Chapter 7 Selection of the Target Villages for PV Electrification

Chapter 7 Selection of the Target Villages for PV Electrification

7.1 PV Electrification Rate and Tariff Level

As mentioned in Chapter 2, the electrification rate by means of grid expansion is projected to reach about 60% of households in grid-connected villages within 10 years. Given the projection and in overall consideration of the following factors, the target PV electrification rate is set at over 40% of households at P40/m/50Wp tariff level in the target villages during the projected Master Plan period for PV rural electrification (from 2003 to 2012) based on the following facts and assumptions.

1) The grid electrification rate is projected to reach 60% as shown in Section 2.2.4.
2) On the other hand, in case of PV electrification;
   a) The service level accomplished by PV electrification is more limited than that of grid electrification as described in this Chapter
   b) Villages to be served by PV electrification are located in rural areas with lower income than those accessible to the grid
   c) Tariff for PV electrification beneficiaries is higher than that of BPC's tariff (grid electrification beneficiaries) to enable the implementation body of PV electrification to sustain its operation, giving the priority to cost recovery as described in this Chapter, Chapter 9 and 13.
   d) The tariff level for SHS should be the same level as the monthly expenditure for lighting and battery for electrical appliances spent in rural households. Such expenditures are supposed to be P30 to P50/m as described in Section 6.2.3.1 (3) hereof. The tariff level for SHS should also be the similar level as grid-connected user's tariff level including monthly charge for connection fee based on RCS, which is supposed to be P50/m per rural household. Taking the above-mentioned consideration into account, the tariff level for SHS (50Wp) is set P40/m. In this case, if Figure 6.2-11 curve for ability-to-pay is applied, expected electrification rate is supposed to be 55%. However, as described in Section 6.5.3 hereof, the most provable ability-to-pay curve is assumed as Figure 6.5-1 and the attainable electrification rate is assumed as 40%.

Taking the above into consideration, target PV electrification rate will be set up at 40% which is rather lower than that of grid electrification rate.

At the same time, to achieve the objective of PV rural electrification, efforts will be made to raise the electrification rate by introducing the BCS system to the villages and localities of specific size, thereby to supply electricity to low income households as far as possible. If accomplished, this will exceed the levels of neighboring countries except South Africa (that aims at universal access to electricity by 2010) and North African countries where electrification has already reached a significant level.

7.2 Least-cost Options for Rural Electrification

The service provided by SHS is more limited than that provided by the grid in that SHS is essentially confined to lighting, with a few additional low-load uses such as cassette players or small TVs used for a few hours in the evening. Nevertheless, a long grid extension makes neither economic nor technical sense for villages with such small loads, unless consumer density is extremely high. If a grid extension is provided where the density is low, the cost of the electricity will far exceed what can be recovered with locally acceptable tariffs, and the grid extension cannot be justified economically. The same arguments apply to isolated grids supplied by diesel generators.

Where a substantial prospect for substantial load growth exists, however, the grid connection is technically the ideal way to provide electricity. Once the main feeder line is in position, no significant constraints remain on the number of consumers that can be connected or the loads they can impose on the system. The grid connection, therefore, opens the possibility of substantial growth in domestic, commercial, and small industrial consumption of electricity at low marginal costs. Hence, where it is economically justifiable, the grid is the first-choice option, and PVs are not likely to be competitive. The two options are sufficiently different to be mutually exclusive.
Thus, it is obvious that power consumption level is important for the selection of PV electrification villages as well as the distance from the existing grid tie-in point.

7.2.1 Rural Household Electricity Consumption

Household electricity consumption shows large local and international variations, as is the case in most features of rural energy use. These variations are broadly related to income. Families with higher disposable incomes tend to consume more electricity. Consumption may also be significantly affected by costs, climate, culture, reliability of supply, and a variety of other factors.

Power consumption according to use of various electric appliances is shown in Table 7.2-1.

Where lighting is the only significant use of electricity, monthly consumption tends to be in the range of 10 to 20 kWh monthly. A radio, cassette player and a small fan can be used for 10 hours each day for an additional consumption of 10 to 15 kWh per month. A small color TV used for 6 hours a day will add a further 10 kWh a month. A family could accommodate all these uses, as well as that of an electric iron, within a consumption range of 50 to 60 kWh monthly.

