Volume 2 Master Plan

Part 1	Baseline Study
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THE MASTER PLAN STUDY
ON
RURAL ELECTRIFICATION BY RENEWABLE ENERGY
IN THE KINGDOM OF CAMBODIA

FINAL REPORT
VOLUME 2 : MASTER PLAN

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1. DEVELOPMENT STRATEGY

1.1 POLICY TARGETS OF RURAL ELECTRIFICATION

1.1.1 Goals and Policy Targets of the Rural Electrification Sector

The ultimate goal of the rural electrification (RE) sector is to achieve, as stated in a Rural Renewable Electricity Policy 1) to reduce poverty level, 2) to improve the living standard, and 3) to foster rural economic development. As a step towards the goal, the targets of rural electrification are set out by MIME and adopted in the Master Plan as follows:

1) To achieve 100% level of village electrification, including battery lighting by year 2020

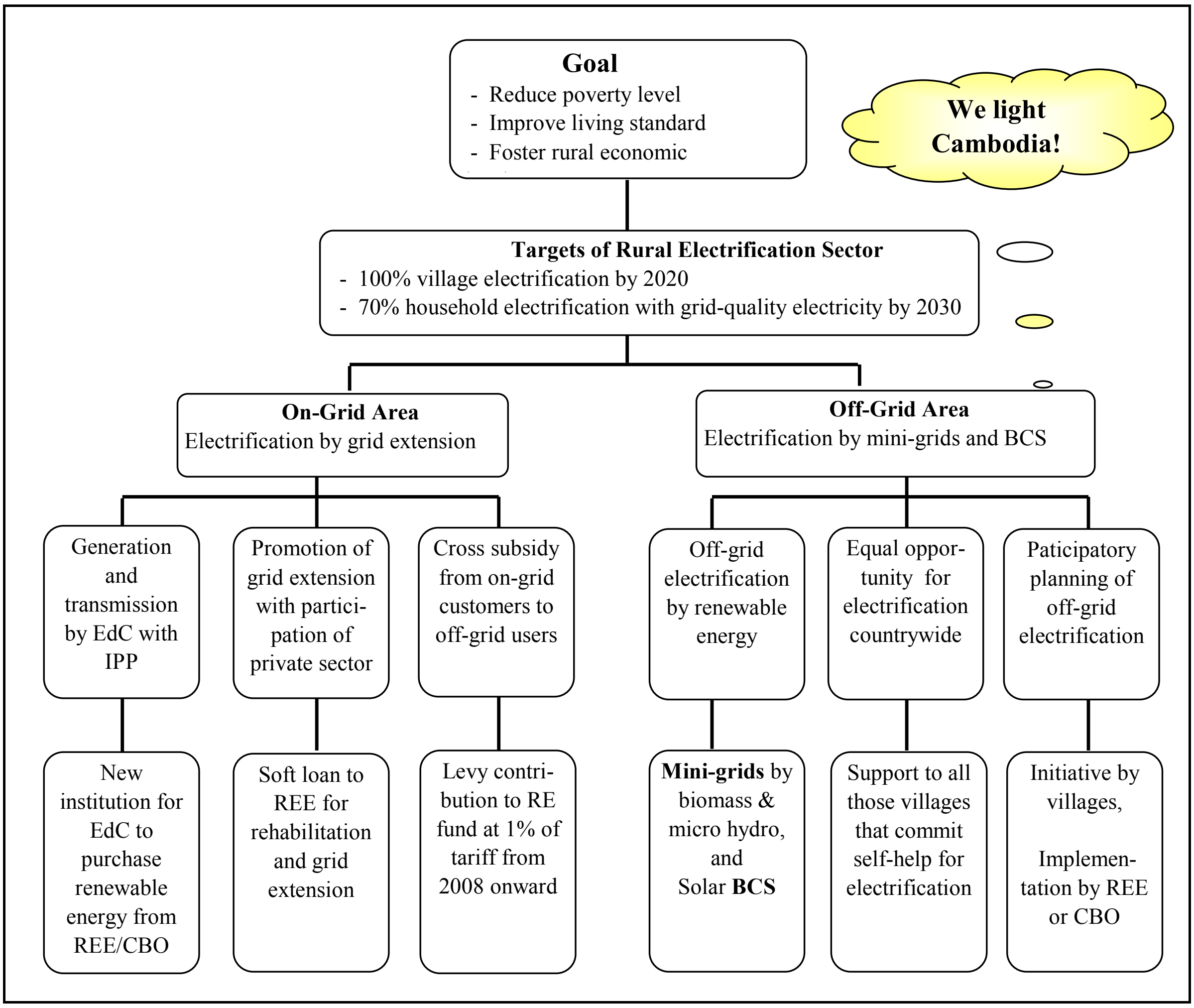
2) To achieve 70% level of household electrification with grid quality electricity by year 2030

To achieve the policy targets above, the rural electrification in Cambodia will be implemented with a strategic framework as shown in Figure 1.1.1. The rural electrification will be implemented by two ways; 1) electrification by grid extension in the on-grid area, and 2) electrification by mini-grids and BCS in the off-grid area.

The on-grid electrification will be led by EdC through extension of the national grid. It shall be noted that EdC will offer wholesale services of stable and inexpensive electricity to the mini-grids managed by the private sector, however, that it will be allowed to run power distribution businesses only within the areas of its license approved by EAC. Therefore, the promotion of rural electrification by grid extension will be accomplished by active implementation and management of sub-grids connected to the national grid by the private sector. Customers connected to and serviced by the national grid can benefit from the low cost and quality electrification of the national grid and, therefore, are required to contribute to a fund for supporting the costly off-grid electrification.

The off-grid electrification will be implemented with *Renewable Energy*, *Equal Opportunity* to all the villages, and *Villagers' Initiative*. The electrification will be by isolated mini-grids powered by biomass and micro hydro as well as by solar BCS[1]. A high priority in financial support will be given to those electrification schemes that are planned and proposed by villagers in accordance with a supporting system designed and proposed in the Master Plan. Such electrification schemes will be implemented either by villagers themselves (CECs) or private businesses (REEs).

[1] Wind power BCS is considered when wind potential is high due to local wind corridor.



Source: JICA Study Team

Figure 1.1.1 Goals, Targets, Effects and Actions of Rural electrification Sector

1.1.2 Rural Electrification by EdC Grid

(1) Features of Power Sector in Cambodia

In most of the Southeast Asian countries, the power sector is managed by separating into three functions; generation, transmission, and distribution. A state-owned national power utility is given a monopoly with concession countrywide or region-wide. Privatization of the power sector has been in progress. However, in many countries a distribution company, whose facilities and services are directly connected to customers, is given a regional monopoly. The monopoly is given because of such nature of distribution services as distribution networks are an immovable infrastructure established in the region and its alternative cannot be built without duplication in investment. In barter of the regional monopoly, such distribution service provider is mostly required to supply power to any users inside the monopoly region who wish to have services, as his duty. In other words, a duty of rural electrification is imposed on and undertaken by a distributor.

Power tariff is, in most cases, subject to approval by a government. Such power tariff and subsidy system is employed that mitigate financial burden on the distributor resulting from the duty of rural electrification. A subsidy policy employs, in many countries, a mutual loss covering system as part of the power tariff structure, that is, cross subsidy. The power tariff structure of EdC also includes such cross subsidy. However, it is not for rural electrification but to help urban residents with low income have electricity, as a policy of RGC. (Actually, these poor households consume the least energy per customer and, therefore, unit cost for supply is the highest among the various customers of EdC.)

In rural areas, ability to pay for electricity is in general low and consumption per customer is also low (typically 7-10 kWh per month in rural area of Cambodia and 50 kWh in urban area). Connection and supply to such low consumption customers for promoting rural electrification will also need expenditures for tariff collection and maintenance of distribution facilities that can exceed the tariff revenue from such customers. This will be a financial burden to a distributor.

In Cambodia EdC was, once in the past, given a monopoly over the whole country. However, its power supply has been limited to Phnom Penh and some provincial capitals due to power facilities and financial resources available for EdC. Power supply in the other areas has been provided by DIME and private sector (REE, etc).

Upon promulgation of the Electricity Law in 2001, a privatization policy of the power sector has been clearly established. Any person can now participate in electricity supply business in Cambodia. This is a policy unique to Cambodia and clearly different from neighboring countries. The policy is introduced for achieving the policy targets of rural electrification. The policy would facilitate substantial achievement in the rural electrification by extension of the EdC grid including sub-grids, subject to implementation measures of the policy.

Another important driving factor of the rural electrification in Cambodia is in a fact that more than 80% of the population are living close to the 24 provincial capitals within a circle of 40 km in radius. This high concentration of the population contributes to achieving a high investment efficiency, compared to the neighboring countries, in extension of the national grid for rural electrification.

After privatization of the power sector, many Rural Electricity Enterprises (REE) have participated in the market in Cambodia. However, except for those mini-grids that import electricity from neighboring countries, most of the REEs' mini-grids use second hand or over-aged small diesel generators. This, combined with low utilized capacity and energy consumption limited to lighting and TV, makes unit generation cost high and results in the very high tariff of $0.30-0.90/kWh in the rural areas of Cambodia.

(2) Electrification by Extension of the National Grid

MIME established a policy target to electrify 70% of in households with grid-quality electricity (equivalent to that of the national grid) by year 2030. An average annual growth rate of the number of electrified households required to achieve this target was derived based on the actual level as of the end of 2004 as shown below:

Table 1.1.1 Annual Growth Rate Required to Achieve RE Target

Power Provider Group	Level of Household Electrification (%)			Average Annual Increasing Rate (%)	
	2004	2020	2030	(1)	(2)
1. EdC only	8.4	31.0	70	8.4	10.6
2. EdC + Licensed REE	10.8	34.1		7.5	9.6
3. EdC + Licensed REE + Others	18.5	41.9		5.3	7.4

Note: (1) Annual increasing rate of electrified households based on the population growth rate of 0%
(2) Annual increasing rate of electrified households based on the population growth rate of 2%
Source: JICA Study Team

In the past 6 years the average annual growth rate of the number of electrified households in the EdC supply area was 15.0%. This figure includes such growth as resulting from expansion of the supply area of EdC by taking over some mini-grids from DIME and REE. If it is limited only to the then supply area of EdC in 1999, the average growth rate of the number of electrified households was 11.4%.

The rates of increase (7.4-10.6%) of electrified households required to achieve the target level of 70% by 2030 are lower than the EdC record of 11.4%. At a first glance, it seems possible to achieve the target level of 70% by 2030 even without new policy measures. However, the present supply area of EdC is limited only to densely populated urban areas. Significant fund inputs have been mobilized in generation expansion and improvement and extension of the EdC grid. The past high increasing rate of 11.4% was resulted from these efforts. This suggests that the similar efforts will be required to promote electrification in the rural areas nationwide.

Principal parts of such efforts will be extension of 115 kV and 230 kV transmission network and extension of MV lines to outside the EdC supply area (to supply low cost energy to existing mini-grids that are suffering from high generation costs). If these extension works are implemented properly, it would be possible to achieve the target level of 70% even by the grid extension alone.

1.1.3 Rural Electrification by Rural Electricity Enterprises

The rural electrification will be promoted with participation of private sector (REE). This policy aims at:

1) Mobilization of resources of the private sector such as capital, human resources, know-how, and efficiency, in the rural electrification both in the on-grid and off-grid areas;

2) Promotion of rural electrification by mini-grids and BCS in the off-grid areas;

3) Contribution of the private sector participation to the small government policy, that is, let the private sector do what the private sector can do.

To further invite private investors into the rural electrification sector, a supporting system will be provided by the Royal Government of Cambodia (RGC).

To complement the rural electrification by the private sector, another mode of implementation with villagers' initiative (community-based organization, CEC) will be encouraged. It is only CEC who can implement and manage mini-grids and BCS in remote and small villages that cannot be electrified by the private (REE) interests. The essence of CEC model is to achieve the possible lowest power tariff through contribution of equity, labor forces as in-kind equity, etc. However, it could lead to a disaster if implemented without proper planning and guidance. A support system is designed and proposed to provide *Equal Opportunity* also to such villages.

1.1.4 Rural Electrification by Renewable Energy

The final stage of the electrification is to connect most of the households located inside PAGE (Potential Area of Grid Extension, areas encircled with a radius 40 km centering at each provincial capital) to and supply electricity through the national grid. This is to supply the low cost and quality energy available in the national grid, benefiting from the scale merits both in the scale of generating equipment and load pattern (daytime demand existing in a large grid). However, rural electrification, if it depends only on the grid extension, will inevitably incur such issue that the electrification can be progressed only step by step from urban towards rural, or in other words:

1) expansion of power supply capacity to the national grid by construction of HV lines to import low cost electricity from Vietnam, Thai, and Lao (planned for completion in 2007);
2) extension of HV transmission lines countrywide and construction of grid substation in each provincial capital;
3) extension of 22 kV lines along major roads from the grid substation within PAGE (this would be implemented in 2-3 stages grouping into primary area, secondary area, and complementary area);
4) electrification of households along the 22 kV lines (within 1 km from each line on both sides) by extending LV distribution lines by REE or CEC.

The rural electrification by the nationwide grid extension will need to wait for the reach of the 22 kV lines to villages. This means that those villages outside PAGE will not have an opportunity for the national grid extension unless transmission lines are extended to those areas. In addition, villages inside PAGE but away from the 22 kV distribution lines by more than 1 km will need additional extension of 22 kV lines.

This is the background of the present Master Plan Study for electrification of the off-grid areas in Cambodia. Any village in Cambodia, irrespective of its relative location to the provincial capital or the national grid, can be electrified by installing mini-grids or BCS. This is to provide *Equal Opportunity* for electrification to all the villages in Cambodia.

In addition, it is recommended that such mini-grids and BCS be powered by renewable energy. The renewable energy has the following advantages:

1) Energy cost is free or very low that contributes to securing sustainability of operation and management.
2) Medium to long-term average costs are lower than that of diesel power particularly as the utility capacity increases (owing to no or low fuel costs). This contribute to lowering the tariff level of mini-grids to some extent ($0.35/kWh).
3) It is locally available, clean, renewable, and can control an increase of fuel import related to the improvement of the electrification level. Money for fuel costs, if paid to tree growers in the case of biomass power, will remain in commune and can have secondary effect to stimulate the commune economy.
4) As a whole, it can contribute to saving oil import of Cambodia as well as to controlling the increase rate of CO_2 emission.

On the other hand, the renewable energy requires high initial capital cost compared to conventional diesel power. In Cambodia, a commercial bank loan system is not practically functioning and not available for most of REEs. Therefore, financial support to the private sector is essential to promote capital intensive but economic projects, that is, off-grid electrification by renewable energy.

In addition installation of solar powered BCS in non-electrified remote villages is recommended. This aims at poverty reduction by providing the minimum home lighting for children to read a book. This is also an effective tool to certainly achieve another policy target of 100% level of village electrification by 2020. To promote the village electrification, it is proposed that solar BCS will be provided and leased in non-electrified villages under a full subsidy program as *Social Electrification*.

1.2 GRID EXTENSION PROGRAM AND TARGET AREA OF MASTER PLAN

1.2.1 Definition of Transmission Grid and its Target Areas

The grid extension in the country were clearly defined in the “Regulatory Treatment of Extension and Distribution Grid in Cambodia” approved by Session No. 27 of EAC dated 28 October 2003.

The power supply system is divided into three categories by voltage level, i.e. HV system with 115 kV and higher voltage, MV system (22 kV) and LV system (400/230 V). These are further divided into the transmission system and distribution system from the viewpoint of their use and purpose.

Transmission facilities are defined as the ones used for transferring and delivering or selling the electricity to distribution licensees and bulk customers. All the HV facilities including lines and substations are treated as part of the transmission system. A licensee, who owns and operates HV facilities, will need a Transmission License. As for the MV system including distribution transformers, it is further divided into two categories: 1) all the MV facilities of a licensee, used for supplying electric power to its customers in its supply area, are treated as part of the distribution system; and 2) MV lines of a licensee including transformers, but located in the supply area of the other distribution licensees and used to supply power to the other licensees, are treated as part of the transmission system. The later transmission system is called either “sub-transmission system” or “interim transmission system” and shall be operated under a transmission license.

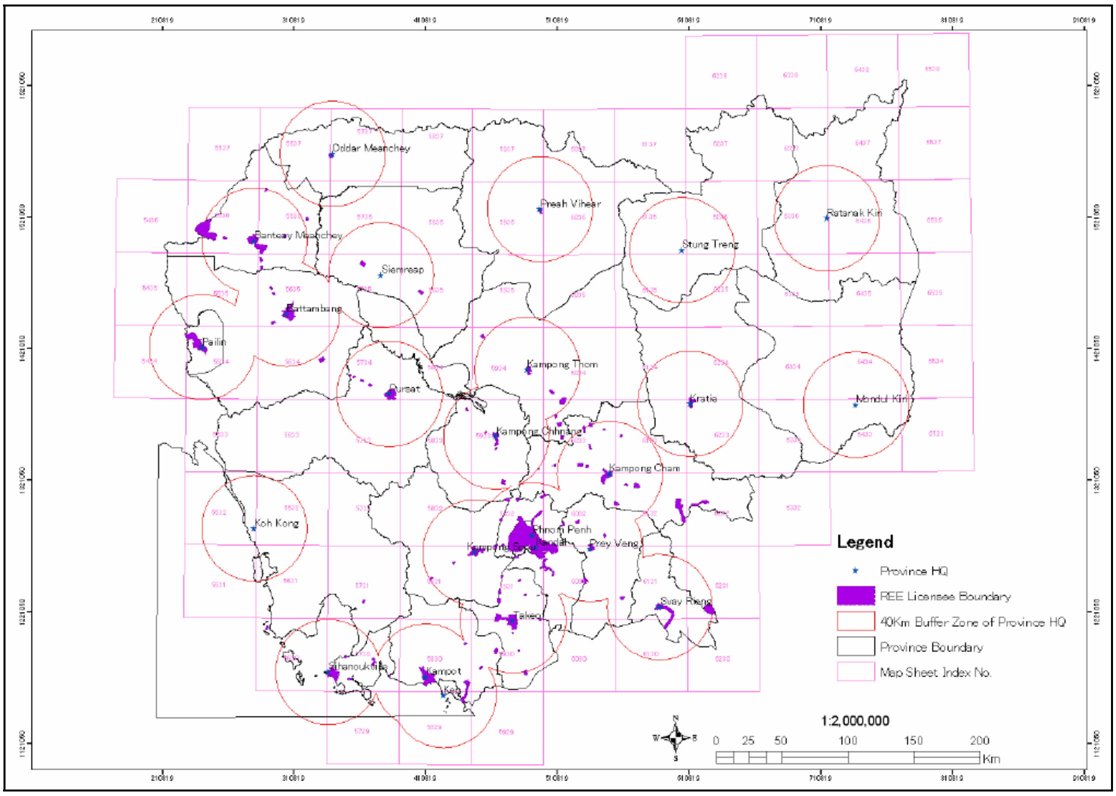
Those systems not connected to the national grid are to be considered as isolated and hence consolidated license can be issued to such system operator. This means that consolidated license cannot be issued to the systems connected to the national grid.

