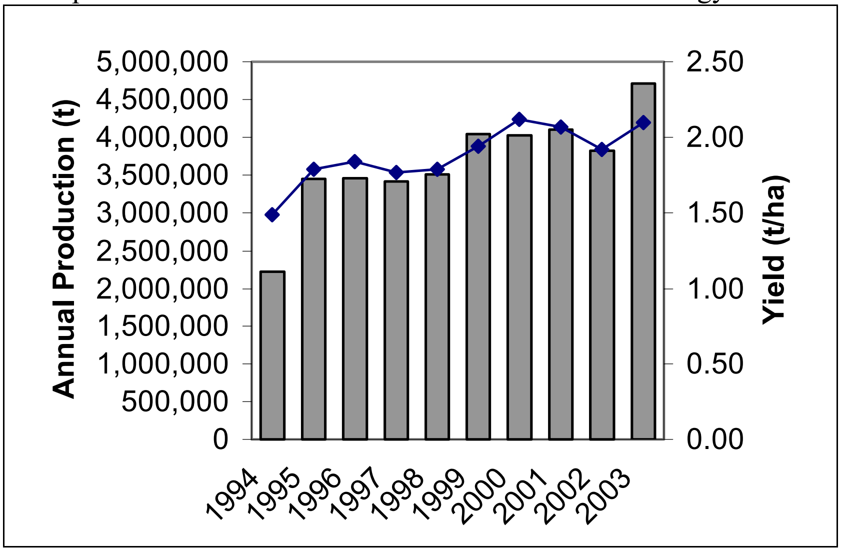


Source: Agricultural Statistics 2003-2004, MAFF 2003
Notes: Bars indicate the production with left Y axe and the plots indicate production per capita with right Y axe.

Figure 5.2.1 Rice Production and Production per Capita in 2003 in Each Province and Major Cities in Cambodia

[24] For the technology of biomass electrification, refer to the Section 1.2.1 of Chapter 1, Part 3.

Prey Veng province produced highest amount of rice, 639,452 t (14%) and followed by Takeo (13%), Kampong Cham (10%), Battanbang (9%) and other twenty provinces (Figure 5.2.1). Only 19% of rice is produced in dry season but those high productive provinces produce fairly good amount even in dry season (27-31% of total production) except Battambang (1%). Rice husk is assumed to be available all year around in most high productive provinces. Prey Veng and Takeo Provinces have also high production per capita basis (0.62 and 0.69 t). Svay Rieng, 6th productive province and produces 7% of national production, produced 0.59 ton per capita which is 4th highest in the country (Figure 5.2.1). It can be assumed that the area with high production per capita has better chance for excess rice husk. Generally wood is preferred to rice husk as domestic energy source. Where wood is sufficient it might have more excess rice husk available. Forest cover of top eleven high rice production provinces is below national average of 60% (DFW 2003). Prey Veng and Takeo, the highest two rice production provinces, are the least two forest cover area (2%) but Battambang (4th rice production) province is covered more than 45% by forest and presumed more wood materials are available for energy use.



Source: Agricultural Statistics 2003-2004, MAFF 2003
Notes: Bars indicate the annual production with left Y axe and the plots indicate yield in hectare base with right Y axe.

Figure 5.2.2 Annual Rice Production and Rice Yield per Unit Area in Cambodia

International Rice Research Institute reported that about 2.5 million hectare was planted to rice in the 1960s in the country. It declined remarkably during the long continued turbulent history. Both area rice planted and annual production have been dramatically increased in last 10 years (Figure 5.2.2). It is expected that rice production continue to increase through expanded area and technical improvement. As results, rice husk production is expected to be increase too. But rice husk is generally utilized well as the main energy source for household cooking and cottage industries such as brick factories. Using rice husk for generating power might affect seriously to energy supply of local communities. On the other hand, some researchers for rural development, agriculture and energy sector or NGO officers told us that there are some excess rice husk in some particular area. We visited a village where 14 rice mills standing nearby in Battambang Province. The village people said there are excess rice husk burned at the field and they want to use it to generate electricity. It is very important to conduct full research for current use of rice husk before introducing electricity generation system using rice husk. It is also worth to conduct survey of excess rice husk of provincial or country level.

The COGEN3 program which is funded by European Commission to promote the use of cogeneration in ASEAN countries has conducted a pre-investment study for a potential biomass-fired cogeneration project of 1.5MW electrical capacity at the Angkor Kasekam Roongroeung rice mill just outside Phnom Penh (Williamson 2004). But COGEN3 decided not to invest it at this stage (Williamson personal comm.). Currently there is no electricity generated using rice husk in Cambodia.