Table 7.2-1 Power Consumption Ladder

Appliance	Power Consumption	
Lighting only	10 to 20	kWh/m
Light +Radio and Cassette Player (10h)	20 to 35	kWh/m
Light +Radio and Cassette Player (10h)+ Color TV (6h)	30 to 45	kWh/m
Light +Radio and Cassette Player (10h)+ Color TV (6h)+ Iron	80 to 105	kWh/m
Light +Radio and Cassette Player (10h)+ Color TV (6h)+ Iron+ Fridge	130 to 155	kWh/m
Light +Radio and Cassette Player (10h)+ Color TV (6h)+ Iron+ Fridge+ Freezer	230 to 255	kWh/m

(Source: Reference List No.88)

The use of appliances with greater energy requirements pushes consumption up considerably. A refrigerator uses about 50 kWh and a freezer around 100 kWh monthly. Cooking, depending on the method used and the type of meals cooked, can use from 10 kWh up to 50 kWh each month. Water heating and, above all, air conditioning bring much higher consumption levels.

Based on an ESMAP (1992) survey of a total of 2,500 rural households in the Philippines, in general, it shows that for each end-use, consumption increases with income. It also shows that some end uses – such as freezers, water heating, and air conditioning – are entirely confined to the upper-income groups. The averaged total consumption for each income group, ranging from 17 kWh monthly for the lowest up to 69 kWh monthly for the highest.[1)]

The general trend in power consumption in rural households in South Africa after connection to the grid shows that the consumption level is almost same as in the case of the Philippines (Refer to Appendix 7.1-4).

[1)] Reference List No.88

The average consumption in rural households in Botswana is 122Wp (14.6kWh/m) and 68Wp (8.2kWh/m) obtained though the socio-economic survey mentioned in Chapter 6 and the Dissemination Project respectively, both of which are lower than the aforementioned consumption. (Refer to Table 6.5-1, Chapter 6)
The reason why rural households in Botswana have relatively lower power consumption than the other counties is considered that because the grid has already been extended to major villages, most of un-electrified villages are as small as having population less than 1000 which is corresponding to 200 households approximately, and such villages have neither small industries nor sufficient income level villagers who can buy electric appliances. The average power consumption per household in such village is, therefore, assumed to be maximum 200Wp (24kWh/m) even including the demand of public facilities, on which the life cycle cost evaluation between PV and grid electrification is done from the next section.

7.2.2 Cost Comparison of SHS Versus the Grid-based Electrification

Break-even distances for various village sizes on the basis of costs for PV and Grid electrification at electricity consumption levels of 100Wp (12.2kWh/m), 200Wp (24.3kWh/m), and 400Wp (48.7kWh/m) equivalent per household are calculated. The study was to find a break-even distance for the various consumption levels, assuming that there is no limitation of consumption due to affordability of each household (thus neglecting the maximum consumption level of 24Wh/m in each village estimated in 7.2.1.). The results are shown in Figure 7.2-1.

In the case of per household electricity use in an SHS scheme being on the order of 200 Wp (24.3kWh/m), when the village is made up of 50 households of actual connection, a distance from the grid of 13.7 km and when the village is made up of 200 households a distance from the grid of 53.5 km is taken as the breakeven point. For such villages that are located far from the breakeven points, SHS schemes are advantageous.

In Botswana most of un-electrified villages and localities have less than 200 households (1,000 population) and actual connection rate to electricity will be up to 60% of the total households. Average consumption will be less than 24kWh/m. Therefore, the villages and localities that are located from the grid in a distance far from the breakeven point for the consumption level of 200Wp can be the candidates for PV electrification.