In Article 32 of the Electricity Law, it is clearly defined that the National Transmission License shall be issued to the state power transmission company who has the right to provide the transmission service for delivering the electric power to the distribution companies and bulk power customers throughout the country. At present, only EdC meets this requirement. The Special Purpose Transmission License will be given to the companies other than EdC subject to the decision in accordance with the government regulation.

Under the above-mentioned situations, the grid subject to the Grid Extension Program in the Study is defined as a power transmission system that consists of 1) 115 kV and higher voltage lines and substations (hereinafter referred as GS) owned and operated by EdC; and 2) HV and MV systems extended to outside the supply area of EdC for supplying and selling electric power to the other distribution licensees and bulk power customers. The existing grid at present is a transmission system of 115 kV in Phnom Penh and 115 kV Kirirom line, including its GS at Kampong Speu, feeding the Phnom Penh system.

The 22 kV line has capability of transferring electric power over a distance of 50 km. The line length can be even longer, if proper reactive power compensators are provided, in rural areas in particular where demand density is considerably low. The distance of 22 kV line from GS, however, is limited to 40 km in the Study in accordance with “the Energy Strategy of Cambodia” prepared by MIME. The target area of rural electrification by the grid extension is the ones within 40 km radius from GS as indicated in Figure 2.2.1.

As of 2005, there are no sub-transmission lines extended to outside the supply area of EdC for supplying and selling electricity to the other licensees and bulk power customers.



Source: JICA Study Team

Figure 1.2.1 Target Area of Electrification by Grid Extension

1.2.2 Target Areas of Renewable Energy Development for Rural Electrification

Promoting of effective use of renewable energy as electric power sources of rural electrification is meaningful for the country, since most of the fossil fuel consumed in the country is heavily reliant on imported oil. However, the following characteristics and economic viability should be considered for the selection of location, ranking of its priority of development, etc:

Unit capacity of a generating plant using renewable energy is comparably small and is competitive with a small scale diesel generator widely used in the rural areas. However, its unit generating cost is at much higher level that that of large-scaled power plants or of imported energy from neighboring countries. In other words, almost all the small generating units using renewable energy to be developed in the rural area will no longer be operated, after their connection to the national grid, since large generating plants on the grid will feed much cheaper energy.

Characteristics of prospective renewable energy applicable to rural electrification in the country are as follows:

1) Micro hydro: Potential sites and scales of development are limited due to geographical features and river flow characteristics. Its potential power and energy outputs will fluctuate seasonally in a wide rage. In addition, micro hydro is capital intensive compared to fuel intensive diesel power plants. Construction period of micro hydro is also long. However, operation and maintenance cost is much cheaper than that of generating plants using fossil fuel.

2) Biomass: In general, site and scale of development of biomass gasification power are not site-specific unlike micro hydro. Initial cost of development is comparatively low. Operating cost including fuel cost is lower than that of diesel generators but higher than that of micro hydro. Its life time and maintenance cost are at a level similar to those of diesel generators.

3) Solar power: There is no site limitation for development of solar power in the country, since Cambodia has plenty solar potential throughout the country. Even though there is small difference by area in solar radiation, its construction period including procurement period of materials is quite short. Initial costs are higher than that of micro hydro. However, maintenance is quite simple and the facilities are mostly maintenance free.

As explained in Clause 1.2.1 of Part-2, the target area of electrification by the grid extension will gradually be expanded along with extension of the HV system and construction of new GS. Those areas that will be situated within 40 km radius from new GS will be added to the target area of the grid electrification. This means that the off-grid areas (the target area of rural electrification by renewable energy) will gradually be decreased with the expansion of the on-grid area (the target area of the grid electrification).

It is necessary to decide whether the generating plants by renewable energy, which will be developed in the off-grid area, should be operated in parallel with the grid; or should be shifted to other non-electrified area; or scrapped upon their connection to the grid. Generation costs of such small scaled generating plants are mostly high compared with that of large units of the grid. The small units, however, have economic advantages in the off-grid areas until the grid reaches there. For avoiding double investments in generation facilities in those off-grid areas that will be covered in the near future by the grid with high probability, only those generating plants that can continue power generation at acceptable costs also after the grid integration should be developed.

The target area for rural electrification by renewable energy will depend on and be limited by type of renewable energy as discussed below:

1) Micro hydro: Micro hydropower plant will be operated continuously in parallel with the grid also after the grid connection, since its generation cost is comparable with that of middle scaled hydropower plant. Also parallel operation with the grid is technically and economically viable. A master plan for development of micro hydropower plants will be prepared based on a study of potential and village demand situated in the non-electrified areas including study on their development priority.

   Cambodia presently has only two hydropower plants; the Kirirom hydropower station owned and operated by IPP, and the O Chum mini hydropower plant of Ratana Kiri transferred to EdC in 2004. This means that the fields and chances for training staff for operating and maintaining (O&M) hydropower plants are quite limited. Many skilled staff for O&M of hydropower plants will be needed upon implementation of many hydropower projects in the future. Implementation of micro hydropower plants will provide places for training of the technical staff for these future hydropower plants. Micro hydro can be developed with smaller capital costs and shorter implementation period while it can contribute not only to rural electrification in the off-grid areas but also to training of O&M staff for future large scale projects.

2) Biomass: Small scaled generating plants for rural electrification may be competitive with diesel generators in a small decentralized power supply system. However, it might be difficult to operate in parallel with the grid upon the grid connection mainly from the technical points of view partly from generation cost aspect, subject to specifications of the biomass power equipment installed. In such case, it is also possible to shift such biomass power equipment to the other non-electrified villages at low costs without technical difficulty. The farmland planted with fuel trees can either continue tree farming for fuel wood supply to

market or can be reverted to crop farming depending on land owner judgment. A farmland in the new village should be planted with fuel trees one year in advance of the machine shifting. Thus, it can start fuel supply upon reinstallation of the equipment in the new village. Therefore, the biomass power schemes may be installed also in the circular areas of 40 km radius (as indicated in Figure 1.2.1) where the grid connection may or may not be realized by 2020, including the border areas with neighboring countries where low-cost imported energy is available but the grid may not cover all the villages there by 2020.

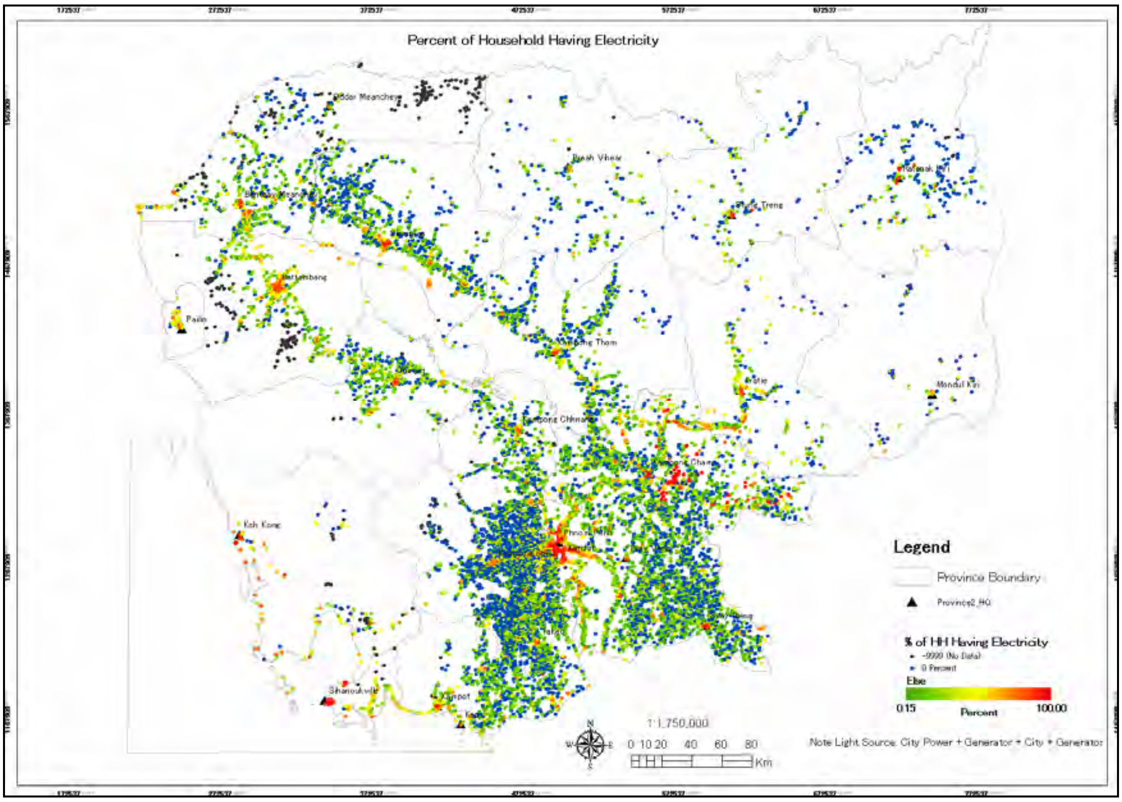
3) Solar energy: Solar energy can serve for lighting, radios and audio equipment which is the minimum requirement of the people. But it is economically difficult to feed energy to the grid. Therefore, shifting of the solar facilities to the other non-electrified areas upon the grid connection will be the basic policy in the Master Plan.

For smoothly shifting these solar facilities to the other non-electrified villages under the rural electrification project, it is needed to make clear the ownership of the facilities. It is difficult to shift solar home systems (SHS) or to sell in the market because their ownership may not be clear when provided with partial or full grant supports. Therefore, it is recommended in the Master Plan that solar battery charging station (solar BCS) be adopted. In addition, it is also recommended for promoting sustainable usage of solar energy for rural electrification that the BCS should be owned by the Government organization and be rent to providers or village organizations with reasonable rental charge. A part of collected rental charge may be used for technical support for such providers and remaining should be saved up to use for the procurement of new system for sustainable development of solar energy in the country. It is recommended that the rental charge should be decided based on the reading of energy meter equipped on the system.

The target area for installing solar BCS is those villages where no BCS exists or BCS is located at distant places from the village. There are many diesel BCS even within the grid electrified areas for serving those non-electrified households nearby. It suggests a need of installing a solar BCS also in a newly electrified area by mini-grids or by the grid extension.

1.3 DISTRIBUTION OF NON-ELECTRIFIED VILLAGES AND ELECTRIFICATION DEMAND

The level of electrification (excluding battery lighting) of all the villages in Cambodia is shown in Figure 1.3.1. The data source is NIS 1998.



Source: Compiled by JICA Study Team based on NIS census 1998.

Figure 1.3.1 Level of Electrification by Village

As can be seen from the figure, the demand to electrification in Cambodia is quite high except in Phnom Penh and some provincial capitals.

By applying GIS technology, village maps with potential area (GIS Village Map) were prepared, of which maps show 1) rivers and counter lines, 2) locations of micro hydro potential site, 3) village locations and their number of households, 4) layout of roads, 5) administrative boundaries, and 6) percentage of households having electricity in the village. Sample village map is as shown in Figure 2.3.2 of Part 4-1.

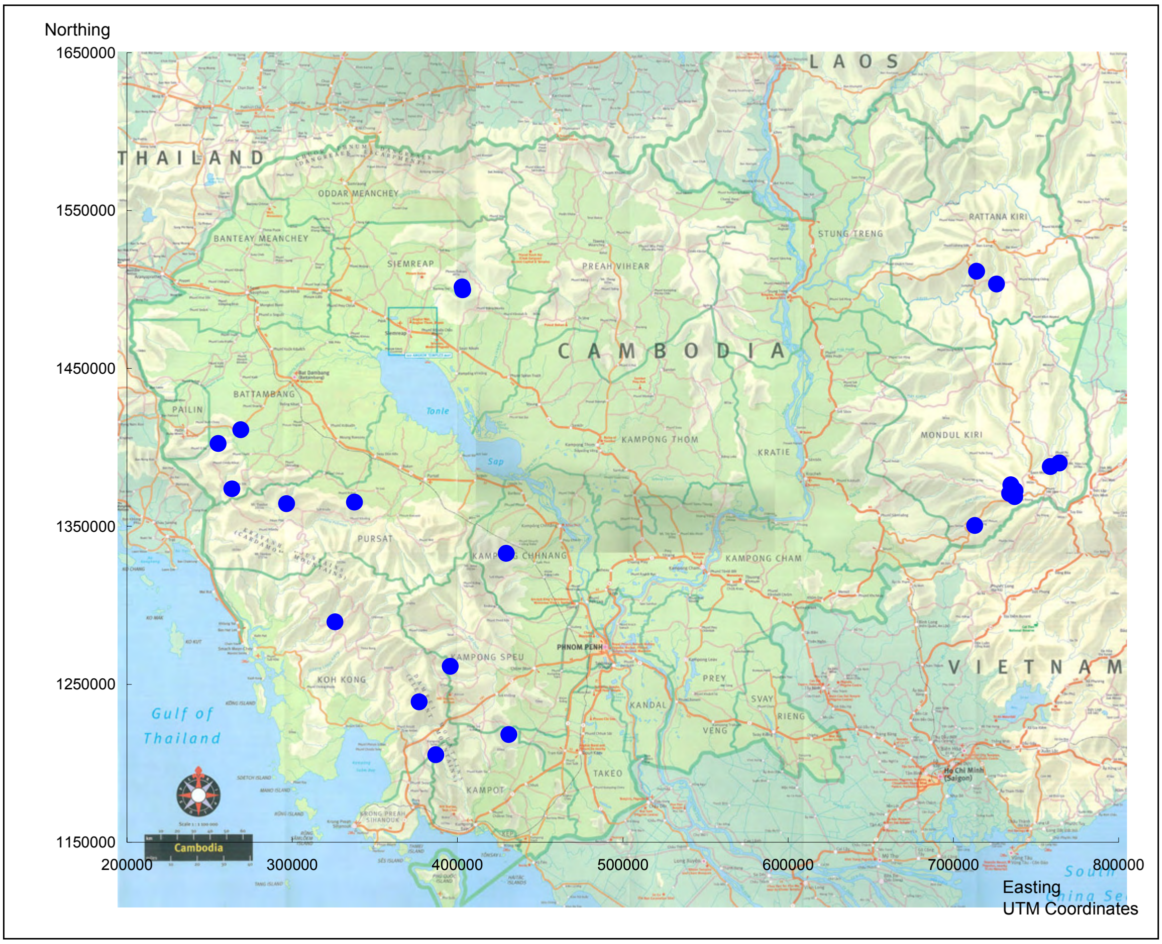
GIS Village Map was prepared and printed in color in a size of A1 with a scale of 1:100,000. There are 89 sheets of GIS Village Map prepared for whole area of Cambodia.

1.4 RENEWABLE ENERGY POTENTIAL

1.4.1 Micro Hydro Power

Map study was conducted taking into account of natural conditions and hydrological characteristics of Cambodia as described in Part 1. Through map study, 145 micro hydro power potential sites were identified. Out of 145 potential sites, 44 sites have target villages to electrify. Further, by screening with criteria of availability to pay (ATP), 21 schemes covering 137 villages were selected. The rest of 23 schemes covering 74 villages were judged to be still premature to apply micro hydro mini grid. Details of selection criterion are given in Volume 3.

Screened 21 schemes are as shown in Figure 1.4.1 and listed in Table 1.4.1. These 21 schemes include 4 schemes of hybrid type development with biomass gasification power and 4 schemes with back up diesel power.