(2) Cashew Nuts Shell

The cashew *Anacardium occidentale* is a tree in the flowering plant family, Anacardiaceae. Cashew nut is the single seed of the cashew fruit. Cashew nuts trees have been planted 37,140 ha in Cambodia (MAFF 2004) and the number of grower is increasing. They are mainly planted in Kampong Cham province (17,136 ha, 46%), Rotanakiri province (6,505 ha, 18%) and Kampong Thom province (6,371 ha, 17%). Fruits are produced three years after planting. Full production is attained by 10th year and continues to bear about 30 years old. Farmers get R1,500 to 2,000/kg for their sun-dried fruits in Cambodia. Cashew nut shell represents 70% of the fruit total weight, while the remaining 30% is the nut itself. The High Heating Value (HHV) of cashew nut shell is 18.84 MJ/kg (Gaur & Reed 1995) and suitable for direct combustion for producing steam and generating power. The suitability for gasification is not known well. There is no statistical data for cashew nuts production. The average yield of other tropical countries is said to be 800-1,000 kg/ha. The production in Cambodia would be 14,000 t/yr if we apply this figure and nearly 10,000 t of shell is able to be produced annually. But currently most of sun-dried raw nuts are sent across to Vietnam in an informal border trade (Mathew 2003) for processing therefore actual cashew nut shell production would be much lower than the potential. The potential for generating electricity using cashew nuts shells is not high at the moment but installation of electricity generation unit using the shells should be considered when cashew nuts processing factory is planned to be built.

(3) Other Agricultural Residues

Bagasse is the residue of sugar processing from sugarcane. It represents 30% of total sugarcane weight and its HHV is 15.68 – 19.50 MJ/kg (Graboski & Bain 2002). Direct combustion power generating system has been widely introduced to the sugar processing factory in the major sugar production countries. Cambodia produced 330,649 t of sugarcane in 2003. There is no information about sugar processing factory. The possibility of installation of biomass electricity generation to the factories not only supplying electricity for the factory itself but also for surrounding villages should be assessed.

Coconut husks, cassava stems and mulberry stems were tested with the 9 kWe capacity gasification electricity generator at Centre for Livestock and Agriculture Development in Kandal province. Those agricultural residues were all suitable for gasification and their fuel efficiency was 1.3-1.5 kg/kW[25] (Phalla unpublished data). The production of cassava in 2003 was 330,649 t and the area of coconut farm was 27,054 ha. The productions of coconut and cassava residues are not known. The peanut production in 2003 was 18,483 t. Peanuts shells represent approximately 30% of the total weight of the peanuts. The HHV of shell is 18.84 MJ/kg (Gaur & Reed 1995). It can be used for electricity generation if there are

[25] Miech P. Adding value of edible fibrous biomass residues in ecosystem farm for socio-economical and environmental benefits. MSc dissertation. Swedish University of Agricultural Sciences. 2005. p.46.

large processing factories.

(4) Old Rubber Tree

There are about 40,000 ha of rubber plantation in Cambodia (JAFTA 1995) and 40,000 t of rubber block, also known as rubber resin crepe rubber, are annually produced, and almost all of them are exported to the countries such as Malaysia, Singapore, and Vietnam (Marubeni Corporation 2004). The rotation period, when the trees are cut down for replanting, is 25-30 years. This suggests that about 3-4% of the planting area is cleared annually and about 180 t of woody biomass are obtained per hectare (Prasertsan & Krukanont 2003). It is estimated that about 25,000 t old rubber trees are harvested annually in Cambodia. Those harvested rubber trees are said to be utilised well as the fuel for brick kilns and household. The excess wood availability is not known well.

(5) Woody Biomass from Forests

Cambodia's forest remains generally much better status compare to other Southeast Asian countries. However serious deforestation has been occurring last several decades. In 1960, forests covered 73% of the total land area of the country. It has been decreased to 58% in 1998 (MOE 2002). It is expected to be decreased further to 50–56% in 2010 (FAO 1997). The reduction has been attributed mainly to commercial logging and agricultural encroachment. The 95% of population is dependent on woodfuel for cooking (NIS 1999) and the biomass energy covered 86% of the total national energy supply (ADB 1996). The total fuel wood consumption was estimated about 6 million m^3, while log production estimated 1.5 million m^3 in 1995 (World Bank and others 1995). Cambodia's population is increasing rapidly. The annual growth rate is 2.5% (MOE 2002). The fuel wood consumption in 2010 is estimated 40% more to 1995 level (ADB 1996). It is concerned that vast fuel wood consumption might cause further forest destruction. Top et al. (2004) reported that fuel wood consumption to forest biomass increment was only 0.02 in Kampong Thom province and concluded that fuel wood consumption does not cause deforestation. But fuel wood consumption might cause degradation of forest near villages where most fuel wood collection is concentrated. The degradation of high diverse Cambodian forests is the international concern. The increase of flooding in recent years also arrests people's attention to forest conservation. The fuel wood for biomass electricity generation has to be supplied only from the forest under sustainable management to avoid causing any natural forest degradation. Plantations, tree farming and community forests are the ideal fuel wood resources for biomass power generation.