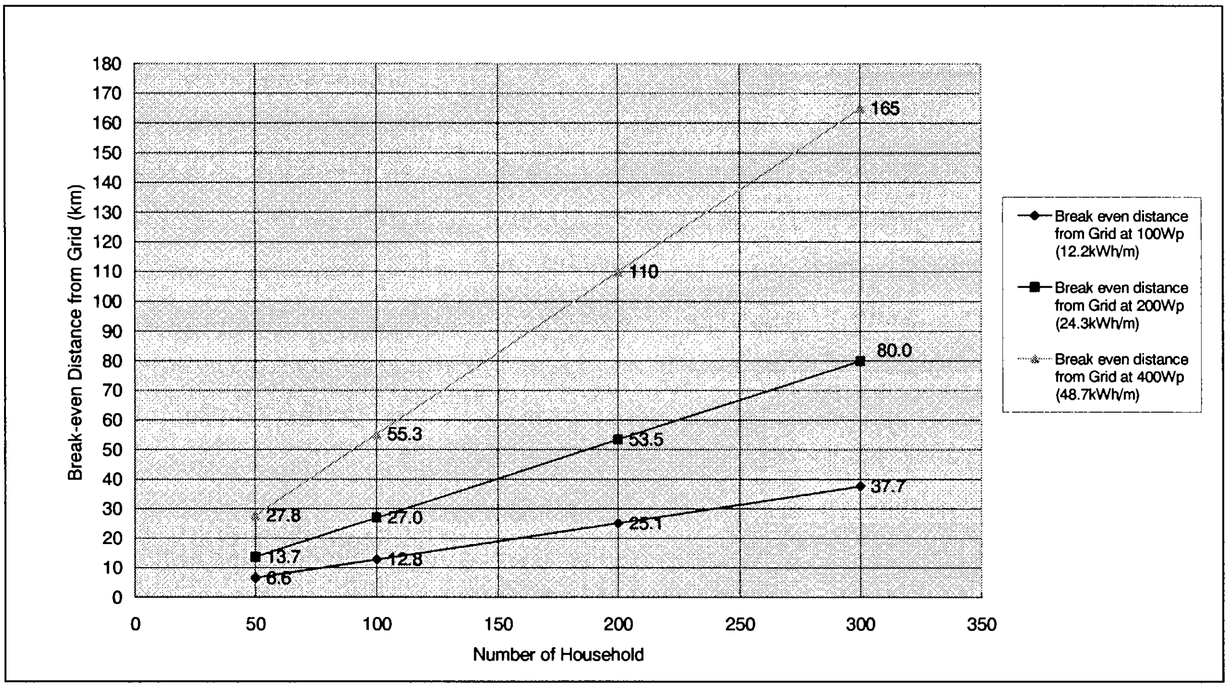

Figure 7.2-1 Break-even Distance from Grid for Grid Versus SHS

7.2.3 Comparison of Cost Recovery of SHS Versus the Grid

In the above analysis, a breakeven point was determined under the assumption that the electrification cost is recovered from electricity charges (or if not fully recovered, the recovery rate is assumed to be same).

Then, simulation was made using actual data from BPC's grid extension project covering 72 villages to compare cost recovery in the case of PV electrification.

The results are summarized in Table 7.2-2. (Detail: Appendix Table 7.1-4)

Assumptions

1) 72 villages (estimated population of 109,577 in total) were supposed to have 21,915 households (assuming that each household consists of five persons), and 60% of which, 13,149 households would be electrified by grid connection or the PV system.
2) Electricity demand was assumed to be ranging between 100Wp and 200Wp in case of SHS. On the other hand, electricity demand by households connected to the grid would be expected to be larger. Namely case studies for the loads of 100Wp (12.2 kWh/m) equivalent, 20, 50 kWh/m and 100 kWh/m were examined.

3) Capital investment and system operation and maintenance costs required during the 20-year period are discounted at an annual rate of 15% to obtain their net present value (NPV). Then, a) an incremental cost due to grid connection (P/kWh) and b) the SHS cost (P/kWh) were estimated.
4) In addition, revenues are estimated on the basis of electricity charges under BPC's current tariff rate structure in the case of grid connection, and the monthly rate of 50Wp – P40/m in the case of PV electrification. Based on the estimated revenues (NPV), the cost recovery rate over 20 years is determined to recoup the above total cost.