Source: JICA Study Team

Figure 1.4.1 Screened 21 Micro Hydro Schemes

Table 1.4.1 Selected Candidate Villages for Electrification by Micro Hydro (1/2)

No.	MHP Reference No.	ID No	Name of RE Scheme	Sub-scheme No.	Province	District	Commune Name	Village Name	ID No. by Seila	Potential Dry Season Power (kW)	Total Demand incl. loss (kW)	Backup Capacity (kW)	Nos. of Total Households	Nos. of HHs to be Electrified	Length of MV Trans. Lines (km)	Cost ($1,000)				Remarks
																G.E.	Back up	MV & LV	Total	
1	1-2	HB0209-01	**Sangke D/S**	1	Battambang	Rotonak Mondol	Phlov Meas	Phlov Meas	2070301	**59**	**706**	**562**	**6,786**	**5429**	**115.0**	**649**	**843**	**2,290**	**3,781**	Hybrid with Biomass
	1-3	HB0209-02	**Sangke U/S**	2	Battambang	Rotonak Mondol	Phlov Meas	Tuek Sab	2070303	**85**										
				3	Battambang	Rotonak Mondol	Phlov Meas	Ou Treng	2070305											
				4	Battambang	Rotonak Mondol	Phlov Meas	Ou Lmun	2070307											
				5	Battambang	Rotonak Mondol	Traeng	Kilou	2070401											
				6	Battambang	Rotonak Mondol	Traeng	Phcheav	2070402											
				7	Battambang	Rotonak Mondol	Traeng	Chea Montrei	2070403											
				8	Battambang	Rotonak Mondol	Traeng	Chi Sang	2070404											
				9	Battambang	Rotonak Mondol	Traeng	Svay Sa	2070406											
				10	Battambang	Rotonak Mondol	Traeng	Ta Krok	2070407											
				11	Battambang	Samlout	Ou Samrel	Ou Rumchek Kraom	2090201											
				12	Battambang	Samlout	Ou Samrel	Ou Rumchek Leu	2090202											
				13	Battambang	Samlout	Ou Samrel	Chamlang Romeang Kraom	2090203											
				14	Battambang	Samlout	Ou Samrel	Ou Samrael Kraom	2090206											
				15	Battambang	Samlout	Ou Samrel	Ou Samrael Leu	2090209											
				16	Battambang	Rotonak Mondol	Phlov Meas	Sek Sak	2070302											
				17	Battambang	Rotonak Mondol	Phlov Meas	Chi Pan	2070304											
				18	Battambang	Rotonak Mondol	Phlov Meas	Ou Da	2070306											
				19	Krong Pailin	Pailin	Ou Tavau	Kra Chab	24010206											
				20	Battambang	Samlout	Ou Samrel	Chamlang Romeang leu	2090204											
				21	Battambang	Samlout	Mean Cheay	Sre Sdao	2090401											
				22	Battambang	Samlout	Mean Cheay	Kampong Touk	2090402											
				23	Battambang	Samlout	Mean Cheay	Sre Chi Pao	2090403											
				24	Battambang	Samlout	Mean Cheay	Kam Chat	2090404											
				25	Battambang	Samlout	Mean Cheay	Ambib	2090405											
				26	Battambang	Samlout	Mean Cheay	Ta Non	2090406											
				27	Battambang	Samlout	Samlout	Chhar RoKar	2090501											
				28	Battambang	Samlout	Samlout	Kantuot	2090502											
				29	Battambang	Samlout	Samlout	Ou Chrab	2090503											
				30	Battambang	Samlout	Samlout	Samlout	2090504											
				31	Battambang	Samlout	Samlout	Srae Andoung Muy	2090505											
				32	Battambang	Samlout	Samlout	Bueng Run	2090506											
				33	Battambang	Samlout	Sung	Chamkar Chek	2090601											
				34	Battambang	Samlout	Sung	Kandal	2090602											
				35	Battambang	Samlout	Sung	Kanh Chaang	2090603											
				36	Battambang	Samlout	Sung	Sre Reach	2090606											
				37	Battambang	Samlout	Sung	Shoung Muoy	2090607											
				38	Battambang	Samlout	Sung	Shuong Pir	2090608											
				39	Battambang	Samlout	Ta Sanh	Anlong Pouk	2090701											
				40	Battambang	Samlout	Ta Sanh	Doun Troek	2090702											
				41	Battambang	Samlout	Ta Sanh	Ou Sngout	2090703											
				42	Battambang	Samlout	Ta Sanh	Ou Tontim	2090704											
				43	Battambang	Samlout	Ta Sanh	Prey Rumchek	2090705											
				44	Battambang	Samlout	Ta Sanh	Ta Sanh Khang Chhueng	2090706											
				45	Battambang	Samlout	Ta Sanh	Ta Sanh Khang Tboang	2090707											
2	1-2	HB0209-03	**Sangke D/S Alternative**	1	Battambang	Rotonak Mondol	Phlov Meas	Phlov Meas	2070301	**59**	**138**	**79**	**1,324**	**1059**	**13.0**	**233**	**119**	**353**	**704**	Small scale of scheme 1. Target village overlapped. Hydrid with Biomass
				2	Battambang	Rotonak Mondol	Phlov Meas	Sek Sak	2070302											
				3	Battambang	Rotonak Mondol	Phlov Meas	Tuek Sab	2070303											
				4	Battambang	Rotonak Mondol	Phlov Meas	Ou Treng	2070305											
				5	Battambang	Rotonak Mondol	Phlov Meas	Chi Pan	2070304											
				6	Battambang	Rotonak Mondol	Traeng	Phcheav	2070402											
				7	Battambang	Rotonak Mondol	Traeng	Kilou	2070401											
				8	Battambang	Rotonak Mondol	Traeng	Chea Montrei	2070403											
3	10-10	MH1605-02	**Bay Srok**	1	Ratanak Kiri	Lumphat	Ka Laeng	Bay Srok	16050204	**65**	**58**	**0**	**560**	**448**	**3.0**	**139**	**0**	**124**	**263**	
				2	Ratanak Kiri	Lumphat	Ka Laeng	New Ka Laeng	16050205											Village for Gem Stone
				3	Ratanak Kiri	Lumphat	Ka Laeng	New Sayos	16050206											
4	8-17	MH1104-01	**Bu Sra**	1	Mondul Kiri	Pech Chenda	Bu Sra	Phum Lekh Muoy	11040401	**91**	**93**	**2**	**899**	**719**	**25.0**	**462**	**1**	**401**	**864**	Use Water Fall or O Phlai River
				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											
5	6-19	MH0908-01	**O Sla D/S**	1	Koh Kong	Kampong Seila	Kampong Seila	Cham Srei	9080201	**283**	**130**	**0**	**1,249**	**999**	**15.0**	**543**	**0**	**360**	**903**	
				2	Koh Kong	Kampong Seila	Kampong Seila	Krang at	9080202											
				3	Koh Kong	Kampong Seila	Kampong Seila	Thmei	9080203											
				4	Koh Kong	Kampong Seila	Kampong Seila	Veal	9080204											
6	9-1	MH1506-02	**Xtung Tun Po**	1	Pursat	Veal Veaeng	Pramaoy	Stueng Thmei	15060403	**55**	**47**	**0**	**451**	**361**	**11.0**	**121**	**0**	**186**	**307**	
				2	Pursat	Veal Veaeng	Pramaoy	Tumpor	15060405											
				3	Pursat	Veal Veaeng	Pramaoy	Pramaoy	15060404											
7	5-9	HB0704-01	**Srae Cheng**	1	Kampot	Chum Kiri	Srae Chaeng	Pong Tuek	7040404	**6**	**30**	**24**	**284**	**227**	**8.0**	**22**	**36**	**128**	**186**	Landmines Hybrid with Biomass
8	6-12	MH0907-01	**Tatai D/S**	1	Koh Kong	Thma Bang	Ruessei Chrum	Trapeang Chheu Trav	9070403	**62**	**16**	**0**	**155**	**124**	**10.0**	**122**	**0**	**127**	**249**	
				2	Koh Kong	Thma Bang	Ruessei Chrum	Kokir Chrum	9070404											
9	1-1	MH0209-01	**Tributary Stung Cra Nhung**	1	Battambang	Samlout	Ta Taok	OU Nonoung	2090101	**330**	**88**	**0**	**844**	**675**	**33.0**	**603**	**0**	**471**	**1,075**	
				2	Battambang	Samlout	Ta Taok	Ou Traeng	2090103											
				3	Battambang	Samlout	Ta Taok	Peam Ta	2090104											
				4	Battambang	Samlout	Ta Taok	Peam	2090105											
				5	Battambang	Samlout	Ta Taok	Ou Ta Teak	2090106											
				6	Battambang	Samlout	Ta Taok	Ta Tok	2090107											
				7	Battambang	Samlout	Ta Taok	Veal Rolueum	2090108											
				8	Battambang	Samlout	Ta Taok	Phnum Rai	2090109											
				9	Battambang	Samlout	Kampong Lpou	Svay Chrum	2090301											
				10	Battambang	Samlout	Kampong Lpou	Ou Daem Chek	2090302											
				11	Battambang	Samlout	Kampong Lpou	Ou Choam Kandal	2090304											
				12	Battambang	Samlout	Kampong Lpou	Ou Choam Kraom	2090305											
				13	Battambang	Samlout	Kampong Lpou	Ou Choam Leu	2090306											
				14	Battambang	Samlout	Kampong Lpou	Kandal	2090307											
10	9-6	MH1504-01	**O Leach Meas**	1	Pursat	Phnum Kravanh	Samraong	Roveang	15040710	**35**	**17**	**0**	**164**	**131**	**13.0**	**74**	**0**	**158**	**232**	
				2	Pursat	Phnum Kravanh	Samraong	Ongkrong	15040711											
11	8-5	MH1101-01	**Prek So Long Lower**	1	Mondul Kiri	Kaev Seima	Srae Khtum	Srelovi	11010403	**42**	**30**	**0**	**286**	**229**	**14.0**	**263**	**0**	**188**	**450**	
				2	Mondul Kiri	Kaev Seima	Srae Khtum	Sreampil	11010404											
				3	Mondul Kiri	Kaev Seima	Srae Khtum	Srae Khtum	11010407											
				4	Mondul Kiri	Kaev Seima	Srae Preah	Pu Char	11010502											
				5	Mondul Kiri	Kaev Seima	Srae Preah	Srae Preah	11010505											

Source: JICA Study Team

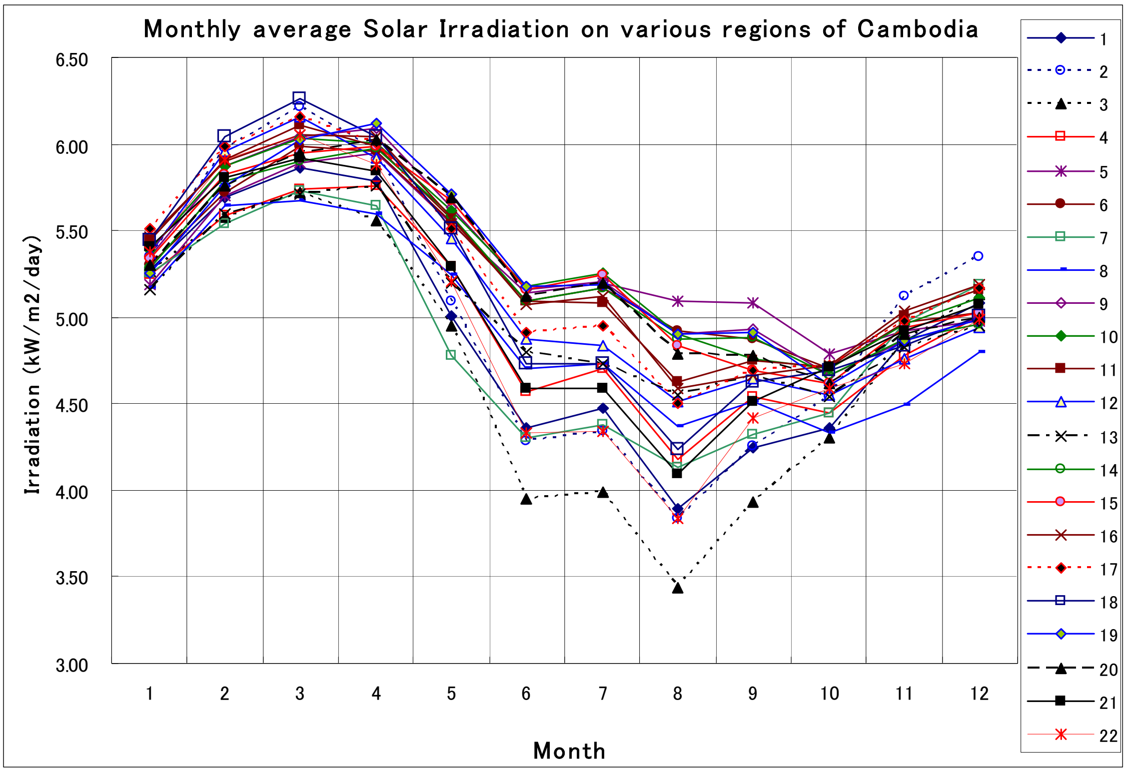
Table 1.4.1 Selected Candidate Villages for Electrification by Micro Hydro (2/2)

No.	MHP Reference No.	ID No	Name of RE Scheme	Sub-scheme No.	Province	District	Commune Name	Village Name	ID No. by Seila	Potential Dry Season Power (kW)	Total Demand incl. loss (kW)	Backup Capacity (kW)	Nos. of Total Households	Nos. of HHs to be Electrified	Length of MV Trans. Lines (km)	Cost ($1,000)				Remarks
																G.E.	Back up	MV & LV	Total	
12	2-3	MH0408-01	**Stung Thum**	1	Kampong Chhnang	Tuek Phos	Chieb	Kos Khtum	4080211	**14**	**11**	**0**	**107**	**86**	**2.5**	**129**	**0**	**43**	**172**	
13	5-1	MH1802-01	**Ou Treb Da**	1	Krong Preah Sihanouk	Prey Nob	Cheung Kou	Anlong Krapeu	18020407	**165**	**6**	**0**	**61**	**49**	**8.0**	**250**	**0**	**90**	**339**	
14	8-12	MH1105-01	**O Moleng**	1	Mondul Kiri	Saen Monourom	Monourom	Daeum Sral	11050101	**82**	**149**	**15**	**1,434**	**1147**	**5.0**	**190**	**8**	**291**	**665**	B/D on going by Japanese Grant Back up power necessary
15	8-13	MH1105-02	**O Romis**	2	Mondul Kiri	Saen Monourom	Monourom	Chrey Saen	11050102	**19**					**1.5**	**74**				
16	8-14	MH1105-03	**Prek Dak Deurr**	3	Mondul Kiri	Saen Monourom	Sokh Dom	Mean Leaph	11050201	**33**					**9.0**	**103**				
17	8-15	MH1105-04	**Prek Dak Deurr D/S**	4	Mondul Kiri	Saen Monourom	Sokh Dom	Daoh Kramom	11050202	**206**	**149**	**0**	**1,434**	**1147**	**4.5**	**481**	**0**	**286**	**767**	Superior site for succeeding project to the above Japanese Grant Scheme. Will be sent to Senmonorom mini-grid.
				5	Mondul Kiri	Saen Monourom	Sokh Dom	Svay Chek	11050203											
				6	Mondul Kiri	Saen Monourom	Sokh Dom	Lao ka	11050204											
				7	Mondul Kiri	Saen Monourom	Spean Mean Chey	Ou Spean	11050301											
				8	Mondul Kiri	Saen Monourom	Spean Mean Chey	Chambak	11050302											
				9	Mondul Kiri	Saen Monourom	Spean Mean Chey	Kandal	11050303											
				10	Mondul Kiri	Saen Monourom	Spean Mean Chey	Chamkar Tae	11050304											
				11	Mondul Kiri	Saen Monourom	Romonea	Pu Tang	11050402											
18	10-2	MH1605-01	**O Katieng**	1	Ratanak Kiri	Lumphat	La Bang Muoy	Kam Phlenh	16050301	**40**	**31**	**0**	**295**	**236**	**6.5**	**77**	**0**	**114**	**191**	On going by UNIDO
				2	Ratanak Kiri	Lumphat	La Bang Muoy	Ka Tieng	16050303											
				3	Ratanak Kiri	Lumphat	La Bang Muoy	Ka Lang	16050304											
				4	Ratanak Kiri	Lumphat	La Bang Pir	Ka Tieng	16050401											
19	6-35	HB0506-01	**Stung Sva Slab**	1	Kampong Speu	Phnum Sruoch	Chambak	Krang Chek	5060101	**56**	**69**	**13**	**665**	**532**	**12.0**	**91**	**7**	**232**	**330**	Little water in dry season Hybrid wiith Biomass
				2	Kampong Speu	Phnum Sruoch	Chambak	Beng	5060102											
				3	Kampong Speu	Phnum Sruoch	Chambak	Chambak	5060104											
				4	Kampong Speu	Phnum Sruoch	Chambak	Thmei	5060103											
20	14-1	MH1713-01	**Stung Siem Reap U/S**	1	Siem Reap	Svay Leu	Khnang Phnum	Ta Penh	17130301	**73**	**63**	**0**	**604**	**483**	**23.0**	**229**	**0**	**331**	**560**	MIME/JICA Study on going Sightseeing spot
				2	Siem Reap	Svay Leu	Khnang Phnum	Khla Khmum	17130302											
				3	Siem Reap	Svay Leu	Khnang Phnum	Thma Chruonh	17130303											
				4	Siem Reap	Svay Leu	Khnang Phnum	Sangkae Lak	17130304											
				5	Siem Reap	Svay Leu	Khnang Phnum	Anlong Thum	17130305											
				6	Siem Reap	Svay Leu	Khnang Phnum	Popel	17130306											
				7	Siem Reap	Svay Leu	Khnang Phnum	Thmey	17130307											
				8	Siem Reap	Svay Leu	Khnang Phnum	Preas Angthom	17130308											
21	14-2	MH1703-02	**Stung Siem Reap D/S**	1	Siem Reap	Banteay Srei	Khnar Sanday	Banteay Srei	17030101	**348**	**385**	**37**	**3,697**	**2958**	**55.0**	**748**	**19**	**1,172**	**1,938**	MIME/JICA Study on going Back up power necessary TL line from Thai Land ?
				2	Siem Reap	Banteay Srei	Khnar Sanday	Khnar	17030102											
				3	Siem Reap	Banteay Srei	Khnar Sanday	Prei	17030103											
				4	Siem Reap	Banteay Srei	Khnar Sanday	Sanday	17030104											
				5	Siem Reap	Banteay Srei	Khnar Sanday	Kakos Chrum	17030105											
				6	Siem Reap	Banteay Srei	Khnar Sanday	Toul Kralanh	17030106											
				7	Siem Reap	Banteay Srei	Khun Ream	Khnar Roveas	17030201											
				8	Siem Reap	Banteay Srei	Khun Ream	Kamprum	17030202											
				9	Siem Reap	Banteay Srei	Khun Ream	Khun Ream	17030203											
				10	Siem Reap	Banteay Srei	Khun Ream	Chuksor	17030204											
				11	Siem Reap	Banteay Srei	Preak Dak	Ta Koh	17030305											
				12	Siem Reap	Banteay Srei	Rumchek	Rumchek	17030401											
				13	Siem Reap	Banteay Srei	Rumchek	Sala Kravan	17030402											
				14	Siem Reap	Banteay Srei	Rumchek	Rovieng Ta Tum	17030403											
				15	Siem Reap	Banteay Srei	Tbaeng	Tbaeng Kaeut	17030601											
				16	Siem Reap	Banteay Srei	Tbaeng	Tbaeng Lech	17030602											
				17	Siem Reap	Banteay Srei	Tbaeng	Voat	17030603											
				18	Siem Reap	Banteay Srei	Tbaeng	Srah Khvav	17030604											
				19	Siem Reap	Banteay Srei	Tbaeng	Kulen Thmey	17030605											
									Total	2,149	2,078	653	19,975	15,980	374	5,368	913	6,989	13,270	
Note : 1) "Total, Max, Min and Mean" in all categories were calculated without HB0209-03.									**Max**	348	706	562	6,786	5,429	115	748	843	2,290	3,781	
									Min	6	6	0	61	49	2	22	0	43	172	
									Mean	102	115	36	1,110	888	19	268	51	388	737	

Source: JICA Study Team

1.4.2 Solar Power

According to a satellite data, the annual average solar irradiation is higher than 5.1 kWh/m^2/day in Cambodia. The solar irradiation is lower on south and southeast region being around 4.7kWh/m^2/day on an average, which is lower by 10% than the country average. The annual average of the minimum monthly solar irradiation is 4.6kWh/m^2/day which is lower by 3% than the south and southeast region average. The seasonal variation is high in the south and southeast region especially in the rainy season, the lowest in August. Even though the potential of solar energy is high allover the country, the seasonal variation should be taken in account in deigning the system. Because if system is deigned on national average than there will be less power in the rainy season in low irradiation region. Battery charging at solar BCS should be continued also in the rainy season except during consecutive heavy rainy days. Therefore, for those reasons where annual average solar irradiation is lower than country annual average the system should be deign on annual average of the minimum monthly solar irradiation 4.6kWh/m2/day. Figure 1.4.2 represents the average solar irradiation of various regions of Cambodia and detail data is given in Appendix-B.