(6) Plantations

There are total 11,125 ha of forest plantations mainly with *Acacia spp*. and *Eucalyptus spp*. in Cambodia (DFW 2003). The purpose of plantation of most case is production of wood chip materials for export. The selling price for woodchip companies is about $23/t according to DFW. If the plantation wood is supplied for biomass power generation with the same price, the cost is estimated $0.03/kWh and this is about one fourth of the fuel cost of diesel power generation, $0.12/kWh. We have observed the operation of Mear Nork plantation (Figure 5.2.3) in January 2005. The thinned stems and branches were brought to the road and burnt for prevention from forest fire (Figure 5.2.4). Those woody residues are perfectly suitable for electricity generation.

There are about 2.5 million ha of grassland and scattered trees area in Cambodia (JAFTA 1995). There are still lots of land available for forest plantations. Using woody biomass of forest plantations has high potential not only for rural electrification but also for main grid electricity supply.

Source: JICA Study Team
Notes: Both stand are similar size of about 7 m in height by sight observation.

Figure 5.2.3 *Acacia* sp. (front) and *Eucalyptus camadulensis* 3.5 year old stand at Mear Nork forest plantation in Kampong Chhnang Province.

Source: JICA Study Team

Figure 5.2.4 Thinned waste woods were carried to road then burnt for preventing from forest fire at Mear Nork forest plantation in Kampong Chhnang Province.

(7) Tree Farming

Tree farming of fast growing species is an appropriate method of supplying biomass for village level electrification. Anlong Ta Mei Community Energy Cooperative in Battambang province, the only biomass electricity generation operating in practical manner in Cambodia uses tree farming system for fuel supply (details are described in Chapter 3.7.3). We roughly estimated that 2.5 ha of tree farming is sufficient to supply the average size (140 households) rural villages (estimated using following assumptions; 10 kWh/HH/month and 10 t/ha biomass productivity). The area can be fragmented. Trees can be planted on roadside, at garden edges, in fallow land, with cash crops as agroforestry or any land not suitable for agriculture such as steep slopes. Some legume species such as *Cassia* spp., *Gliricidia* spp.

and *Leucaena* spp. are nitrogen fixing trees. They can grow well on the nutrient poor soils and prevent from soil degradation. The two to three centimetre diameter of stems and branches are big enough to be used as fuel therefore harvesting can be started only one year after planting. They are also called multipurpose tree species. Their foliages, flowers, fruits and seeds are often very good source for fertilizers, multi, stock feed and even tasty nutrient rich food for human. Village people are benefited not only biomass fuel but also many other aspects from growing these trees.

(8) Community Forestry

Community forestry (CF) is recognized as an important strategy to manage the forest at sustainable manner in Cambodia. The majority case of CF activity is managing existing primary or degraded forest rather than reforestation by planting. They are organized by the government (MOE for conservation area and DFW for production area) or NGOs. The methodology varies a lot depending on the forest status and social environment. Some are only zoning forest for human activities such as fuel wood collection and timber harvesting. Some carries out forest management practice such as thinning, weeding and enrichment planting. A technical advisor of Concern Worldwide (NGO) told us that they carried out thinning at one of their CF site and they harvested 60 ox cart, 12 t fresh weight (6-8 t for dry) woody biomass waste from 1 ha. Village people refuse to conduct further thinning practice after some hectare of operation because they cannot utilise so much of wood. Such excess wood residues of forest management practice can be used for electricity generation.

5.2.2 Current Biomass Electrification used in Cambodia

There are only three biomass fuelled electricity generation facilities in Cambodia. Two of them are introduced mainly for research purposes and only one system is operating for practical use. The details are described below.

(1) Centre for Livestock and Agriculture Development (CelAgrid)

CelAgrid is the institute conducting various research on rural development mainly based on agricultural technologies. There are 17 academic staff and 40 students working in the institute. They purchased a 9 kWe (gross) biomass gasification electricity generation system from Ankur Scientific (India) in September 2004 (Figure 5.2.5). Mr. M. Phalla is currently conducting a research on comparing different biomass such as coconut husk, cassava stem, mulberry stem and Cassia tree for suitability and efficiency for gasification.

Source: JICA Study Team
Notes: The orange body at the back is the gasifier and the front green part is the generator unit.

Figure 5.2.5 The 9 kWe Woody Biomass Gasifier Installed to Centre for Livestock and Agriculture Development

(2) Anlong Ta Mei Community Energy Project

Anlong Ta Mei village (Bannan District, Battambang Province) community energy cooperative project is the only biomass electricity supply system operated profitable base rather than research. The project introduced a 9 kWe biomass gasification electricity generation system (same model as CelAgrid) and set up a mini grid. They use planted *Leucaena* branches for the fuel. They started the operation in February 2005 and currently supplying electricity to 70 households for 7 hours (4:30-11:30 pm) a day. The details of the project are described in Chapter 3.7.3.