Table 7.2-2 Comparison of Grid Extension and SHS (Case Study in 72 Village Electrification)

		SHS100Wp	SHS200Wp	Grid Extension	Grid Extension	Grid Extension	Grid Extension
Electricity consumption per household	kWh/m	12.2	24.4	12.2	20	50	100
No. of households (60% of total households in 72 villages)	No.	13,149	13,149	13,149	13,149	13,149	13,149
Total electricity consumption	kWh/y	1,919,754	3,839,508	1,925,014	3,155,760	7,889,400	15,778,800
Discounted Grid Extension Cost	kp			149,840	149,840	149,840	149,840
Discounted Connection Cost (reticulation Cost)	kp			25,780	25,780	25,780	25,780
Discounted present value of investment costs for 20 years at a 15% discount rate	kP	158,226	316,452	175,620	175,620	175,620	175,620
Discounted present value of operation costs for 20 years at a 15% discount rate	kP	29,084	32,996	29,317	29,890	32,090	35,758
Discounted present value of electricity consumption for 20 years at a 15% discount rate	kP	29,084	32,997	11,931,897	19,560,487	39,120,974	39,120,974
Discounted Total Costs excluding Connection Cost (reticulation cost)	kP			179,157	179,730	181,930	185,598
Discounted Total Costs including Connection Cost (reticulation cost)	kP	187,310	349,448	204,937	205,510	207,710	211,378
Total costs per kWh (NPV)	P/kWh	15.7	14.7	17.2	11.1	4.4	2.2
Subsidy(NPV)	kP	108,973	217,948	199,374	199,374	199,374	199,374
Subsidy/ Total cost	%	58.2%	62.4%	97.3%	97.0%	96.0%	94.3%
Subsidy per household	P/house	8,288	16,575	15,163	15,163	15,163	15,163
Tariff	P/m, P/kWh	P80/m	P160/m	P0.2523/kWh	P0.2523/kWh	P0.2523/kWh	P0.2523/kWh
Discounted present value of tariff revenues for 20 years at a 15% discount rate	kP	78,242	156,484	3,010	4,935	12,338	24,676
Discounted present value of collected connection fee for 20 years at a 15% discount rate	kP			34,303	34,303	34,303	34,303
Discounted Total Recovered cost	kP	78,242	156,484	37,313	39,238	46,641	58,979
Percentage of costs recovery (excluding grid connection cost)	%			1.7%	2.7%	6.8%	13.3%
Percentage of costs recovery (including grid connection cost)	%	41.8%	44.8%	18.2%	19.1%	22.5%	27.9%

General findings are as follows:

a) The incremental cost for grid extension and connection is affected by electricity demand. Even if the grid connection rate of 60% is achieved, the incremental cost will be in the range of 17.2 to 2.2 P/kWh, 10 to 70 times the current rate of BPC (0.2523 P/kWh). Thus, under the current rate structure, only 2.7% of the total cost excluding connection cost can be recovered from electricity charges collected from households to be electrified in case the load of 20 kWh/m per household would be expected.
   Even in case of 100 kWh/m per household load, 13.3% of the total cost would be recovered. The connection cost to the grid (reticulation cost) is fully recovered by RCS. Then, taking the cost recovery of the connection cost into account, the percentages of total cost recovery are 18.2 to 27.9%.

b) As for the SHS system, the unit cost per kWh is P14.7 to P15.7/kWh. However, if the monthly rate of 50Wp – P40 is collected, the cost recovery rate will be 41.8 to 44.8% of total cost for SHS 100Wp and SHS 200Wp respectively.

Figure 14.1-1 shows the lifelong cost (20 years) for each electrified household, the total subsidy, and cost recovery from the electricity charge.

The above analysis indicates that rural electrification by grid extension is rarely feasible due to low demand, which comes from low population density of the country, absence of local industries, and dominance of low-income households. As grid connection will extend to rural areas with less favorable conditions, it is the time to discuss and determine whether grid extension will be continued by providing government subsidy or a strategic shift will be made to PV rural electrification.

7.2.4 Cost Comparison of SHS with PV Mini-grid Electrification

Similar comparison of costs for PV mini-grid and SHS was made.
Figure 7.2-2 shows such break-even points of cost on the basis of parameters of number of households of the village and average power consumption level. In case of the villages having 100 and 200 electrified households, the break-even points are 170Wp and 155Wp respectively

In case of lower power consumption than 170Wp in a village having 100 electrified households, SHS is more economical than PV mini-grid electrification. In the opposite case, PV mini-grid becomes more economical. The more users exist, the less break-even capacity will become (Refer to detailed calculation sheet in Appendix 7.1.4).