Source: JICA Study Team

Figure 1.4.2 The Average Solar Irradiation of Various Regions of Cambodia

1.4.3 Wind Power

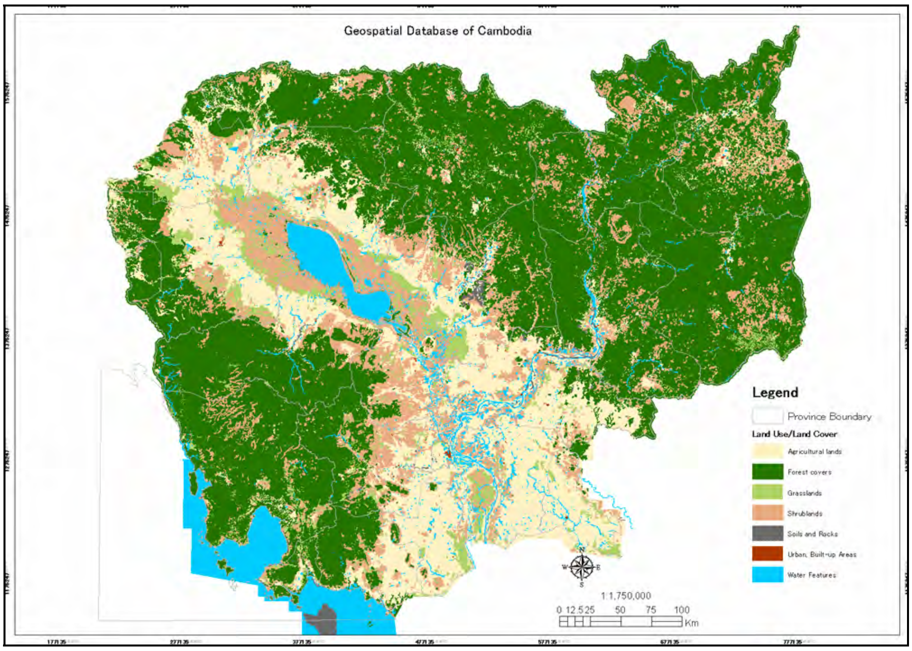
The wind power potential in Cambodia is low and is not appropriate as energy source of mini-grids for rural electrification in the off-grid areas, except for certain wind corridors where some wind potential may exist depending on the local topography.

1.4.4 Biomass Power

There are 6,328 villages with 1,006,033 households selected as appropriate biomass mini-grid candidates through the selection system explained in Part 3 Section 3.1. The biomass mini-grid villages consist of 45% of all the villages in Cambodia and 56% of currently not electrified villages. These villages contain 0.02 ha per household of grassland and shrubland as potential energy crop cultivation land. Flooded grassland is not included because the cultivation is suspicious. The shrubland 'woodland and scattered trees (C<10%)' is not included either because such land is a potential land for rehabilitation of original vegetation. The selection criterion of 0.02 ha per household is calculated using the following criteria:

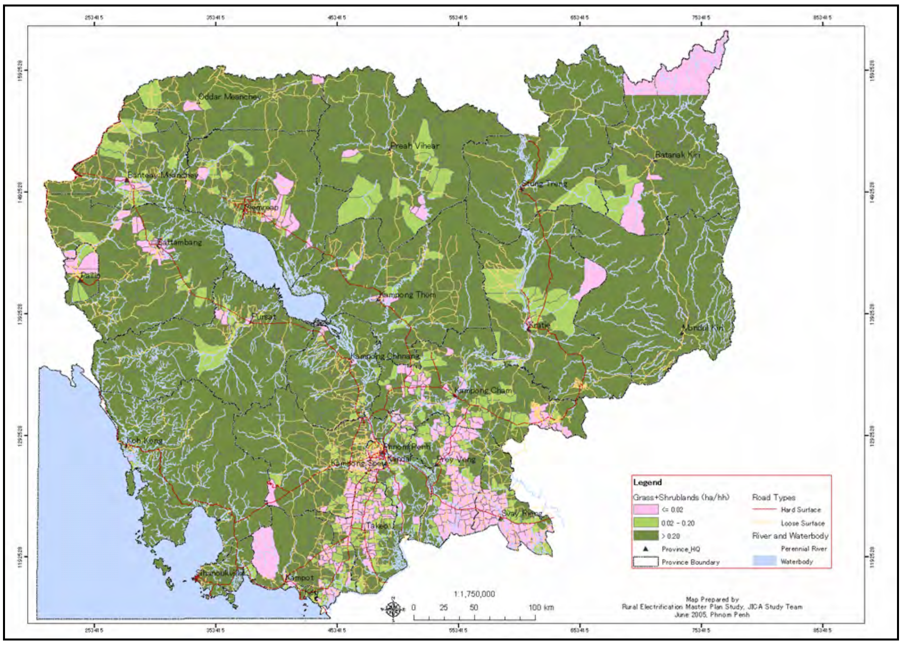
The average monthly consumption of each household is assumed to be 10 kWh/month (including 10% loss) which is some 20-30% higher than average consumption of actual rural village mini grid. The wood fuel efficiency is set as 1.5 kg/kWh and the annual biomass productivity per unit area is set as 10 t/ha/yr which would be the minimum productivity of most area of Cambodia (explained later in this chapter). The required land for each household energy tree cultivation is calculated 0.018 ha/HH therefore only those villages with more than 0.02 ha/HH of grassland and shrubland are selected as biomass electrification potential village.

In the case of Anlong Ta Mei (see Part 1, 3.7.3), only cultivated biomass power supply system in Cambodia, all trees are planted in farmland. They are planted in such as fallow gardens, mixed with fruit trees and around gardens. None of trees are planted in grassland or shrubland. It is assumed that majority energy trees will be planted in farmland but another criterion of 0.02 ha/HH is added for further guarantee of planting area.



Source: Ministry of Public Works and Transport

Figure 1.4.3 Land Use Map of Cambodia (2003)



Source: JICA Study Team

Figure 1.4.4 Per Household Area of Grassland and Shrubland As Potential Fuel Resource

(1) Biomass Availability

If all the 6,328 villages with 1,006,033 households are electrified by biomass and each household consume 10 kWh/month, the national annual power consumption would be 124 GWh. The woody biomass required for generating this amount of power is 186,000 t. In the case of rice husk, 248,000 t would be required. It is estimated that about 1 million ton of rice husk is produced in the country annually (Part 1 Section 5.2.1). Only about a quarter of the total annual national rice husk production is required to electrify all the villages (ditto). About 25,000 t of old rubber woods is produced annually. This can theoretically cover 13% of all the required woody biomass. Table 1.4.2 shows the summary of the potentials of different agricultural residues for power generation in Cambodia. The details are described in Part 1 Section 5.2.1.

In this Master Plan, use of natural forest wood is not considered at all. But people always concern the deforestation threat resulted by installation of biomass power generation therefore the following analysis is provided. Top et al. (2004) estimated average annual biomass increment of various forest types of whole Kampong Thom province as 4.77 t/ha. If this figure is applied to the forest in whole country, the annual biomass increment Cambodian forest would be about 52 million ton. The required woody biomass for rural electrification defined above would be only 0.4% of the annual biomass increment. Even if all the woody biomass for rural electrification were supplied from natural forest, there would be no problem for sustainability and no threat for deforestation theoretically. Even with the fact above, it is again recommended that woody biomass be not obtained for electrification from natural forest at all.

Table 1.4.2 Potentials of agricultural residues for biomass electrification in Cambodia. Monthly electricity consumption is presumed as 10 kWh/HH to calculate the number of HH can be electrified.

	Annual production (t)	Fuel efficiency (kg/kWh)	Number of HH can be electrified	Remarks
Rice husk	1 million	2	4 million	
Cashew nut shell	*n.a.*	*n.a.*	*n.a.*	Currently not suitable for gasification but good for direct combustion.
Sugarcane bagasse	*n.a.*	*n.a.*	*n.a.*	Currently not suitable for gasification but good for direct combustion.
Coconut husk	*n.a.*	1.3	*n.a.*	
Cassava stem	*n.a.*	1.4	*n.a.*	
Mulberry stem	*n.a.*	1.5	*n.a.*	
Peanut shell	5,500	*n.a.*	*n.a.*	
Old rubber tree	25,000	1.5	140,000	

Data is derived from various sources.

(2) Biomass Crop Productivity and Sustainability

Lugo *et al*. (1988) reported the aboveground biomass accumulation rate for most tropical plantations is in the range of 6-15 t/ha/yr. There are much higher accumulation rates for tropical plantation reported e.g. 21.0 t/ha/yr of 4-y-old *Acacia mangium* stand in Peninsula Malaysia (Tsai 1988); and 24.9 t/ha/yr of 5.5-y-old *Gmelina arborea* in Nigeria (Chijoke 1980). In case of harvesting coppiced branches of *Leucaena leucocephala* in India, Tewari *et al*. (2004) reported up to 50 air-dry ton/ha/yr biomass production but productivity varies a lot with different management method and at different site (Kumar *et al*. 1998). There is little information for biomass productivity and nutrient sustainability of either large scale forest plantation or small scale tree farm in Cambodia. Mr. Ponh Oudam, Chief of Agricultural Extension in Battambang, is conducting small scale research at the back of Agricultural Extension building. He obtained about 80 air-dry ton/ha/yr of *Leucaena leucocephala* branches at forth year annual harvest without irrigation. The Study Team is conducting productivity survey of *Leucaena leucocephala*, *Eucalyptus camaldulensis* and *Acacia auriculiformis*. The results of the survey and the data analysis are shown in Volume 5 Appendix C. Soil nutrient sustainability is also critical for biomass electrification. If the soil nutrient degradation occurs at energy crop farm, the system will no longer sustainable. The great deal of research of biomass productivity, nutrient sustainability and appropriate management methodology of energy tree farming and plantation is required in furtherance of biomass rural electrification in Cambodia.

(3) The Most Appropriate Biomass Resource for Rural Electrification

Tree farming should be considered as the primary fuel source for rural electrification by biomass. Any excess biomass residues should be fully utilised where they are available. The reasons are explained below:

- Agricultural residues are generally well utilised in Cambodia.
- The capacities of agricultural products processing factories (such as rice mills, sugar and cashew nuts) are generally small. The sustainable and stable fuel supply of all year round is questionable.
- The cost for fuel is only a minor portion of unit electricity generation cost (16% in the case of Anlong Ta Mei Community Energy Cooperative Project) therefore using agricultural residues does not reduce the cost significantly.
- Purchasing price of fuel wood of tree farming is low ($20/t, in case of Anlong Ta Mei Community Energy Cooperative Project). Abandoned old rubber trees might cost more if the transportation required.
- The land required for village electrification is only about total 2.5 ha of fragmented area for 140 households. We assumed that this much of land is available in most villages. Farmers can earn attractive profit ($200/ha/yr) at fallow land with growing trees. The profit can even stand comparison with paddy farming ($200-$450).

Reference for Biomass

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Kumar, B. M., George, S. J., Jamaludheen, V. and Suresh, T.K. 1998. Comparison of biomass production, tree allometry and nutrient use efficiency of multipurpose trees grown in woodlot and silvopastral experiments in Kerala, India. *Forest Ecology & Management*, 112:145-163.

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1.5 DEMAND-SUPPLY BALANCE OF RENEWABLE ENERGY AND ROLE OF DIESEL GENERATORS

1.5.1 Micro Hydro Power

As for micro hydro potential sites, 145 sites were identified through map study. Total potential is about 17,000 kW. Most of these potential sites are located in the mountainous region of northeastern part and southwestern part.

Demand assessment was made in the village level for micro hydro potential site. For village level demand assessment, 1) number of households in the village and 2) its location were derived from Seila database and used for assessment.

As a result of village level demand assessment, it was realized that 44 schemes could supply electricity to 211 villages in total. Out of 44 schemes, 21 schemes with 137 villages seem to have sufficient ability to pay. Therefore, these 21 schemes were categorized into priority schemes. Ability to pay (ATP) was judged using diffusion level of television as an index.

While, other 23 schemes covering 74 villages were categorized into second priority schemes, because these 74 villages seems to have less ability to pay for micro hydro mini grid.

Through assessment above, it was realized that out of about 11,205 villages located in the off-grid area, only 137 villages (1.2 %) can choose micro hydro mini grid as an energy source for electrification.

Further, total development potential of micro hydro is about 17,000 kW. But total potential to be used for micro hydro mini grid is only 2,200 kW (13%). Main reasons are that, 1) micro hydro potential sites are mostly located in the mountainous area with sparsely populated villages, and 2) in those mountainous area, people's ability to pay for micro hydro mini grid may not be sufficient.

In this master plan level, demand assessment was made in the village level for the purpose of formulating village electrification plan. However, by assuming smaller scale settlement as demand, there may be some possibilities of pico hydro for limited demands, which were not identified though map study.

Numbers of villages and households which can be electrified by micro hydro are summarized by province as shown in Table 1.5.1. From this table, it can be said that in Mondul Kiri province, micro hydro mini grid greatly contributes to village electrification. Provinces in northeastern part and southwestern part have rather high ratio of electrification by micro hydro.

Table 1.5.1 Number of Villages and Households to be Electrified by Micro Hydro

No.	Province	Household			Village		
		Total	to be electrified by		Total	to be electrified by	
		Number	Number	(%)	Number	Number	(%)
1	Mondul Kiri	9,455	2,934	31.0%	90	29	32.2%
2	Battambang	179,574	9,004	5.0%	741	55	7.4%
3	Koh Kong	24,867	1,031	4.1%	132	6	4.5%
4	Ratanak Kiri	23,435	855	3.6%	240	7	2.9%
5	Seimreap	139,035	4,301	3.1%	913	27	3.0%
6	Pailin	10,450	255	2.4%	79	1	1.3%
7	Pursat	73,280	1,081	1.5%	501	5	1.0%
8	Sihanoukville	31,212	115	0.4%	94	1	1.1%
9	Kampot	120,693	308	0.3%	736	1	0.1%
10	Kampong Speu	129,333	295	0.2%	1,358	4	0.3%
11	Kampong Chhnang	335,800	87	0.0%	1,768	1	0.1%
	Total	1,077,134	20,266	1.9%	6,652	137	2.1%

Source: JICA Study Team

1.5.2 Solar Power

There is no restriction on solar power potential from supply side. Solar potential is abundant. Its development depends on demand to solar BCS.

1.5.3 Wind Power

For electrification of villages in the off-grid area, a storage battery system is essentially required unlike wind power that feeds a grid where dependable power plants exist. Wind power in a decentralized mini-grid cannot meet the demand without a large battery system. Accordingly, the wind power is not taken up as the main energy source of BCS or mini-grids in the off-grid areas.

1.5.4 Biomass Power

Biomass power supply system is very similar with diesel power supply system. Fuel is the only major difference. Biomass fuel can be cultivated by power suppliers themselves or purchased from contracted farmers. Producer gas from biomass gasifier can be used with diesel generator with minor modification as duel fuel operation. This is one option for existing REE to mitigate high diesel cost and could possibly be the option to mitigate current high capital cost of biomass power supply systems upon start of manufacturing of domestic cheap gasifier in the near future. In the case of duel fuel system, only small modification is required to diesel engines to use both fuel simultaneously, when 100% producer gas engine is rather expensive or difficult to modify.