(3) NEDO SV and Biogas Hybrid Power Generation Project

In December 2003, Japan's NEDO completed the construction of a hybrid electricity generation system consist of a solar photovoltaic (50 kW) and 2 x 35kWe duel fuel biogas engine near Sihanoukville. The biogas is extracted from cattle excrements from a farm. The system is currently operating but the project is considered to be mainly a demonstration and research venture and would not economically viable yet.

5.3 SOLAR POWER

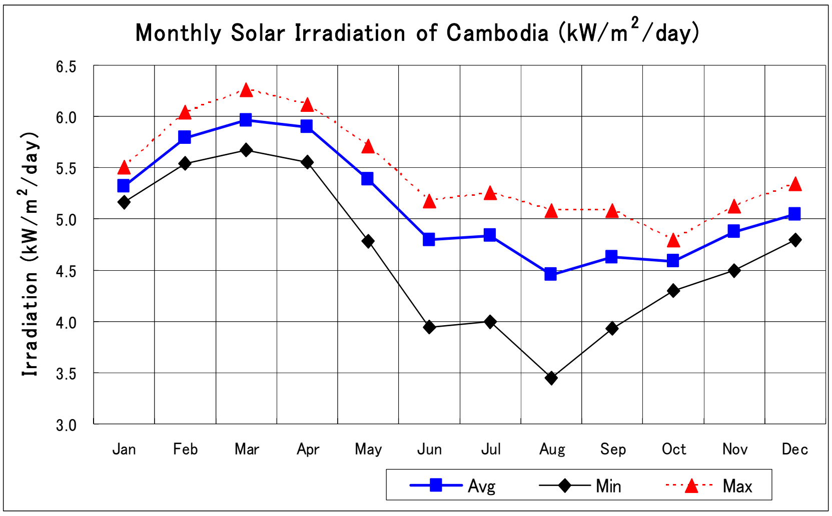
In remote areas that are sparsely populated it would take a significant time and capital investment to realize electrification by grid extension, which will require a long distance of transmission lines and significant capital investment. In such areas, renewable energy resources can be the best option since these do not need long distance of transmission and distribution lines from grids and can be of small scale fitting the scale of local villages. Among the renewable energy resources, solar energy can be the best option to RE of those small villages scattered in wide areas for its following features:

- high solar irradiation almost uniformly available throughout the country;
- unit size of solar power system is flexible to match the demand from one household (SHS) to 100 households (through BCS) or even greater
- design, installation and O&M can be standardized since solar is not site specific
- O&M can be undertake by villagers if initial training and periodical monitoring are secured; and
- No equipment replacement will be required for 10-20 years.

5.3.1 Solar Irradiation

In Cambodia there are a few stations observing surface solar irradiation. These stations were installed under the research demonstration project by NEDO, Japan in cooperation with MIME. The project was implemented a few years ago but data has not yet been published to date. Though the surface data are site specific, it is useful for calibration of the satellite irradiation data that covers the whole country.

Since there is no surface irradiation data available to the Study Team, satellite data have been collected to grasp the potential of solar energy over the whole country. The data were downloaded from NASA home page (http://eosweb.larc.nasa.gov). The satellite data on annual average solar irradiation were collected for 10 years and are summarized in **Appendix B**. The annual average irradiation is 4.7 kWh/m^2/day in the lowest area, 5.3 kWh/m^2/day in the highest area, and 5.1 kWh/m^2/day is an average over the country.