That is to say that the PV mini-grid system is only viable in densely populated areas with a high level of consumption. Non-cost factors include the difficulty in maintenance of the mini-grid system located in remote villages (Refer to Appendix 2.3.2).

The same conclusion can be said about the diesel mini-grid system (Refer to Appendix 7.1.5).

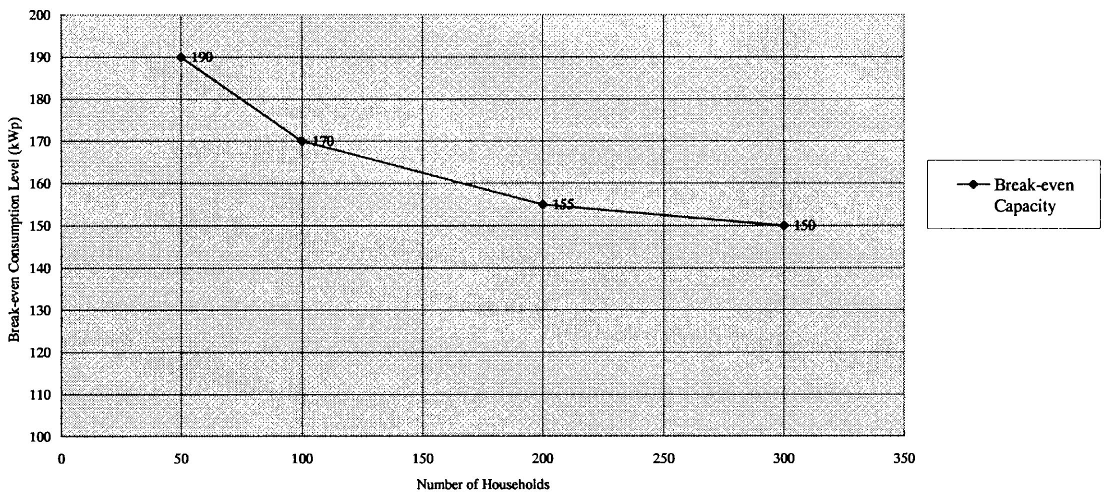

Figure 7.2-2 Comparison of Life Cycle Cost of SHS Versus PV Mini-grid (Break-even Consumption Level)

7.2.5 Selection of the Least Cost Option

The analysis and evaluation made in 7.2.1 through 7.2.4 indicates that the least cost solution for electrification of un-electrified villages in the country is the SHS system.

7.3 Criteria for The Village Selection for PV Rural Electrification

The World Bank suggested that the following indicators would provide a guide for selection of an area suitable for rural grid based electrification programs:

* The quality of infrastructure, particularly of roads, is reasonably good.
* Agricultural output is growing.
* Evidence indicates a growing number of productive uses in farms and agro industries.
* An area contains a number of large villages, not too widely scattered.
* Income and living standards are improving.
* Plans are in progress for developing the area.
* The region is reasonably close to the main grid (if the demand is particularly strong, remote regions may be considered, too).

"Relatively high tariffs, typically $0.12 to $15/kWh, low costs of grid extensions and distribution systems, and high numbers of consumers" make it possible to electrify areas where the majority of loads are less than 20 kWh/m and still meet these criteria. Other countries, particularly in Sub-Saharan Africa, have much lower tariffs, higher construction costs, and far lower consumer densities. Under those conditions, it is much more difficult to find a financially justifiable program.[2)]

In Botswana, the government allocates a high level of subsidy for grid extension to alleviate those difficulties. However, the grid electrification is not likely to continue forever to all villages and localities which are not economically viable. Accordingly there should remains un-electrified villages and localities in the future. In order to improve social equity in Botswana rural areas and to develop rural level of living standard, PV electrification should be disseminated in the areas where the above mentioned criteria cannot be satisfied.

Criteria for the selection of areas for PV electrification will be:

1) The area is further than break-even distance apart from the grid as shown in Figure 7.2-1 supposing 200 Wp (24.3 kWh/m) load and in the area, a prospect of substantial load growth will not exist.
2) The ability to pay fee for service is high (more than 40% of total households).
3) The village is willing to organize autonomy to operate and maintenance PV systems.