1.5.5 Role of Diesel Generators

Diesel generators can be a last resort as an energy source for mini-grids, if the target villages have the following conditions:

1) No micro hydro potential available
2) No biomass potential available
3) Village demand to mini-grids in an order of 100W, 10kWh per month per household exists
4) Villagers have ability to pay in an order of $3-5 per month
5) Transportation of diesel oil to village is possible (with good access road in the rainy season in particular)
6) Grid extension is not expected in the foreseeable future.

By looking at the result of GIS screening for energy source selection, such diesel mini-grid candidate villages can be found in a plain region in general, namely in provinces of Takeo, Kampong Speu, Svay Rieng, Prey Veng and Siemreap. In these provinces, diesel mini-grid candidate villages can be found where distance from one digit national road is in an order of 2 to 15 km in most cases.

In these villages, grid extension should first be pursued. If it is not available at all, then diesel generator is the only energy source for mini-grid.

1.6 INSTITUTIONAL FRAMEWORK FOR RURAL ELECTRIFICATION

1.6.1 Outline

The basic strategy for RE is mentioned in the new Cambodia energy strategy paper as discussed in Chapter. 3.8.1 of Part 1. The RE strategies consist of two approaches: grid-based supply and off-grid supply. The grid-based supply is public-grid supply and the power supply will be extended from existing substations to surrounding district and communes[2]. EdC is principally responsible for the public grid supply and various PPP options involving EdC and REEs are used. The off-grid (mini-grid and stand-alone system) for rural areas (with no access to public grids) will be operated by REEs and CECs with assistance of MIME and REF/JBF[3].

Each RE component has various sub-components depending on energy sources, type of owners/operators, capital funding sources, etc. Details of financial arrangements by electrification types will be discussed in Chapter 2.2.3.

1.6.2 Barriers and Issues on Off-Grid RE

Cambodia RE sector faces various barriers and constraints as often discussed and clarified in workshops and seminars on this subject. These problems are summarized and focused into one key word: that is **finance**. This is especially true for off-grid areas that are not accessible to less expensive and stable supply of public electricity[4]. The Cambodia's off-grid RE challenges center on supplying electricity to rural areas that are hard to get to, where a majority of the customers have low income and where the population is sparse. As a result, there are two key issues in all RE projects in Cambodia. Firstly, the high cost of delivering electricity services and, secondly, who will pay for the service – whether it be the government, donors, financial institutions, private sector, or the customer/beneficiary.

So firstly, it is required to reduce costs of supply. This requires provision of **low cost financing** and **reduction of tax duty** for RE equipment as well as efficient and effective operation and management of the service provision. At the same time, it is essential to empower rural communities so as to **raise their affordability-to-pay for electricity** in order to maintain financial sustainability (based on users-pay principles) and minimize government fiscal burdens (grants and subsidy).

These issues are in line with demands surged from many REEs and REBs as well as NGOs to the Government: these are summarized as follows:

- to reduce or exempt import tax or VAT against renewable energy technologies (RETs);
- to provide financial support/incentives (capital grant, smart credit, guarantee etc);
- to provide technical assistance to REEs and CECs for building their technical, operational and management capacities; and
- to enhance local people to participate in the project and to raise their income and living standards.

Meanwhile, the current legal and institutional framework is weak, as the Cambodia energy strategy paper admits, and there are a lot of areas to be improved. In this respect, mere provision of capital grant by the REF is not sufficient for stimulating and enticing private equity and finances into RE sector. Considering lack of financing sources from current financial institutions an appropriate institutional financing system using ODA loans is desirable to be introduced.

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2 The official definition of "rural areas" will be defined by the REF established by Royal Decree. At the moment, the rural areas are the areas other than the cities (Phnom Penh, Shihanoukville, Pailin and Kep) and provincial towns.

3 JBF stands for Japan Biomass Fund which is under examination by the JICA study team for an funding agency complementing the REF (see Chapter xxx for detailed discussion of JBF).

4 Grid-based supply areas by EdC has less financial issues since EdC is accessible to various finance sources (state budgets, ODA loans, and own funds) as shown in **Table 2.3.2** of Part 1. So, further discussion on institutional reform will be focused on to off-grid RE areas.

1.6.3 Recommended Institutional Framework for Off-Grid RE Implementation

The institution is an organizational framework showing the implementation responsibilities of entities concerned in the rural electrification development. It is a framework showing who does what to achieve the goals as shown in Table 1.6.1. There are five business models as shown in the table. For each model, a relevant entity is assigned for each of five roles of ownership, O&M, facilitation, approval, and regulation.

Here we focus on off-grid electrification by the broad private sector, including REE and CEC. There are not so much essential difference between REE and CEC, just the ownership of properties: local businesses for REE and local communities for CEC. CEC is further divided into two types: community-owned enterprises and user associations (cooperatives). Both implementing entities are entitled to receive the support of the incumbent REF and CFR to be established. The REF and CFR are funding agencies which provide technical and financial assistances. CEC is able to access to non-REF/CFR support system, like Commune/Sangkat Fund (C/SF) under the SEILA program administered by the Ministry of Rural Development. It does not look like MIME/DIME has participated in the SEILA program so far.

Table 1.6.1 Business Models and Role Division for Rural Electrification

Business Model		Owner	Operation	Facilitation	Approval	Licensing & Regulation
On-grid	EdC, REE	EdC, REE	EdC, REE	-	MIME	EAC
Off-grid	REE	REE	REE	REF and EdC or NGO	MIME (DIME)	EAC
	CEC	CEC	CEC	REF and NGO	MIME (DIME)	EAC
	Central Gov't	Central Gov't	EdC or REE	-	-	EAC
	CEC	Local Gov't (Commune)	REE or NGO/CEC	SEILA Task Force & NGO	-	EAC

(Note) [shaded box] Entitled to receive REF/JBF support scheme

Source: JICA Study Team

The implementation structure of the off-grid rural electrification is shown in Figure 1.6.1. Five major entities[5] are involved: MIME, EAC, REF/CFR, Service Providers (REE and CEC) and NGO. **MIME** will provide credible and predictable investment environments as a policy maker and an administrator of REF/JBF. **EAC** will work as a regulator to approve cost-recoverable tariff system, oversight and handle conflict resolution. **REF/CFR** will be a facilitating partner providing technical assistance and funds (grant and/or loans) to the service providers under co-financing with financial institutions[6], including commercial banks, specialized banks and micro finance institutions. The REF Royal Decree mentions part of grant funds come from the tariff surcharge levied on existing grid customers. This is a desirable policy in terms of social equity since this is a cross-subsidy from urban EdC customers to rural non-electrified population. This fund source forms a kind of universal service fund for rural electrification. The **service providers** or operators include REE and CEC. They will invest in equity or community contribution besides REF/CFR grants and cofinancing loans and provide the electricity services to rural customers to their satisfaction in terms of price and reliability. And lastly **NGO** is also an important player in the rural areas and will help REE and CEC and empower the communities by participatory approach.

[5] The five entities are sector-specific ones. The role of MEF shown in the figure is not discussed here since MEF provides general budget supports and relends the original loans from donors as the general borrowers. The details of funding arrangements will be discussed in Chapters 2.2.3.

[6] Rural Development Bank has proposed their idea of loan operations to JICA Study Team as per Appendix-G.

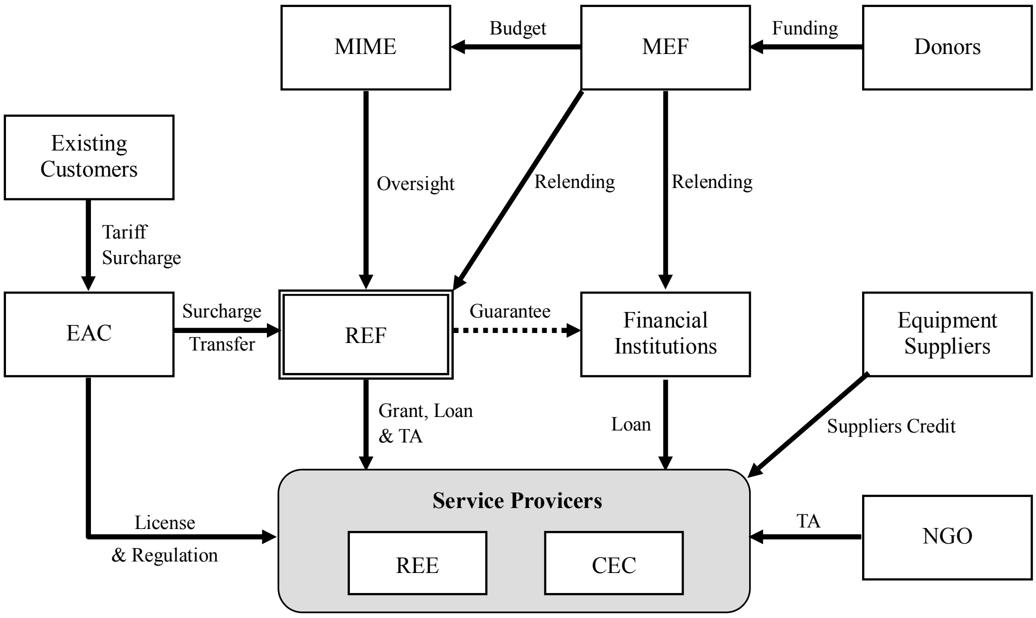


Figure 1.6.1 Proposed Institution Framework for Off-grid Rural Electrification Development

1.7 POWER TARIFF AND SUBSIDY SYSTEM

1.7.1 Tariff Setting Principles and Regulations

The Electricity Law (the Law) assigns the EAC to determine and review the tariff rates, charges and service conditions of the licensees based on their tariff proposals. The Law raises five principles of tariff setting as follows[7]:

- to protect consumers against monopolistic prices;
- to permit licensees to recover their reasonable costs incurred under proper business practices;
- to encourage the efficiency of operation and management resulting in reduction of service costs and improvement of service quality;
- to encourage economic efficiency of power sector by reflecting marginal costs and demand-supply balances; and
- to set different tariffs for each customer category to reflect quantity and type of services, affordability to pay, and social factors for poor residential and rural customers

The Sub-Decree on Business Principles for Tariff Setting specifies basic business principles of tariff setting. These include:

- to apply different pricing methods to different licensees considering different sizes, locations and objective circumstances;
- to provide separate cost information of generation, transmission and distribution/supply;
- to provide separate cost information of each separate service area of the licensee;
- to apply performance-based tariff regulation methodologies that are designed to encourage cost reduction, efficient operation and improved service quality; and
- to determine the reasonable costs of a licensee not to threaten the long-term financial sustainability.

7 Based on Article 48 of the Electricity Law

The Sub-Decree also 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 cost component are also specified in the Sub-Decree. Detailed methodologies for calculation and quantification of the reasonable costs are specified in the Regulations and Procedures drafted subsequently to the Sub-Decree.

Design of actual tariff tables will be started in the middle of year 2005 with assistance of ADB (as of June 2005, the consultants are being recruited for this task).

In April 2005 was passed the Sub-Decree on Tariff which stipulates the basic policy for evaluating the cost of electricity business in order for EAC to examine and appraise the electricity tariff.

1.7.2 Tariff Setting Principles

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[8], 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.

Table 1.7.1 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

[8] 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.

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 as presented in Volume 4 on pre-feasibility study.

1.7.3 Financial Support Facility (Provision of Subsidy and Soft Loan)

There are no clear subsidy and financial support policies issued by the Government. The Electricity Law and subsequent Sub-Decree/Regulations just state that the reasonable costs of services shall be covered by tariffs (customers payment) and subsidies given by the Government if any. At present the Government has not implemented any subsidy policies. Up to now all the electricity services have been provided under a full-cost recovery by tariff revenues.

As discussed in Chapter 3.10 of Part 2 and the results of socio-economic surveys rural consumers have a limited ability to pay the high up-front costs of renewable technologies and supplies will find it difficult to mobilize adequate financing on their own to support the services. Therefore subsidies and concessional loan financing are required to overcome financing barriers.

The RGC will introduce a subsidy scheme to compensate a part of capital costs under the pilot REF project. The outline of REF mechanism and subsidy rates are given in Table 1.7.2. The REF subsidy targets the capital costs and the subsidy to the O&M costs is not considered. The latter aspect is based on an observation that it is indispensable for the customers to pay at least full O&M costs in order to run the electricity business in a financially sustainable way.

Table 1.7.2 REF Mechanism and Subsidy Rates

<table>
<tr><td>REF Mechanism</td><td>The REF will call for proposals from private developers to implement rural electrification solutions in particular nominated areas, consisting of either:

a) New mini-grids based on generation from diesel, solar or hydropower generation;
b) Extension of an existing small grid systems to connect new households;
c) Solar Home Systems (SHS); or
d) Mini or Micro hydropower system.

Proposals will be selected according to eligibility criteria.
Successful proposals will receive an REF grant (see rates below) which is expected to contribute approximately a quarter of the total project investment costs:

Grants 25%
Equity 25%
Loans 50%

The intended effects of the REF grant is to reduce the capital cost and thus the retail cost of power in rural areas and also, combined with an operating license from the Electricity Authority of Cambodia (EAC), to enable the proponent to successfully obtain the remaining finance from a private finance institution. Technical assistance will be provided to further assist proponents to secure appropriate debt finance.</td></tr>
<tr><td>Subsidy Rates</td><td>
<table>
<tr><th>Project Type</th><th>Total Cost</th><th>REF Grant (max)</th></tr>
<tr><td>New household connected to existing diesel mini-grid</td><td>US$150 per connection</td><td>US$45</td></tr>
<tr><td>Mini hydro (0.75 - 5 MW)</td><td>US$1,744/kW installed</td><td>US$400/kW installed</td></tr>
<tr><td>Micro hydro (average 50kW)</td><td>US$2,700/kW installed</td><td>US$400kW installed</td></tr>
<tr><td>Solar Home System</td><td>US$400 per set of 40 Wp</td><td>US$100 per set of 40 Wp</td></tr>
</table>
</td></tr>
</table>

Source: MIME (www.recambodia.org)

The JICA Study Team does not consider applying of a uniform subsidy (25%) for all electrification types is practical. The 25% grant facility is too small for solar PV standalone systems. International experiences indicate almost 100% of capital grant is a norm for installing solar BCS/SHS system in remote isolated villages.

Additional grant assistance as well as soft loan financing is required as far as it is justified for social and economic development reasons. The REAP program actually proposed higher grant supports as shown in Table 3.8.1 of Part 1 of this report. The REF uniform subsidy rate is not in line with the REAP.

Thus public and private blended or mixed financing approaches will be used for rural electrification projects. There are three main funding sources: (i) government subsidy (grant), (ii) investors' equity or contributions, (iii) loan (debt). The current pilot REF scheme, as shown above, is providing one menu: 25% grant, 25% equity and 50% loan.

We don't consider one size is sufficient. We have to cope with variety electrification methods, technologies used, type of investors (REE or CEC), economic viability, and so on. Rural customers have a lot of body sizes and waistbands. We consider several sizes are necessary in order to meet all the needs of rural electrification. More detailed discussion on funding options will be given Chapter 2.2.3 (Capital Requirement, Financing Plan, Funding Sources)

2. DEVELOPMENT SCENARIO OF RURAL ELECTRIFICATION

2.1 NATIONWIDE ELECTRIFICATION BY GRID

2.1.1 Basic Policy of Nationwide Electrification by Grid

Power supply systems of Cambodia consist of the biggest Phnom Penh/Kandal system, the other EdC systems, providers (REE) licensed by EAC and providers licensed by DIME before 20202 and non-licensed providers. These power supply systems are isolated each other except for the Kampong Speu system of EdC. Electricity tariff of EdC who owns the biggest power supply areas in the country is at the lowest level with unit price of US¢ 15.3/kWh (Riel 610/kWh in 2004) in average. Electricity tariff of providers who import electric energy from Thailand and supply to their customers in the areas near the bordr is the second lowest of US¢10.75 to US¢18.75. Electricity tariffs of the other REE are set at the very high level between US¢23.7 (Riel 950) /kWh and US¢ 80.0 (Riel 3,200) /kWh (customers with energy meter).

It will be feasible and viable for promoting the rural electrification program as well as for lowering the tariff level to extend 22 kV lines from the supply area of EdC to the surrounding private providers' areas in order to supply low cost electric power of the EdC grid. However, no 22 kV line was ever extended from the EdC grid to the surrounding areas to promote the rural electrification. As explained in Clause 3.2.1 of Part 1, some provincial towns and villages located near the border with Vietnam have been integrated into the supply area of EdC in the recent year.

No grid extension was made for promoting rural electrification in the past because of the following reasons:

(1) Addition of generating plants in the past was concentrated in Phnom Penh. The generating facilities were augmented only to meet the demand increase in the other provincial towns of limited number. Therefore, the system generation capacity has been in absolute shortage for meeting the rural electrification demand.

(2) The generating facilities of EdC consist of small scaled diesel generators with unit capacity of 100s kW to a few MW class. The unit energy generating cost is much higher than those of the neighboring countries.

(3) Price of electric energy purchased from IPP, which shared about one half of the consumed energy, is very high at US¢ 12.4/kWh to US¢ 19.8/kWh except for the energy from the Kirirom power plant. Such high purchasing energy costs have been a heavy burden to the financial management of EdC. In other words, there is no economic merit for EdC at present to extend the grid to outside their service areas, because the extension means to increase energy purchased from IPPs.

(4) Almost all the fuel oil of the generating facilities is imported through the Mekong River under the control of Vietnam. Its cost including delivery through the River is high. Therefore, the electric power demand has been depressed.

However, as explained in Clause 4.8.3 of Part-1, the first 220 kV cross border transmission project has been launched for importing electric energy from Vietnam. Consultants for the project have been selected and its design works have been commenced for implementation of both of the two work sections, i.e. the construction of 220 kV line and its associated substations under the ADB-NDF finance; and the augmentation of existing 115 kV system including substations under the WB finance. The completion time of the project is scheduled at the end of 2007. According to the power purchase agreement (PPA) concluded in July 2000 between EDC and Vietnam, power with maximum capacity of 80 MW will be supplied from 2003 to 2005 and 200 MW after 2005. Daytime tariff by season is planned to be applied at unit prices between US¢ 3.0/kWh for the off-peak hours in the rainy season and US¢ 8.5/kWh for the peak hours in the dry season, about US¢7.0 in average.