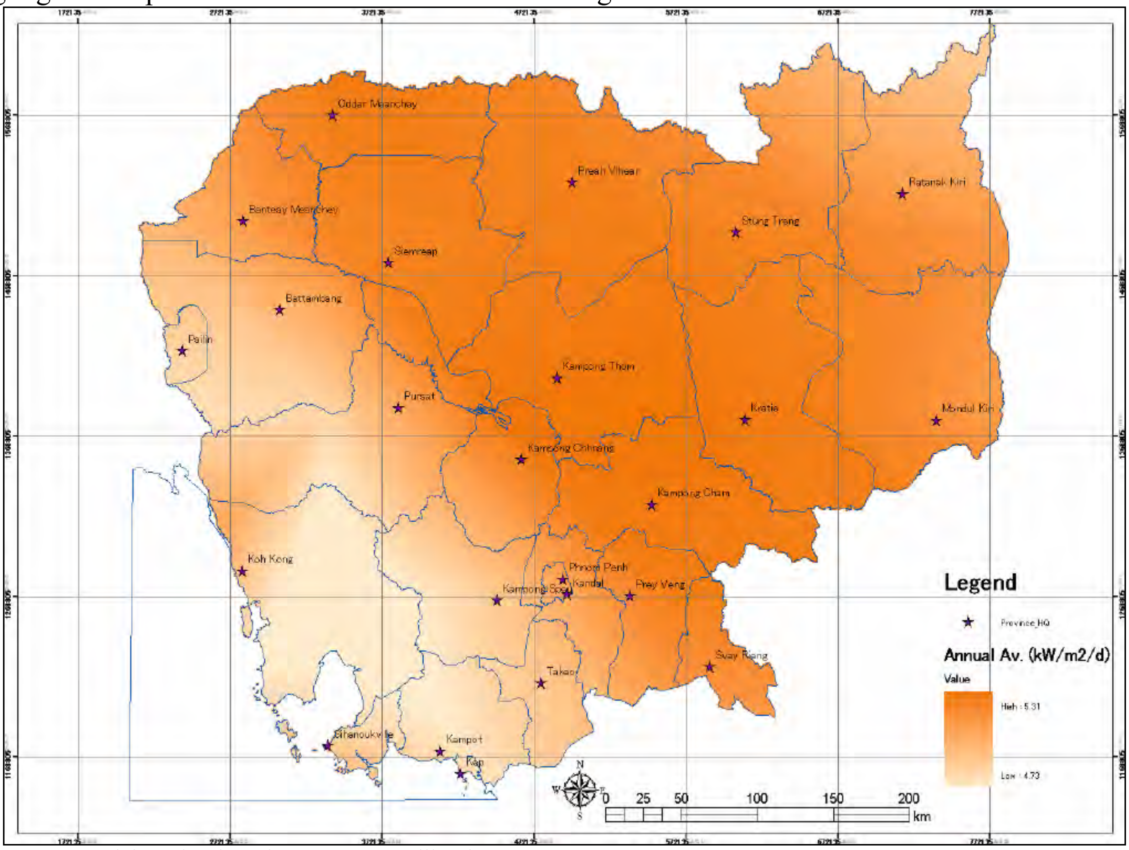


Source: JICA Study Team (based on NASA data, http://eosweb.larc.nasa.gov)

Figure 5.3.1 Monthly Avg., Min. & Max. Irradiation

Figure 5.3.1 represents the monthly average, minimum and maximum solar irradiation. The maximum irradiation is higher than 6.0kWh/m^2/day in March and the minimum is lower than 3.5kWh/m^2/day in August. The difference between the maximum and minimum is also high in August.

Figure 5.3.2 represents spatial distribution of the solar irradiation based on the 10 years annual average satellite data. The south and southwestern region has the lowest irradiation and it increases gradually towards central region being the highest. It decreases slightly towards the east and northeast region but being higher compared to the south and southwestern region.



Source: Team elaboration based on NASA satellite data.

Figure 5.3.2 Annual Average Solar Irradiation

5.3.2 Photovoltaic (PV) Systems in Cambodia

According to the record of MIME, as of Dec. 2003 more than 204 kWp of PV modules have been installed in the country. These systems are mainly to supply power for household lighting and small electric equipment of public facilities, and power for telecommunications facilities too. The source of budget for these PV systems has been from RGC, NGO's, telecommunication companies or through donation and demonstration research project. Unfortunately there is no detailed information available on private installations. It is not known whether these systems are functioning properly or not. Figure 5.3.3 shows a few large system which was installed under the research demonstration project, NEDO, Japan. Figure 5.3.4 shows medium and small scale PV systems installed by telecommunications companies at repeater stations. As there is no standard parameter to deign the system, the most of the existing systems were deigned by aiding agencies or system suppliers.

(a) Large scale PV (50 kWp) & biogas hybrid system (b) Large scale PV (30 kWp) & MH hybrid system

Figure 5.3.3 Research Demonstration Projects between NEDO & MIME

(a) Medium scale PV system at telecom center (b) Small scale PV system at repeater station

Figure 5.3.4 PV Systems for Telecommunications Systems

There are some private companies like 'Solar Power Co., Ltd.', 'Khmer Solar' and so on. These provide services commercially within the country. These companies import PV module and related components in accordance with order from individual users, NGO's and government announced tenders as well. There have been some experiences on PV system installation and utilization within the country.