[2)] Reference List No.88

4) Plans are in progress for developing the area to empower the inhabitants.
   NDP9, settlement policy and other development plans in the target areas should be carefully taken into account. The areas where major load growth is expected or where the settlement will soon be vanished according to settlement policy shall be reexamined for the target areas for PV electrification.
   NECC proposed in Chapter 5 shall coordinate various development plans.
5) The willingness of inhabitants and village leaders to improve living standard is very high.

In order to specify PV electrified villages and localities and to give priorities of PV electrification to specified villages and localities, weighted method to the above parameters is applied, which is described in the next section.

7.4 Selection of PV Electrified Villages

7.4.1 Current Electrification Status of Villages and Localities

The database was prepared showing the names, the population, the grid electrified status and the number of households in villages and localities having population 200 or more in the year of 1991 and 2001 in order to evaluate the potential PV market in Botswana, which is shown in Appendix Table 7.2-1. Information on the population and number of households in villages/Localities are referred to "Population and Housing census 1991 and 2001" published by Central Statistic Office. Information on the grid electrification status was given by BPC and MMEWR-EAD. Botswana government has developed grid extension to more than 10 villages every year in accordance with NDP8. As for grid extension program from the year of 2003, 90 villages are planned to be grid electrified by the year of 2008/2009, of which information is also incorporated in the database.

The number of households in villages and localities in the year of 2001 is calculated on the assumption that average family size is 4.48 in each village and locality.

Number of villages and localities, population and number of households in 2001 are summarized as follows;

Villages (Year of 2001)

No. of Villages: 462

Population: 1,023,878 (Average 2,216/ village)

No. of Households: 228,544 (Average No. of family 4.48)

Locality (Year of 2001)

No. of Localities: 5,660

Population: 281,208 (Average 50/ locality)

No. of Households: 62,770 (Average No. of family 4.48)

Out of the above localities having population 200 or more either in 1991 or 2001

No. of Localities: 381

Population: 106,706 (Average 280/ locality)

No. of Households: 23,813 (Average No. of family 4.48)

7.4.2 Selection of PV Electrified Villages

Based on the criteria in Section 7.3, following procedure is adopted to make a selection of PV electrified villages and localities and prioritize PV electrification to selected villages and localities.

(1) First selection (Classification for Grid and PV electrified villages and exclusion of small scale localities)

Villages and localities are classified on the basis whether PV electrification is economical or not. And then small localities where PV operations are considered to be difficult to sustain are excluded from PV electrification targets.

1) Villages and localities which have been grid electrified or are planned to be grid electrified in the future are excluded from PV electrified targets. Villages and localities which have been grid electrified and are planned to be grid electrified by the year of 2009 are shown in Table 7.4-1. These are excluded from PV electrification targets. (Grid electrification is likely more economical for villages and localities based on break-even points calculated for each village and locality. Although these villages and localities are not planned and therefore not assured to be grid electrified, these are excluded from PV electrified targets.)

Table 7.4-1 Current Electrification Status of Villages and Localities

	Number	Population
Grid electrified villages by 2001	195	859,149
Villages which are planned to be grid electrified by the year of 2008/2009	93	78,555
Grid electrified localities by 2001	0	0
Localities which are planned to be grid electrified by the year of 2008/2009	2	2,017
Total	290	939,721

2) Supposing that the average power consumption per household is 200Wp and the target electrification rate is 40%, villages and localities are selected as PV electrification targets, if they are located far from the break-even points from the existing grid tie-in points indicated in Figure 7.2-1. According to this criteria it turns out that grid electrification would be more economical for the following villages and localities, mainly in villages and localities in South East Districts. These are excluded from PV electrification targets although these are not included in grid electrified program by the year of 2009.

Table 7.4-2 Villages and localities that are eligible for grid electrification

	Number	Population
Villages where grid electrification is considered to be economical	29	24,206
Localities where grid electrification is considered to be economical	30	25,369
Total	59	49,575

3) Selection of localities

Although some of localities having population more than 500 have already grid electrified, most of localities remain un-electrified. Localities having population 200 or more are listed in Appendix Table 7.2-1. As for PV electrification target, the following conditions are set according to Section 6.3 "Survey on localities"

i. Localities with 200 or more population should be served by the project.

ii. Public facilities that are located in localities with 200 or more population include at least an elemental school or a health post and electricity demand for the PV system is assumed to be 350Wp.