Upon the completion of the cross-border transmission line project, the above-mentioned bottlenecks for the promotion of the rural electrification projects will be dissolved, because of the low price of imported energy and its available capacity of power. The contracted maximum capacity for trading electric power is 200 MW. It is equivalent that a new 200 MW generating plant has been constructed with unit generating cost at around US¢ 7.0/kWh. The fund otherwise required for developing such large generating plant can be allocated to development of transmission systems within the country as well as to augmentation of the generating facilities in small decentralized systems to meet their growing demand.

As explained above, it is essential for promoting rural electrification to provide the gird with sufficient generating capacity at low generating cost. In this connection, the following three stage developments of generating capacity are recommended:

(1) The First Stage

The imported power will be the main power source for the national grid and the existing generating plants will serve the peak portion of the system load and/or will be kept as standby units. The investments for generation projects should be limited to construct small scaled diesel generators for meeting the demand increase of the decentralized systems and to construct medium/large scale standby units for national security. Funds for the power sector should be allocated as much as possible to the grid extension for rural electrification and rehabilitation of poor power distribution systems of REEs. Gas turbine power plants with medium/large scale are preferable as standby units, of which unit construction cost is the cheapest among the candidates of generation equipment. The gas turbine plants shall be constructed in the costal areas in order to keep a diversity of fuel supply of the country, and be connected with the national grid through double circuits of 220 kV transmission line(s) with enough capacity in order to keep a quick response in the similar level of a standby unit constructed in the demand center. This plant can be easily converted to a combined cycle power generating plant which will be operated with high efficiency with reasonable generating cost cheaper than purchased price of imported energy. As for the augmentation of small scale diesel generators for the decentralized system, the generating units of the supply areas to be covered by the grid from time to time can be shifted to such area to serve its investment cost.

(2) The Second Stage

IPPs shall be invited to implement export-oriented big scaled coal (or oil/gas) fired thermal power plants in the coastal area. These plants should also meet the demand increase of the country. There is no supply capacity limit of IPP for supplying energy to Cambodia, of which installed capacity very huge in comparison with the demand of Cambodia, and energy price from the IPP is to be expected in same level or less of price for exporting energy to the neighboring countries, which is cheaper than the price imported from the neighboring countries. In this stage also, the investment for power generation should be limited as much as possible and the valuable fund should be allocated to the grid extension for promoting rural electrification and establishment of transmission system for purchasing energy from the IPPs. In this stage, if national oil/gas is usable, the gas turbine plants constructed in the above first stage shall be converted to the combined-cycle generating plant to keep cheaper energy.

(3) The Third Stage

Thermal power and hydropower plants should be developed by the Government to fulfill the whole power demand of the country and to make effort for exporting surplus energy. For this purpose, detailed potential studies for development of the national energy resources should be continued throughout each stage.

2.1.2 Basic Policy of National Grid Extension

In the past studies for extension of transmission system, the grid extension plan was formulated linking new power plants of the grid. Therefore, the proposed grid extension plan was inevitably limited to those areas that can be supplied within the capacity of generating plants to be developed. It has been inadequate for achieving the rural electrification in the country in a target period in spite of the title as "Rural Electrification Program".

The transmission lines in the country may be divided into the following three groups by their purposes of usage:

(1) Power Delivery Lines

This group includes transmission lines to be newly constructed for transferring and supplying electric power to decentralized power systems and/or non-electrified areas, and additional transmission lines to meet the growing demand in load centers within the grid coverage. Main features of the lines such as line voltage, size of conductors, etc. will usually be decided on the basis of the forecast power demand of the subject area and transmission system analysis. In most cases, however, standard design of the transmission lines has been provided in advance and applied systematically for the sake of convenience, because of difficulty of demand forecast and saving time and cost for design, procurement of materials, testing of materials, etc. Transmission lines for strengthening the system reliability also belong to this group. The 115 kV cross-border line between Thailand and western part of Cambodia may be included in this category, because it aims to supply electric power only to that area.

(2) Power Source Lines

This group includes transmission lines to be constructed for delivering electric power generated at power plants to the grid. Main features of the line are decided on the basis of the capacity of the power plant including future expansion plan. In general, double circuit line is preferable as the power source line, since a sudden loss of power source from the system much disturbs the stability of the power supply system. For those power plants sharing great parts of the load, an additional bypass line may be needed to avoid blackout of the whole system. Major power plants should be directly connected to the system to secure the system management.

(3) Interconnection Lines between the Systems

This group includes transmission lines constructed for connecting the power supply systems each other aiming at improving the system reliability, reducing reserve capacity and wheeling electric power between the systems. The on-going 220 kV cross-border line to import energy from Vietnam is also included in this group, because of its capability of power wheeling under abnormal situation.

In the Master Plan study, transmission lines in the group (1) above are mainly considered in the grid extension planning for promoting rural electrification.

As for the power source lines, construction of the lines has no direct relation with rural electrification. Instead, the route, construction timing, and main features of the lines depend on the site, timing, scale of a new power plant to be developed. Therefore, power source lines will not be considered in the grid extension planning in the Study.

There is no transmission grid in Cambodia except for the Phnom Penh system. However, the ongoing cross-border lines may become a core of the national grid. Therefore, in addition to the Kirirom 115 kV line, the following three ongoing cross border lines are considered in the Study as part of the present national grid. Such national grid consists of three isolated systems initially. Each system has a capability as a national grid for promoting rural electrification for its capacity of power supply and low energy cost as explained in Clause 2.1 of this Part.

(a) 220 kV Phnom Penh – Vietnam Cross Border Line (end of 2007)

(b) 115 kV Thai – Banteay Meanchey Cross Border Line (end of 2006)

(c) 115 kV Laos – Stung Treng Cross Border Line (end of 2008)

The grid extension plan will be reviewed and established in the Study with the following methodologies:

A GS will be constructed in each provincial town when the grid is extended to isolated provinces. The area within a 40 km radius from GS is considered as the target area of rural electrification in each province.

It is urgently required to extend the national grid to all over the country not only for achieving the national household electrification target of 70 % by grid quality electricity up to year 2030, but also for supplying cheap and stable power to the populations in the country. In this study, the national grid is planned to be extended to almost of all provinces up to year 2020.

The timing for extending a transmission line to isolated systems and its priority will be studied on the basis of review results of the Power Transmission Master Plan & Rural Electrification Strategy study made in 1998, study reports following the master plan and the grid extension plan of EdC for promoting effectively the rural electrification all over the country.

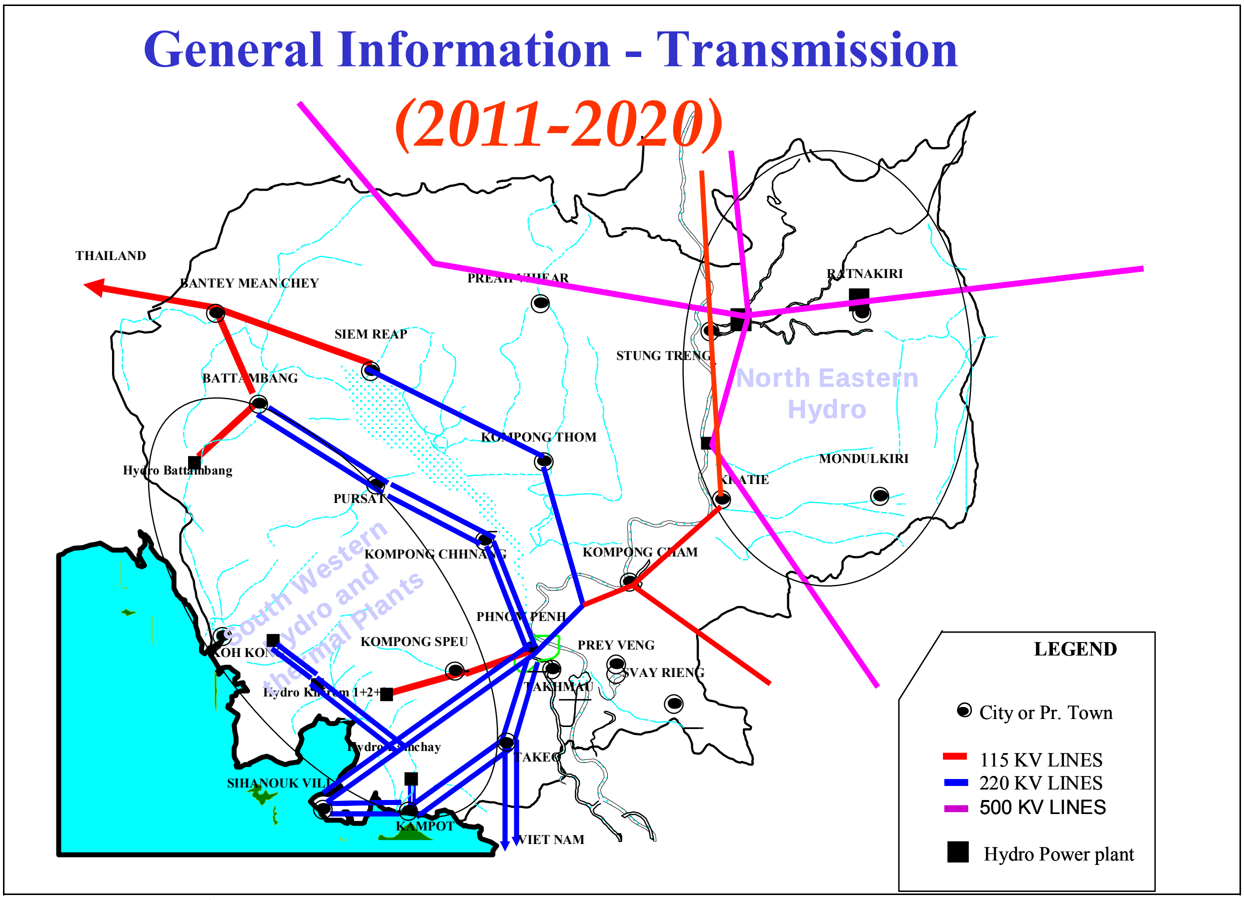
The study will be made with time slices as of 2008, 2012, 2016 and 2020 taking into account of decision of detailed scope of works, preparation of documents for procurement, tendering, construction, etc.

It is preferable for technical training and supporting of private suppliers in each province as well as for operation and maintenance of the 22 kV facilities extended from the GS for supplying cheap and stable energy to the private suppliers that EdC becomes a supplier of each provincial town area, if existing power suppliers of the provincial town area agreed to transferring their licensed area to EdC.

2.1.3 National Grid Extension Plan

A nationwide grid extension plan up to year 2016 had been proposed in the master plan study made by HECEC in 1998. Following this master plan study, series studies for implementing a 230 kV cross border transmission line for importing electric energy from Vietnam had been conducted, and the detail design works for the construction had been commenced in May 2005 under the financial assistance of WB and ADB-NDF. The proposed nationwide grid extension plan however was inevitably limited for promoting rural electrification all over the country in its priority and timing of the extension, because the plan was formulated linking with the development of new power plants aiming to supply power to the Phnom Penh system.

EdC has also prepared own grid extension plan up to year 2016 which is based on the above-mentioned studies and discussions with international agencies, officials of neighboring countries, consultants, etc. The EdC's extension plan is given in Figure 2.1.1. The EdC's plan aims to extend the national grid to major provinces for transmitting electric energy imported from the neighboring countries and seems having more viability than the other plans, though some transmission lines relating new power plant development and power wheeling with neighboring countries.



(Source: EdC)

Figure 2.1.1 National Grid Extension Plan of EdC

In this study, the grid extension plan has been reviewed and studied on the basis of EdC's plan, taking into account (i) to moderate required investment cost for the extension of the grid throughout the study horizon for increasing the viability of the plan, and (ii) to simplify the structure of grid as much as possible for easy operation, i.e. minimizing a number of 230/115 kV substations.

The results of the study are given in Table 2.1.1 and Figure 2.1.2.

It seems not to be feasible to integrate the power supply systems of Pailin and Koh Kong into the national grid by the extension of HV system, because both the provinces are located near the border with Thailand and its province towns and major district centers have been served by electric energy imported from Thailand by private providers and their electric tariff are in the similar level of EdC's ones.

For Mondol Kiri province, the demand level of the province is still in very low level and province town and its major district centers are located near the border with Vietnam. In addition to these situations, a micro-hydro power project is in on-going under the grant assistance of Japanese Government, which is a hybrid system consisting of three (3) micro-hydro power plants (total capacity: 370 kW) and a diesel power plant (250 kW), aiming to supply power to the province town and villages along the 22 kV lines from the micro-hydro power plants. In this study, therefore, it is proposed to import electric energy from Vietnam through a 115 kV single circuit line, when more electricity needed.

Table 2.1.1 Proposed National Grid Extension Plan up to 2020

Stage	Transmission Line	Grid Substation	Sub-Transmission Extension (Provinces)
Existing	1. Phnom Penh GS1-GS3 115 kV 1st cct line 2. Phnom Penh GS2-GS3 115 kV 1st cct line 3. Kirirom-GS1 115 kV 1cct line	1. GS1 115/22 kV substation 2. GS2 115/22 kV substation 3. GS3 115/22 kV substation 4. Kamp. Speu 115/22 kV substation	Nil
Up to 2008	1. (Vietnam)-Takeo-Phnom Penh 230 kV 2cct line (on-going) 2. Takeo-Kampot 230 kV 1st cct line (cmmitted) 3. WPP-Domnak Thom (P.P) 115 kV 2cct lines (on-going) 4. GS1-Domnak Thom (P.P) 115 kV 2nd cct line (on-going) 5. GS2-Domnak Thom (P.P) 115 kV 2nd cct line (on-going) 6. Reroute of Kirirom 1cct line to WPP substation (cmmitted) 7. (Thailand)-Banteay Meanchey 115 kV 1cct line (committed) 8. Banteay Meanchey-Battambang 115 kV 1cct line (committed) 9. Banteay Meanchey-Siem Reap 115 kV 1cct line (committed)	1. West Phnom Penh 230/115/22 kV substation (on-going) 2. Takeo 230/22 kV substation (on-going) 3. Kampot 230/22 kV substation (committed) 4. Upgrading of GS1 substation (on-going) 5. Upgrading of GS2 substation (on-going) 6. Upgrading of GS3 substation (on-going) 7. Banteay Meanchey 115/22 kV substation (committed) 8. Battambang 115/22 kV substation (committed) 9. Siem Reap 115/22 kV substation (committed)	1. Phnom Penh/Kandal 2. Kampong Speu 3. Takeo 4. Kampot 5. Banteay Meanchey 6. Battambang 7. Siem Reap
2009 to 2012	1. (Laos)-Stung Treng 115 kV 2cct line (cmmitted) 2. Kampot-Sihanoukville 230 kV 1st cct line 3. WPP-Kampong Chhnang 230 kV 1st cct line 4. WPP-Kampong Cham 115 kV 2cct line (*1) 5. WPP-Prey Veng 115 kV 1st cct line 6. Prey Veng-Kandol Chrum (Kp. Cham) 115 kV 1st 1cct line (*2)	1. Stung Treng 115/22 kV substation (committed) 2. Sihanoukville 230/22 kV substation 3. Kampong Chhnang 230/22 kV substation 4. Kampong Cham 115/22 kV substation 5. Prey Veng 115/22 kV substation 6. Kandol Chrum 115/22 kV substation (Kp. Cham)	1. Stung Treng 2. Sihanoukville 3. Kampong Chhnang 4. Kampong Cham-1 (West side of Mekong river) 5. Prey Veng 6. Kampong Cham-2 (East side of Mekong river)
2013 to 2016	1. Kampong Chhnang-Pursat 230 kV 1st cct line 2. Pursat-Battambang 230 kV 1st cct line 3. Kampong Cham-Kampong Thom 115 kV 1st cct line 4. Banteay Meanchey-Oddar Meanchey 115 1cct line 5. Stung Treng-Ratanakiri 115 kV 1st cct line 6. Stung Treng-Kratie 115 kV 1st cct line	1. Pursat 230/22 kV substation 2. Extension of Battambang S/S to 230/115/22 kV 3. Kampong Thom 115/22 kV substation 4. Oddar Meanchey 115 kV substation 5. Ratanakri 115/22 kV substation 6. Kratie 115/22 kV substation	1. Pursat 2. Kampong Thom 3. Oddar Meanchey 4. Ratanakiri 5. Kratie
2017 2020	1. Kandol Chrum-Krate 115 kV 1st cct line 2. Peam Ro SW/S (Prey Veng)-Svay Rieng 115 kV 1st cct line (*3) 3. Kampong Thom-Preah Vihear 115 kV 1st cct line 4. Kampong Thom-Siem Reap 115 kV 1st cct line 5. WPP-Peam Ro SW/S 2nd cct line 5. (Vietnam)-Mondolkiri 115 kV 1cct line	1. Peam Ro 115 kV switching station (Prey Veng) 2. Svay Rieng 115/22 kV substation 3. Preah Vihear 115/22 kV substation 4. Mondol Kiri 115/22 kV substation	1. Svay Rieng 2. Preah Vihear 3. Mondolkiri

Note:
(*1) Kampong Cham substation is planned to be located between Prey Chhoe and Province Town in order to cover allmost of all westside areas of Mekong.
(*2) Another substation is proposed to be constructed near Kandaol Chrum in order to cover the east side areas of Mekong.
(*3) Peam Ro switching station is planned to be constructed on the Prey Veng 115 kV line near Peam Chor district town of Prey Veng to feed Svay Rieng line. The switching station will be converted to a grid substation by means of addition of a transformer and 22 kV cubicles when needed.