5.3.3 Type of Photovoltaic (PV) Power Generation Systems

Cambodia targets 100% in village electrification level by 2020. Solar energy will be one of the options for those areas where electrification by grid extension or other renewable energy resources is difficult. MIME considers rural electrification contributes to alleviating the regional economic disparities and population concentration to urban areas through fostering the local economy. Before deciding type of systems to be applied to certain village, basic data are to be clarified such as solar irradiation potential, number of households to be covered, unit demand per household, ability-to-pay and so on. Because of large capacity battery requirement and capital costs, it is not recommendable that solar power be used for 3 phase power supply, nor for mini grids of single phase in the off-grid area. Solar Home Systems (SHS) have been installed by some private entrepreneurs on commercial basis. Systems were installed in those households who can afford to buy SHS. SHS has been benefited only by small numbers of well-off households. From the past experience of SHS installation around the world, replacement of storage battery is the greatest burden to the people. Because of this burden, a great number of SHSs were abandoned. Therefore, PV mini grid and SHS are excluded from the further study for rural electrification, except for encouragement of SHS to those who are affordable to buy. The systems to be targeted by solar energy are as follows:

(i) Solar BCS
(ii) SHS type installations at public facilities with option for BCS function
(iii) Hybrid system

(1) Solar BCS

In Cambodia BCS by diesel generator has been in wide use. Local people have been familiar with it. In most of the existing diesel BCS, batteries are connected charging in series to adapt the output voltage of DG generator. On other hand village people are using battery until it is fully discharged. There is no over discharge indicator at individual households. It is necessary to inform about how to handle their battery to maintain the good condition for long life and to save money for charging too.

Realizing that the Solar BCS can power small equipment and lighting systems in remote areas. And again instead of using diesel BCS or installation of new solar BCS will help mitigate increasing rate of fuel import. A better charging system is introduced in the country, which contributes to keep battery in better conditions or expanding the lifetime of battery. Solar BCS is suitable to those areas where other renewable energy resources are scarce and village size is smaller. Table 5.3.1 summarizes the parameters for system sizing to establish SBCS.

Table 5.3.1 Design Parameters of Solar BCS for Remote Electrification

Item	Parameter	Value	Unit	Remark
1	Horizontal solar irradiation	5.1	kWh/day	Country average (from satellite data)
2	Module derating factor	10	%	Decrease of output due to dirt, years of uses and so on.
3	Columbic efficiency	90	%	To charge battery effectively.
4	Charge controller (C/C) consumption	10	mA/day	Depends on manufacturer
5	Depth of discharge (DOD) of battery	50	%	Manufacturers recommendation for shallow cycle lead acid batteries
6	Charging interval of each battery	5	days	To control deep discharge manually
7	Required Voltage output from charge controller (C/C)	13.5 and above	V	To charge battery effectively
8	C/C capacity	10	Amp	To charge battery effectively
9	Capacity of battery to be charged	50, 70 & 100	Ah	Capacity of batteries used at present

Source: JICA Study Team

In designing solar BCS, a number of batteries to be charged a day should decided first. The capacity of solar BCS is divided into four groups to be applicable to various household numbers to be covered. The numbers of households to be covered and system capacity is summarized in Table 5.3.2. The system capacity is determined on the basis of parameters shown in the table. The number of batteries by capacity to be charged is assumed on the basis of site observations at existing diesel BCS. Detailed system sizing is given in Appendix B.

Table 5.3.2 Number of Households and Capacity of Standard BCS

Group	Numbers of HH to be covered	Percentage (%) of battery to be charged by the system			Nos. of batteries to be charged each day	System Capacity	
		50 Ah	70 Ah	100 Ah		Value	Unit
1	Up to 25	30	50	20	5	1	kWp
2	From 26 to 50				10	2	
3	From 51 to 75				15	3	
4	From 76 to 100				20	4	

Source: JICA Study Team

If a village has more than 100 households to be covered, then the system may be designed as a combination of above mentioned four types. In deriving the system capacity above, the following conditions are assumed;

- Current output of single PV module is calculated on the basis of 3.0 Imp.
- Required capacity is rounded up (this would contribute to minimizing the capacity shortage in the low irradiation area and month.
- PV system voltage is selected to charge the battery even at higher ambient temperature (35^{o} Celsius) and charge controllers to supply 13.5 V for effective charging.
- Grouping of PV modules is required to provide enough current to charge battery within a day.

(2) SHS type installations at public facilities with option for BCS function

The idea of this system is to install a solar system at public facilities such as health center/unit, community center and night school. An option to add extra capacity on the same system, battery charging function can also be attached to system depending on the charging demand around the public facility. Villagers can charge their own batteries paying charging fees. The collected revenue can be used for system operation and maintenance. It is recommended that the system be deigned with deep cycle battery which has better performance and long life. Design parameters are given in Table 5.3.3:

Table 5.3.3 Deign Parameters of PV System for Social Electrification

Item No.	Parameter	Value	Unit	Remarks
1	Horizontal solar irradiation	5.1	kWh/day	Country average (from satellite data)
2	Module derating factor	10	%	Decrease of output
3	Columbic efficiency	90	%	To charge battery effectively
4	Depth of discharge (DOD) of battery	80	%	For deep cycle batteries
5	Days of autonomy (no sunny days)	3	days	Reservation for no sunny days
6	Charging interval for public	5	days	To control the deep discharge
7	Required voltage output from C/C	13.5	V	Minimum voltage to charge battery effectively
8	DC system voltage	12	V	Voltage required for charging option

Source: JICA Study Team

To decide the system capacity, the other parameters such as hours of uses, size of charge controller, requirement of inverter are also needed, which will directly influence the capacity of storage battery. The days of electricity supply without solar charging is determined based on the satellite data on no sunny day. The country average no sunny days 2.9 is rounded up to 3 days. For the regions where no sun day is more than 3 days, than it may need adjustment at the time of system deign depending on the criticalness such as power supply for health center. Detailed data of no sun days are given in Appendix B.