The reasons why localities having population less than 200 are out of PV electrification target in this report are;

- It is not likely in such locality that there exists a kind of central part with any of public facility and an autonomy organization within a settlement. Such small settlement seems to have a limited function of cattle or land farm for people to stay temporarily.
- Even if such locality has a central part with public facilities and has a certain demand of PV electrification, the establishment and operation of PV operation unit within a settlement proposed in this report seems to be difficult because of very few households as many as sixteen in case that PV electrification rate is 40% to total number of households in a locality having population 200 (average family size is taken five people).
- As mentioned in Section 6.1-5, the population of such localities decreased by 25% from 1991 to 2001 in 10 years. This trend would continue in the next decade. Since PV electrification for small localities would be undertaken the latter half of the master plan period, the population of such localities is considered to decrease further.
- Those localities should be reviewed as the next targets of PV electrification after the end of this Master Plan period.

(2) Second selection (Prioritizing the selected villages and localities for PV electrification)

Prioritizing of PV electrification is made for the villages and localities selected as PV electrification targets in the previous paragraph.

Based on the basic criteria mentioned in Section 7.3, the criteria for priority setting were established using several quantitative parameters as follows.

1) Population (as of the year of 2001)

PV demand and the level of needs are considered to be proportional to the population in villages and localities. Considering implementation of PV electrification project, management setup, one of the key factor for success, such as for money collection and maintenance in the village will be organized more easily in proportional to population of the village.

2) Population growth (Population incremental ratio between 1991 and 2001)

This is a parameter of activation of the villages and localities. Increase of PV demand and the level of needs and easiness of formation of autonomous organization are considered to be proportional to this parameter.

3) Infrastructure

The availability of infrastructure (e.g., VDC, school, clinic) is also one of parameters showing how well a village or locality is organized and managed as an integrated community. Generally, these community infrastructures are available in the villages, but not well in the localities.

Correlation between criteria for area selection for PV electrification, parameters for first and second selection and rating scores assigned to each of the three parameters are illustrated in Figure 7.4-1.