Source: JICA Study Team

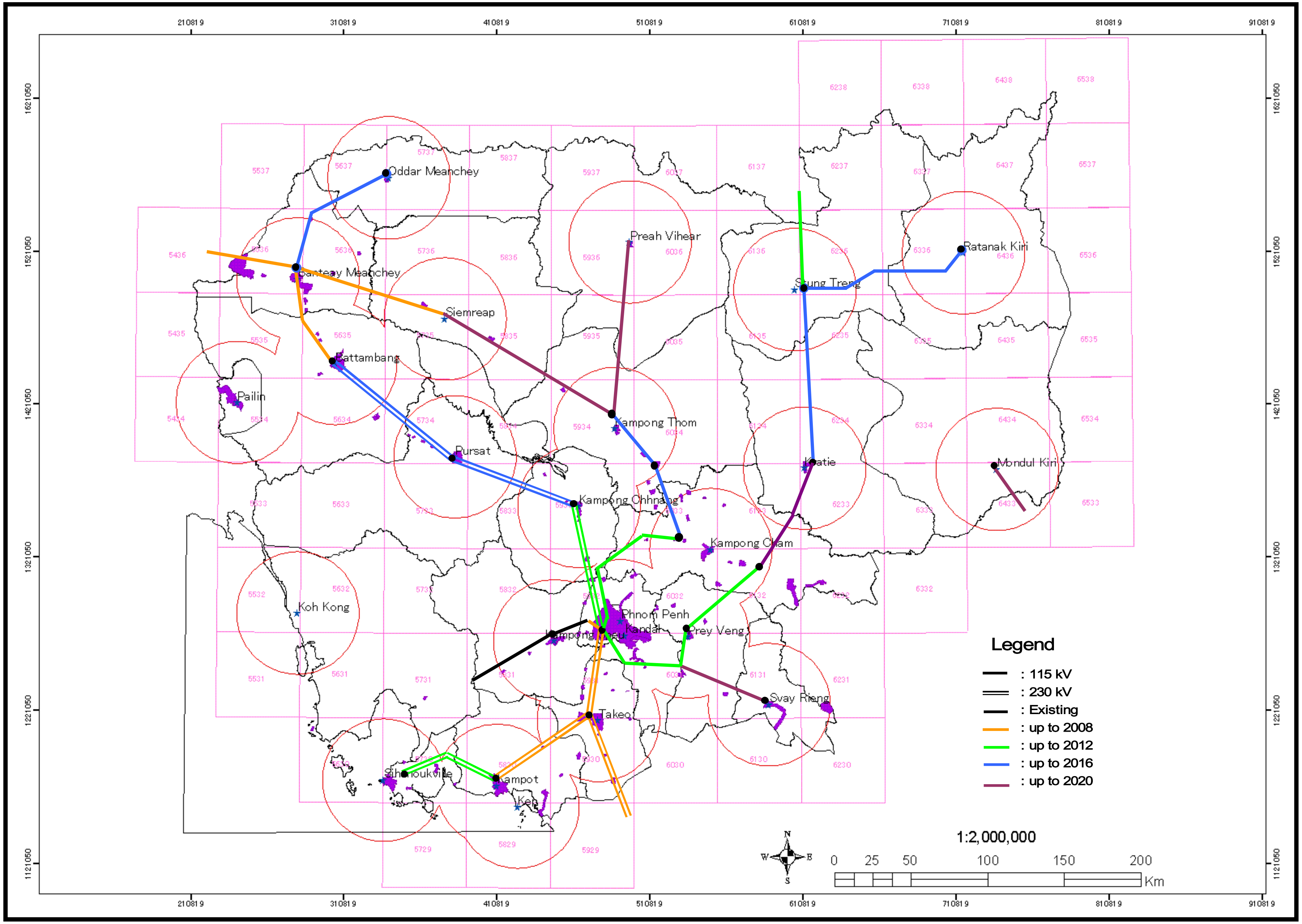


Figure 2.1.2 Proposed National Grid Extension Plan up to 2020

2.1.4 Extension Plan of Sub-Transmission Grid

As explained in Clause 2.1.2 of this Part 2, the target area to be electrified by the national grid is the area within 40 km radius from the GS. Electrification of not only provincial town areas but also its surrounding areas within 40 km from GS should be electrified as substantial part of the rural electrification program. If not, it will become difficult to achieve the target level of the electrification as well as the policy to supply stable and low cost electric energy to the customers throughout the country. Therefore, extensive extension of sub-transmission grid (MV line) from GS to respective surrounding non-electrified areas is essentially needed together with the expansion of HV grid.

Any person, private company and organization have been granted by the Electricity Law to get license of power provider and to distribute electric energy to their customers. Therefore, more attention to the right of these providers shall be paid when sub-transmission grids are extended to such areas.

As explained in the Clause 3.3.1 of Part-1, the national transmission license is necessary for extending MV line to the outside area from licensed distribution area and it can be issued to the state power transmission company under the Government control. In the country, only EdC meets to the terms and conditions for the national transmission license. Therefore, the extension plan of sub-transmission grids shall be integrated into the development plan of transmission and distribution system of EdC and be implemented by EdC initiative.

In addition to the above, it is noted that EdC has a right to extend their sub-transmission grids to outside areas in accordance with their development plan, but has no right to distribute electric energy to the customers outside of their licensed distribution areas except for wholesaling to REE and distributing to the bulk customers.

In the Study, for integrating the power providers in the provinces, it is assumed that the sub-transmission grid from GS will be extended in the following three stages.

(1) The First Stage

The MV lines will be extended in the areas within 40 km from GS in parallel with the transmission extension project to the isolated province town with the following priority:

(i) Along the national road with a single digit, where there are many villages and some existing power suppliers along the road, except for along national road in the sparce area of villages.

For the areas near the border with Vietnam, where some areas have been served by electric energy imported, the extension of MV line along a national road will be considered, because almost of all areas served by 15 kV or 22 kV over the distance of 60 km or more from GS in Vietnam and further extension to the un-electrified villages seems not to be technically feasible.

(ii) Along roads reaching to the district centers within 40 km from GS. As a result of site survey, it is noted that village density along road reaching to the district centers is similar to or higher than that along the national road in some areas.

The existing power providers along the extended MV lines will be connected with the first priority under this stage. However, it is rather difficult to integrate un-electrified villages along the lines to the national grid, because it will take long time to invite a private supplier or to organize CEC, and to construct a distribution system in the area. Therefore, a detail survey of the existing power providers shall be conducted during detail design stage of the extension project for minimizing its investment cost. MV lines shall be routed along national roads and other roads accessible of car for easy operation/maintenance of MV facilities and metering of sold energy (whole sale).

Standard design of trunk MV line of EdC should be applied to the MV lines to be constructed under this stage. Adoption of conductor AAC 150 mm^2 is preferable, because it is effective not only to minimize voltage drop at the end of line and to supply qualified electricity to the REE, but also to minimize forced outage areas by means of switching operation of the MV system.

It is preferable to implement the extension works above under the same project for extension of HV grid, including design, procurement of materials and its construction.

(2) The Second Stage

In this stage, non-electrified villages and communities along the MV lines extended from the GS under the first stage will be electrified with priority for effective use of the existing power transmission facilities. In this stage, the MV lines will be further extended to the other areas having relatively high density of population with reference to distribution maps of villages prepared under the Study. In addition to the new extension, branch lines from the MV lines constructed under the first stage will be also constructed for integrating licensed providers and/or the un-electrified areas apart 1 km more from the MV lines for effective use of the existing facilities, minimizing the project cost.

The electrification project in this stage needs a longer period for implementation, because there are many un-electrified villages or communities and they have some difficulty for providing funds and/or inviting new private suppliers for construction and management of the distribution facilities. Therefore, special assistance frameworks for supporting the rural electrification may become necessary in addition to financial assistance by international organizations or bilateral.

This stage shall be continuously extended up to integrate almost of all providers and/or CEC within 40 km radius from GS to the national grid.

Conductor size of MV lines will be decided on the basis of forecasted demand density of the subject areas. However, it is preferable to adopt AAC 100 mm^2 or bigger size taking switching operation for minimizing forced outage areas due to faults, except for small branch line for supplying limited areas.

(3) The Third Stage

This stage will be applied to the province in case some district centers are outside 40 km from GS and/or harmful effect of voltage drop at the end of MV line constructed under the previous stage is getting more and more obvious.

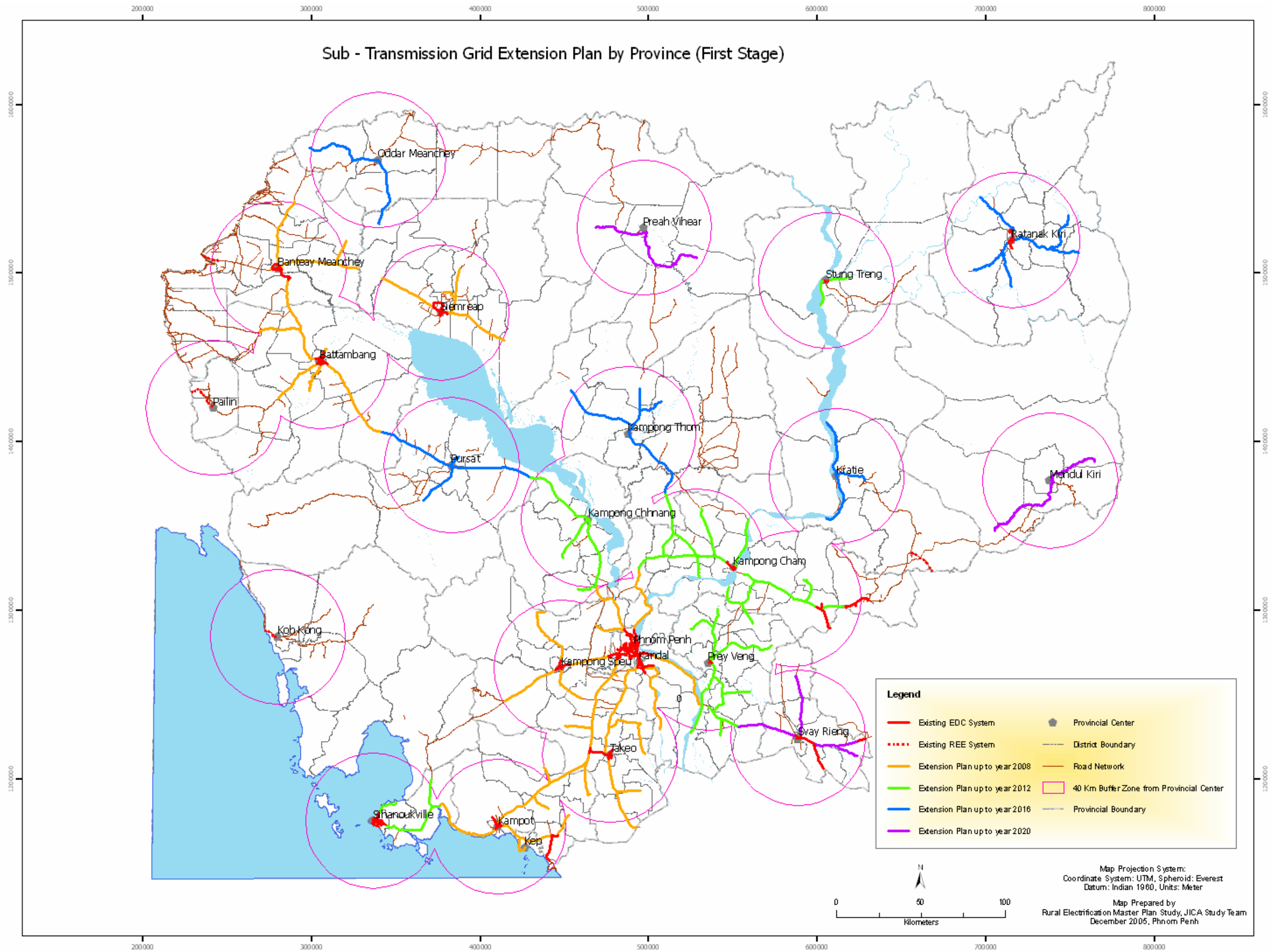
A new GS will be constructed around middle point of the transmission line near comparatively high demand density area and non-electrified villages will be electrified by means of the sub-transmission lines as well as improving voltage drop. If necessary, extension of transmission line from GS and new construction of GS will be made.

In this study, a sub-transmission extension plan by province has been made in accordance with the above-mentioned criteria and its results are given in Table 2.1.2 and Figure 2.1.3.

Table 2.1.2 Proposed Extension Plan of Sub-transmission Grids

Nos to be integrated to National Grid	Up to 2008	Up to 2012	Up to 2016	Up to 2020	Total
Provinces	8	6	5	3	22
District Centers	40	30	21	11	102
Present Licensees	43	25	8	1	77
Nos. of MV Feeders	28	16	13	7	64
Length of MV Line in km	1,127	755	498	272	2,652

Source: JICA Study Team



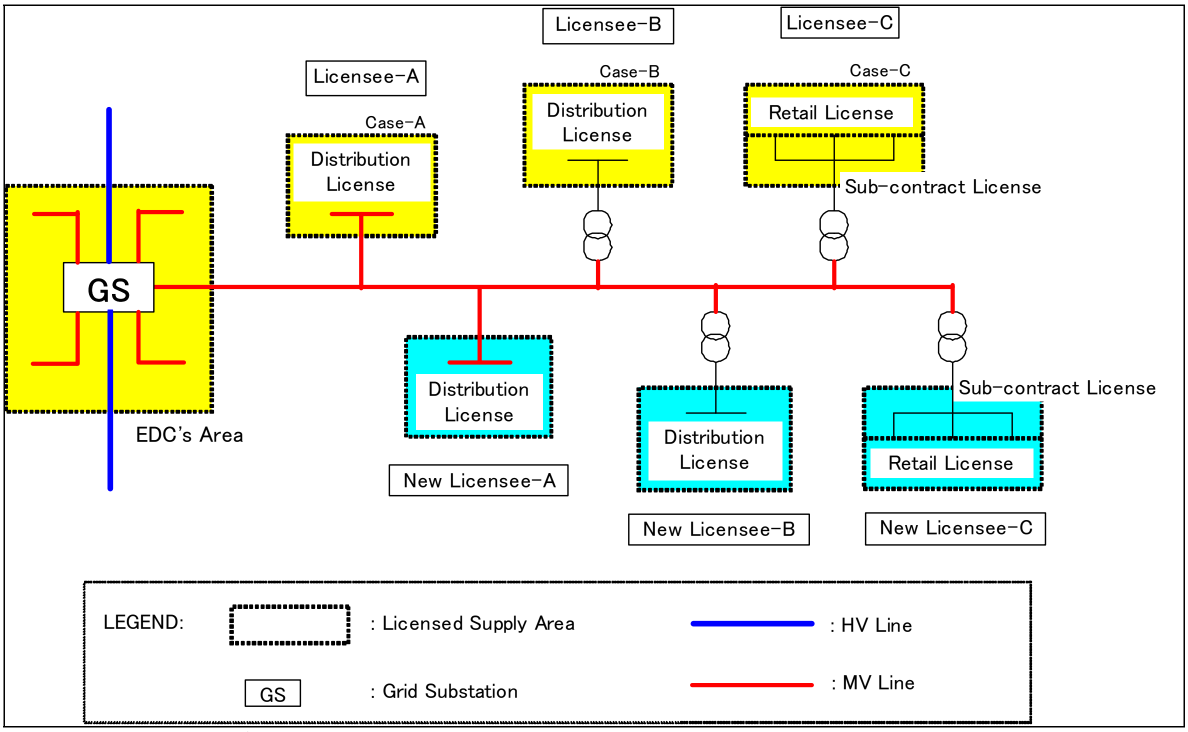
(Source: JICA Study Team)

Figure 2.1.3 Extension Plan of Sub-transmission Grids proposed by Stage

For the provinces of which provincial town area is served by EdC, the length of required MV lines of Table 2.1.2 was counted from the existing MV lines of EdC for avoiding double investment. For other provinces, the length of required MV lines was counted from the center of provincial town. Therefore, the above proposed plan shall be reviewed including the place of GS to be constructed, size of conductor, voltage drop at the end of MV lines, etc. under the more detail study stage.

2.1.5 Integration of Mini-Grid of Licensees into National Grid

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 2.1.4.



Source: JICA Study Team

Figure 2.1.4 Extension of Sub-transmission Grid and Integration of REEs

(1) Supply to existing licensees of EAC and non-licensed suppliers

Most of the licensees and non-licensed suppliers own and operate generating and distribution facilities, and supply to their customers in their supply areas. The connection of these suppliers to the extended national grid is easy. However, these existing generating facilities will need to be removed and sold in the market or scraped upon extension of MV line to the subject area. As for the licensees of EAC, their licenses should be changed from consolidated license to distribution license and non-licensed suppliers should newly obtain distribution licenses.

(i) For supplier having 22 kV distribution system (Case-A)

The sub-transmission line will be connected to the 22 kV lines of licensees through outdoor type, metal enclosed cubicle equipped with a section switch or load break switch and energy meter. Energy meter for whole sale electric energy to the supplier will be installed on the 22 kV circuit in the cubicle. EdC will own, operate and manage their facilities up to the cubicle.