(3) Hybrid System

In Cambodia domestic electricity demand is high in the early morning and evening and very low during daytime. Therefore, solar BCS will not be adequate for 24 hour power supply. In those cases where river flow of micro hydro dries up in the dry season or fuel supply of biomass power becomes scare (like rice husk just before harvesting months), then PV hybrid system could be an option for consideration. PV system can support the main system during the daytime in particular without expensive storage battery. For such hybrid system, the main system should first be designed so that storage battery can be designed at the minimum required capacity or only for power switching process be needed, which would help to reduce the overall system cost. The PV system can hybrid with micro hydro, biomass power or also with diesel power system.

However, as mentioned in Section 5.3.3, those other than hybrid with wind power will not be discussed in this MP because they supply DC power.

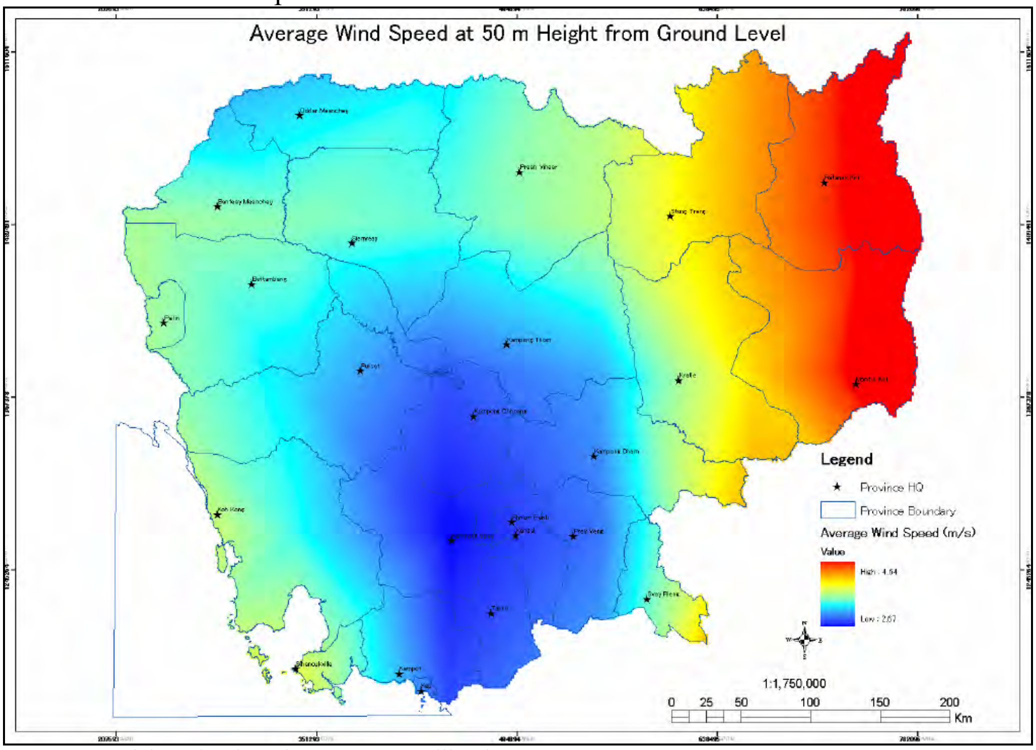
5.4 WIND POWER

Wind power resources are also one of the options for rural electrification in those areas where wind potential is high. Around the world wind power generations are adopted in those areas where wind speed prevails at 7 m/s or higher. Most of the cases wind potential is high around costal and mountainous area. A high potential site situated nearby villages can be a candidate for rural electrification. A large wind system can be built only to feed grid and is not suitable for rural electrification in the off-grid area. The wind power system is very site specific like micro hydro. Unit cost of small wind turbines is much higher than that of large one.