(ii) For supplier having only LV distribution system (Case-B)

The sub-transmission grid will be connected to the LV line of the supplier through lightening arrester, fuse switch, distribution transformer and energy meter for whole sale electric energy. The energy meter will be installed on the secondary circuit of the transformer. EdC will own, operate and manage their facilities up to the energy meter which will be installed on the 22 kV pole. Type (single or 3-phase) and capacity of transformer are subject to the load conditions like size of load, purpose of usage of electricity, demand forecast of the suppliers. As for the type of transformer, single-phase is preferable and low initial cost including distribution facilities for the demand of only domestic use and small scaled water pomp. However, 3-phase transformer should be applied, if medium size of 3-phase load like rice mill is including in the demand. Adoption of single-phase transformer with small capacity is essential for promoting rural electrification by the grid. At present, EdC has standard specifications of transformer for only 50, 100, 160, 250 and 400 kVA, 3-phase. However, 25 and 50 kVA, single-phase transformers have been procured for the Banlung (Ratabakiri) power supply system under the on-going Provincial Power Supply Project.

iii) For supplier having no intention to purchase energy from EdC

The sub-transmission grid will pass through the supply area of the licensee without connection to the distribution system, since connection to the national grid is subject to the decision of beneficiaries.

iv) In case, the supplier wants to close his business

The distribution systems of most of all licensed and/or non-licensed suppliers are far from the technical standard and very poor. The rural electrification program based on the Government policy will give very good chance for rehabilitating and grading-up the existing distribution facilities owned by private suppliers, which is needed for the safety of population in the electric supply areas.

EAC has set up an action plan to promote licensees to improve their situation. This plan has the following three programs:

(a) Advising, Guiding and Training

This methodology is carried out in 3 ways. The first is to visit and study the site of licensees and to advise them at site how to make improvement in the facilities and operation, and to maintain required data. The second is to conduct workshop and exchange idea on improvement of the facilities and its operation, and the third is to provide training to licensees.

(b) Incentive and Penalties

In cases, where improvement is made to the facilities to comply with technical standards and the business is managed efficiently, the licensees have the right to apply for extension of the terms of license and EAC will grant a longer license. In cases the licensee fails to properly improve its facilities, operation and management, EAC will be forced to select another person, who has the ability to provide a better service, to substitute it and will revoke its license and not allow it to continue the electric power service.

(c) Financial Monitoring and Competition

EAC has 2 programs. The first is to request the licensee to prepare the financial report and then monitoring of financial statement by EAC. The second is to set the tariffs for the small providers through tariff table that will induce a competition between providers with similar business conditions.

Therefore, some existing providers, especially no-licensed providers, are required to grade up their poor distribution system to the technical standard level prior to the grid connection, because they are required to get distribution licenses. There are many suppliers who cannot meet such requirements due to its business scale and wish to close their business.

When existing supplier wish to close their business, the following are considered:

- A new supplier will be selected through a competitive tender. The selected supplier has responsibility to receive, rehabilitate and maintain the existing power supply system to comply with the technical standards. He should obtain a distribution license to own and operate a power supply system. In case, the selected supplier construct new distribution facilities, the old facilities shall be dismantled the existing distribution facilities by the old supplier.

- The following will be considered when a new supplier is selected through a competitive tender, but he has less capability to own, operate and maintain the distribution facilities.

  In this case, a competitive tender for the selection of supplier will be done again. The selected supplier should get the Distribution License and to select through competitive tender sub contractor in order to own, rehabilitate and operate the distribution facilities. The sub contractor shall get a Sub-contract License. In this case, the distribution licensee own, operate and manage energy meters only like a retail licensee, then any person including CEC may become licensee.

  As a sub-contract licensee, other existing licensees, any persons (no limitation of living area) and EdC will be allowed to submit their proposal for such competitive tender.

- New suppliers as a distribution licensee and a sub-contract licensee will be selected through a competitive tender, but all the bidders do not meet the requirements. In this case, power supply in the subject area will be stopped from the viewpoint of Electricity Law and the existing power supply facilities shall be removed by the existing licensee with his expense.

(2) Power supply to non-electrified communities and/or areas

There are many non-electrified communities/villages in the areas along the sub-transmission grids to be extended to the licensees of EAC. Electrification of these communities/villages is important to achieve the national target of electrification.

For promoting electrification of these communities/villages, the similar procedure explained above for selecting new supplier should be taken from the planning stage and necessary funds should be provided. In addition to the above, special support for construction of power supply facilities, operation and maintenance of the system and establishing managing system should be provided. The special support for the electrification of the non-electrified areas should be also applied to the all existing suppliers for the rehabilitation and grade-up of their distribution facilities.

In case, no REE offered to the competitive tender for selecting electricity provider of the non-electrified area, village people are required to establish CEC, to provide necessary initial fund and to construct distribution facilities for supplying electricity to the customers. However, power supply by CEC is expected to reduce electricity tariff than that of REE. In case of receiving electricity from sub-transmission grid, construction cost of distribution facilities accounts for a large part of the initial cost. However, many villages may be difficult to provide required initial fund for construction of distribution facilities, even above-mentioned special supports are applied. Therefore, the following supports are recommended for making easy to construct distribution facilities.

(a) To allow to construct LV pole at the middle of MV poles constructed by EdC and to hung LV ABC cables on MV poles and

(b) To allow to install energy meter boxes on the MV poles.

If above countermeasure is applied to CEC and/or existing REE for expansion of their supply area, construction cost of distribution facilities will be much decreased and rural electrification of non-electrified villages will be accelerated.

2.1.6 Power Demand Forecast of On-Grid Areas

The main purpose of the grid extension is to supply stable power at reasonable price to customers throughout the country. In this Clause, forecast of power demand on the national grid was examined.

(1) Target Level of Electrification

The Government set a target level of electrification at 70 % of rural households to be electrified by the year 2030 as part of their rural electrification policy in the draft of Cambodia Energy Strategy, January 2005, subject to availability of sufficient funds for investment and adequate wealth within the rural community for the increased purchase of electricity. On the other hand, in some documents a target level of electrification with grid-quality electricity is indicated as 70 % by the year of 2030. In the Study, the later will be considered for establishing the grid extension plan. Then, the demand forecast will be made on the assumption that 70 % of households in the country have a access to grid-quality electricity up to the year 2030.

(2) Demand on the National Grid

Power supply industries serving grid-quality electricity are managed by not only state owned company (EdC) but also private companies with licenses of EAC as clearly mentioned in the Electricity Law. However, actually, there are many private suppliers operating without license and there are many un-electrified communities/villages surrounding areas of these electric providers.

There are several demand groups in the country, i.e demand of the area covered by national grid (the Phnom Penh system only at present), isolated areas served by EdC, isolated areas served by licensees of EAC, isolated areas served by non-licensees and large latent demand of non-electrified areas. Therefore, power demand forecast of the areas electrified by the national grid will be made on the assumption that above-mentiond sub-transmission grid extension will be made as scheduled efficiently and timely. Number of households customers and their power demand due to the extension of the national grid are gradually increased with the promotion of the connection of not only the existing REE but also new REE and/or CEC for un-electrified communities/villages.

It is noted that EdC has a right to extend their MV grid to outside of their licensed distribution areas, but they has no right to sell directly electric energy to the customers in such outside areas except for whole sale to REE and/or CEC, and sale electricity to bulk customers via their MV grid.

(3) Basic Demand for Forecast

Actual data like number of customers and sold energy of certain years for making demand forecast as a core of basic data. In this study, actual data in 2004 was adopted as basic data and demand forecast by province was made. Actual electric energy demand of grid-quality electricity level in the country is categorized in the following 3 groups:

1) Demand of the areas served by EdC

Number of customers and sold energy for domestic demand by province and sold energy of other tariff groups in 2004 are collected and used.

2) Demand of areas served by licensees of EAC

Number of customers and sold energy of distribution and consolidated licensees reported in the Report on Power Sector of the Kingdom of Cambidia for the Year 2004 of EAC are used. However, data of distribution licensees near the border of Thailand are not used, since some areas are far from province town more than 40 km or the extension of MV grid seems not to be feasible from the economic point of view.

3) Demand of areas served by non-licensed providers

Number of customers served with grid-quality electricity by non-licensees is estimated on the basis of questionnaire to DIME and the above-mentioned information of EAC, because it is clear from site survey that most of reply from DIME includes the number of customers of licensees. For the sold energy by district, averaged unit consumption by customer of each province is applied, since sold energy by providers is not required in the questionnaire.

(4) Estimate of New Customers

A trend of improving the electrification level is estimated by using similar formula for population forecast. In the Study, a logistic curve (S-shaped curve) is used. A typical curve is derived on the assumption that target of electrification of 70% up to 2030 consists of 60% by the national grid extension and 10% by the isolated mini-grid which have not been connected to the national grid.

In addition to the above, the trend of increasing electrification ratio by province is estimated as follow:

1) Before connecting to the national grid by HV system, annual mean increase rate worked out from the past record will be applied.
2) After connecting to the HV system, electrification ratio will be increased with the preset curve.

(5) Energy Consumption per Household

Domestic demand will be worked out based on the number of customers and its unit energy consumption. However, no detail information on the number of customers is available except for EdC. For such demand supplied by private providers, all customers are considered as domestic customers.

In general, unit energy consumption is gradually decrease due to demand level of newly connected customers, when rural electrification program is actively promoted. However, in this study, unit energy consumption level at present is applied throughout study horizon for making simple its estimate.

(6) Households Projection

Household projection between the year 2004 and 2020 is worked out on the basis of population projection up to 2020 provided by NIS.

(7) Results of Demand Forecast

The results of demand forecast on the national grid by province are given in Table 2.1.3.

Table 2.1.3 Summary of Demand Forecast on the National Grid (2004 – 2020)

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Averaged Increase Rate
I. Number of Domestic Customers by Province																			
Up to 2008	Phnom Penh/Kandal	157,438	169,201	181,891	195,533	211,671	228,450	245,752	263,510	281,657	300,125	318,850	337,770	356,829	375,977	395,173	414,380	433,570	6.54
	Kampong Speu	5,295	5,700	6,127	6,587	7,507	8,557	9,748	11,095	12,617	14,332	16,263	18,431	20,859	23,574	26,598	29,959	33,682	12.26
	Banteay Meanchey	44,808	48,280	51,901	57,010	62,417	68,114	74,087	80,317	86,786	93,473	100,356	107,414	114,624	121,967	129,423	136,975	144,608	7.60
	Battambang	17,228	18,516	19,904	23,653	26,659	29,998	33,696	37,778	42,268	47,187	52,555	58,388	64,699	71,494	78,775	86,538	94,772	11.24
	Siem Reap	12,650	13,594	14,614	16,575	18,780	21,248	24,001	27,065	30,464	34,220	38,357	42,896	47,855	53,249	59,091	65,386	72,139	11.49
	Takeo	10,108	10,872	11,687	12,564	14,171	15,971	17,980	20,218	22,703	25,457	28,500	31,852	35,533	39,559	43,948	48,712	53,861	11.02
	Kampot	7,767	8,358	8,985	9,658	10,901	12,297	13,856	15,592	17,521	19,659	22,022	24,623	27,479	30,602	34,004	37,694	41,680	11.07
Up to 2012	Stung Treng	2,376	2,554	2,746	2,952	3,173	3,411	3,824	4,278	4,774	5,312	5,894	6,521	7,192	7,908	8,667	9,467	10,308	9.61
	Sihanoukville	9,556	10,272	11,042	11,870	12,761	13,718	15,160	16,694	18,323	20,045	21,857	23,754	25,732	27,786	29,911	32,101	34,352	8.33
	Kampong Chhnang	6,285	6,758	7,265	7,810	8,395	9,025	9,702	10,429	11,848	13,440	15,224	17,217	19,437	21,902	24,629	27,636	30,939	10.47
	Kampong Cham	31,624	33,973	36,521	39,260	42,204	45,369	48,772	52,430	58,687	65,582	73,143	81,406	90,399	100,145	110,661	121,956	134,027	9.45
	Prey Veng	10,337	11,122	11,957	12,853	13,817	14,854	15,968	17,165	19,251	21,586	24,176	27,042	30,205	33,685	37,502	41,677	46,226	9.81
Up to 2016	Pursat	7,325	7,868	8,459	9,093	9,775	10,508	11,296	12,143	13,054	14,033	15,739	17,625	19,696	21,961	24,428	27,103	29,991	9.21
	Kampong Thom	7,956	8,559	9,201	9,891	10,633	11,430	12,287	13,209	14,200	15,265	17,217	19,390	21,803	24,474	27,421	30,660	34,207	9.54
	Oddar Meanchey	949	911	979	1,052	1,131	1,216	1,307	1,405	1,511	1,624	1,860	2,126	2,429	2,773	3,162	3,602	4,098	9.57
	Ratanakiri	2,141	2,301	2,473	2,659	2,858	3,072	3,303	3,551	3,817	4,103	4,411	4,742	5,359	6,045	6,803	7,638	8,553	9.04
	Kratie	2,758	2,967	3,189	3,428	3,686	3,962	4,259	4,579	4,922	5,291	5,688	6,114	6,954	7,896	8,955	10,140	11,463	9.31
Up to 2020	Svay Rieng	6,256	6,730	7,234	7,777	8,360	8,987	9,661	10,386	11,165	12,002	12,902	13,870	14,910	16,029	17,909	19,991	22,274	8.26
	Previhear	750	829	891	958	1,030	1,107	1,190	1,279	1,375	1,478	1,589	1,708	1,836	1,974	2,257	2,577	2,941	8.92
	Mondolkiri	430	462	497	534	574	617	664	713	767	824	886	953	1,024	1,101	1,257	1,433	1,631	8.69
Whole Country	Total	344,037	369,825	397,562	431,717	470,503	511,912	556,513	603,837	657,709	715,039	777,489	843,842	914,855	990,101	1,070,574	1,155,625	1,245,322	8.37
	New Customers	–	25,788	27,737	34,155	38,787	41,409	44,601	47,324	53,872	57,330	62,451	66,353	71,013	75,246	80,473	85,051	89,697	
	Total Households (1000)	2,290.3	2,335.9	2,382.6	2,430.3	2,478.9	2,528.7	2,579.5	2,631.4	2,684.4	2,738.6	2,793.9	2,850.4	2,908.2	2,967.2	3,027.6	3,089.2	3,152.2	2.02
	Electrification Ratio (%)	15.02	15.83	16.69	17.76	18.98	20.24	21.57	22.95	24.50	26.11	27.83	29.60	31.46	33.37	35.36	37.41	39.51	6.23
II. Sold Energy for Domestic Customers on Grid by Province (MWh)																			
Up to 2008	Phnom Penh/Kandal	257,185	276,474	297,209	319,500	345,870	373,287	401,559	430,575	460,228	490,404	521,001	551,916	583,059	614,346	645,713	677,097	708,453	6.54
	Kampong Speu	1,251	1,345	1,446	1,554	1,772	2,019	2,301	2,618	2,978	3,382	3,838	4,350	4,923	5,563	6,277	7,070	7,949	12.25
	Banteay Meanchey				7,183	7,865	8,582	9,335	10,120	10,935	11,778	12,645	13,534	14,443	15,368	16,307	17,259	18,221	7.25
	Battambang				17,101	19,274	21,689	24,362	27,313	30,560	34,116	37,997	42,215	46,777	51,690	56,954	62,567	68,520	11.15
	Siem Reap				21,266	24,095	27,261	30,793	34,724	39,085	43,904	49,212	55,036	61,398	68,318	75,814	83,890	92,554	11.87
	Takeo					3,925	4,424	4,980	5,600	6,289	7,052	7,895	8,823	9,843	10,958	12,174	13,493	14,919	11.77
	Kampot					3,957	4,464	5,030	5,660	6,360	7,136	7,994	8,938	9,975	11,109	12,343	13,683	15,130	11.54
Up to 2012	Stung Treng							1,147	1,283	1,432	1,594	1,768	1,956	2,158	2,372	2,600	2,840	3,092	10.42
	Sihanoukville							17,918	20,767	22,794	24,936	27,190	29,550	32,011	34,566	37,209	39,934	42,734	9.08
	Kampong Chhnang									5,557	6,303	7,140	8,075	9,116	10,272	11,551	12,961	14,510	12.75
	Kampong Cham									22,184	24,790	27,648	30,771	34,171	37,855	41,830	46,099	50,662	10.87
	Prey Veng									7,007	7,857	8,800	9,843	10,995	12,261	13,651	15,170	16,826	11.57
Up to 2016	Pursat											6,296	7,050	7,878	8,784	9,771	10,841	11,996	11.34
	Kampong Thom											5,492	6,185	6,955	7,807	8,747	9,781	10,912	12.12
	Oddar Meanchey											744	850	972	1,109	1,265	1,441	1,639	14.07
	Ratanakiri													1,543	1,741	1,959	2,200	2,463	12.40
	Kratie													4,096	4,651	5,274	5,972	6,752	13.31
Up to 2020	Svay Rieng															11,963	13,354	14,879	11.52
	Previhear															1,508	1,721	1,965	14.15
	Mondolkiri															377	430	489	13.91
III Total Energy Demand and Peak Demand																			
Domestic Energy (MWh)		258,436	277,819	298,655	366,605	406,758	441,727	497,425	538,663	615,408	663,253	725,660	779,093	840,311	898,772	973,288	1,037,804	1,104,667	9.50
Other Energy Demand (MWh)		294,617	323,659	355,400	445,425	504,380	558,784	641,679	708,341	824,647	905,340	1,008,667	1,102,416	1,210,048	1,316,700	1,450,199	1,572,274	1,701,188	11.58
Total Energy Demand (MWh)		553,054	601,478	654,055	812,029	911,138	1,000,511	1,139,104	1,247,004	1,440,054	1,568,593	1,734,327	1,881,509	2,050,358	2,215,472	2,423,488	2,610,078	2,805,855	10.68
Sent Out Energy (MWh)		655,277	710,547	770,383	953,646	1,066,907	1,168,139	1,326,082	1,447,480	1,666,730	1,810,263	1,995,774	2,158,932	2,345,948	2,527,635	2,757,096	2,960,951	3,174,044	10.36
Peak Demand (MW)		120.7	130.8	141.8	175.6	196.4	215.1	244.2	266.5	306.9	333.3	367.5	397.5	431.9	465.4	507.6	545.2	584.4	10.36