5.4.1 Wind Potential

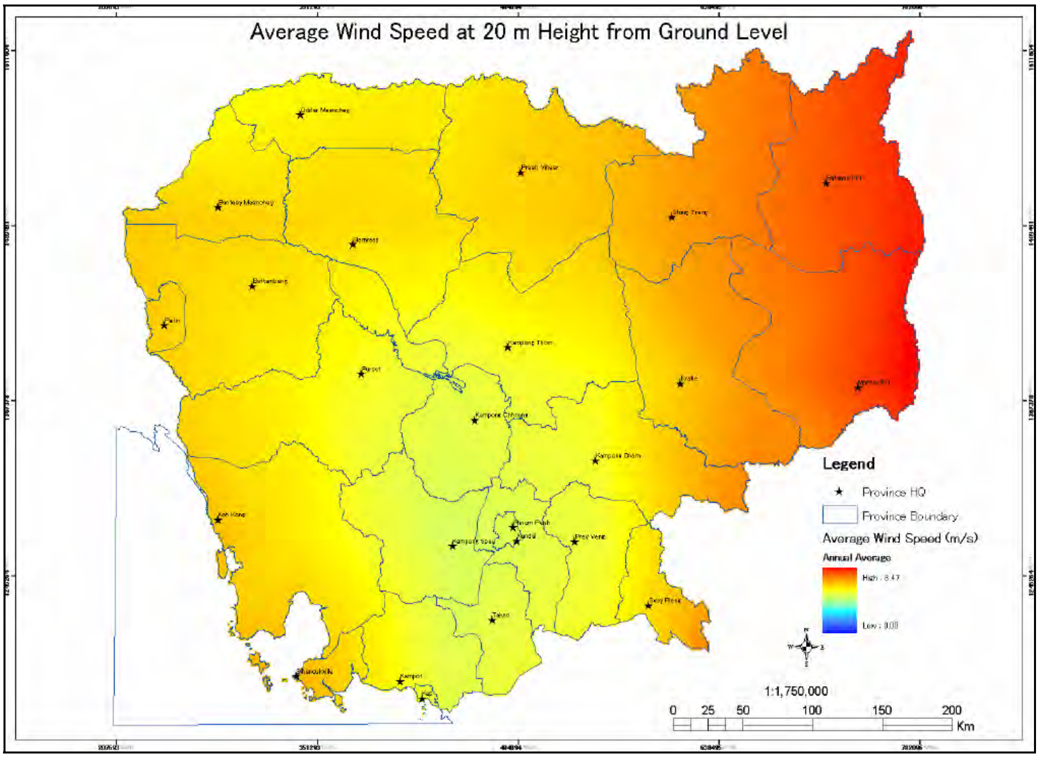
Like solar irradiation, there are only a few observation stations of wind power in Cambodia. This is under research demonstration project, NEDO. Together with a power generation system a wind data measurement instrument was also installed. At Sihanouk Ville NEDO installed it on roof of a water treatment center building and port authority installed at telecom tower above 30 m from ground level but data is not yet available. Therefore, for the Master Plan study satellite data were used to evaluate the wind potential over the whole country. These data are also downloaded from NASA home page. The detailed satellite data for 10 years on annual average wind speed at 50 m and 20 m above ground level is summarized in **Appendix B**. The country annual average wind speed at 50 m is around 3.5 m/sec and at 20 m is around 2.6 m/sec. When these wind data is converted to that at required lower height, wind speed varies depending upon vegetation type over ground surface. Figure 5.4.1 summarizes average wind speed at 50 m. The wind speed is higher towards the eastern and southern regions and the maximum is around 4.6 m/sec on an annual average. Figure 5.4.2 summarizes average wind speed at 20 m. It is high towards the eastern region and the maximum is 3.4 m/sec. According to a report ‘WIND ENERGY RESOURCES

ATLAS OF SOUTHEAST ASIA' prepared for 'The World Bank Asia Alternative Energy Program', at 35 m above ground level the wind speed is high at costal and mountainous area but there is not much wind potential in Cambodia comparing to the other neighboring countries. There may be some specific sites, often called local wind corridor, where high speed wind locally prevails. Such sites need detailed site assessment to evaluate the local potential.



Source: Team elaboration based on NASA satellite data.

Figure 5.4.1 Annual Average Wind Speed at 50 m from Ground Level



Source: Team elaboration based on NASA satellite data.

Figure 5.4.2 Annual Average Wind Speed at 20 m from Ground Level

5.4.2 Wind Power Generation Systems

There is one small few hundred Watts wind turbine installed in cooperation with NEDO (Bangkok) as a hybrid system in Kampot province. Unfortunately it is not working at present. The wind turbine stopped operation few months after the installation. The cause of damage is not known. There is no information on any other wind power installations by NGO's or private sector.

As this Master Plan covers only the off-grid areas, large scale wind power feeding grids is out of scope. Due to lack of surface wind data except for satellite data, it is difficult to identify local potential sites and plan small scale wind power system. Wind power system requires a large capacity of storage battery, which will increase the unit energy cost. Therefore, wind power will be excluded from Master Plan apart from some of those located in a wind corridor. Since the Master Plan covers only the off-grid areas, medium to large scale wind power generation system may be dealt with separately as part of the renewable energy policy in conjunction with the grid generation plan. Windmills are suitable for water pumping for irrigation, livestock, and domestic water supply.