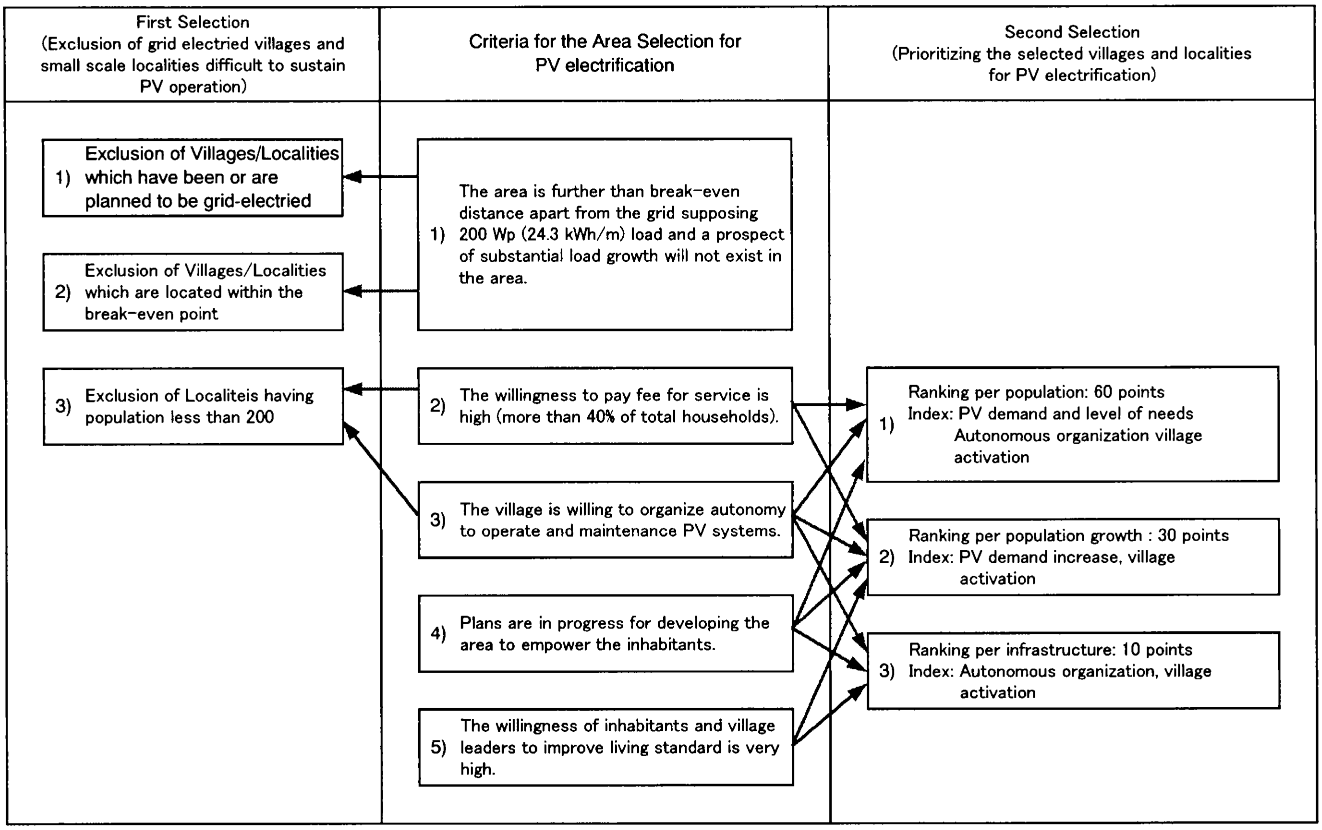

Figure 7.4-1 Correlation between criteria for area selection for PV electrification and parameters for first and second selection and rating scores

Table 7.4-3 Priority Setting Parameters

	Rating score (full)	Criteria	Score assigned
Population	60	Over 1,000	60
		700 ~ 999	50
		500 ~ 699	40
		300 ~ 499	30
		200 ~ 299	20
		100 ~ 199	10
		Less than 99	5
Population growth rate	30	Over 50%	30
		30% ~ 49%	20
		10% ~ 29%	10
		0% ~ 9%	0
		-20 ~ 0%	-5
		-20%	-10
Infrastructure	10	VDC, school, clinic available (village)	10
		No VDC, school, clinic (locality)	0
Total	100		

(3) Result

The villages and localities were rated according to the above criteria and are arranged according to the total score, as follows.

Table 7.4-4 Rating of Villages and Localities by Number

Score	Village		Locality		Total		Year of PV electrification
		Cumulative total		Cumulative total		Cumulative total	
Over 90	11	11	0	0	11	11	Suitable for PV electrification
80～90	15	26	1	1	16	27	
70～80	29	55	7	8	36	63	
60～70	15	70	22	30	37	100	
50～60	23	93	37	67	60	160	
40～50	19	112	20	87	39	199	
30～40	12	124	24	111	36	235	
20～30	14	138	24	135	38	273	
10～20	7	145	35	170	42	315	
0～10	3	148	102	272	105	420	
Less than 0	0	148	77	349	77	497	
Total	148		349		497		

Table 7.4-5 Rating of Villages and Localities by Population (2001 Population Census)

Score	Village		Locality		Total		Year of PV electrification
		Cumulative total		Cumulative total		Cumulative total	
Over 90	10,528	10,528	0	0	10,528	10,528	Suitable for PV electrification
80～90	9,051	19,579	732	732	9,783	20,311	
70～80	14,512	34,091	8,560	9,292	23,072	43,383	
60～70	6,511	40,602	9,107	18,399	15,618	59,001	
50～60	7,975	48,577	10,822	29,221	18,797	77,798	
40～50	6,204	54,781	7,384	36,605	13,588	91,386	
30～40	2,521	57,302	7,535	44,140	10,056	101,442	
20～30	3,411	60,713	8,093	52,233	11,504	112,946	
10～20	1,054	61,767	8,433	60,666	9,487	122,433	
0～10	201	61,968	14,959	75,625	15,160	137,593	
Less than 0	0	61,968	3,695	79,320	3,695	141,288	
Total	61,968		79,320		141,288		

The number of villages and localities and its percentage by score are illustrated in Figure 7.4-2 and Figure 7.4-3 based on the results in the above Tables. The population of villages and localities and its percentage by score are also illustrated in Figure7.4-3 and Figure 7.4-5.

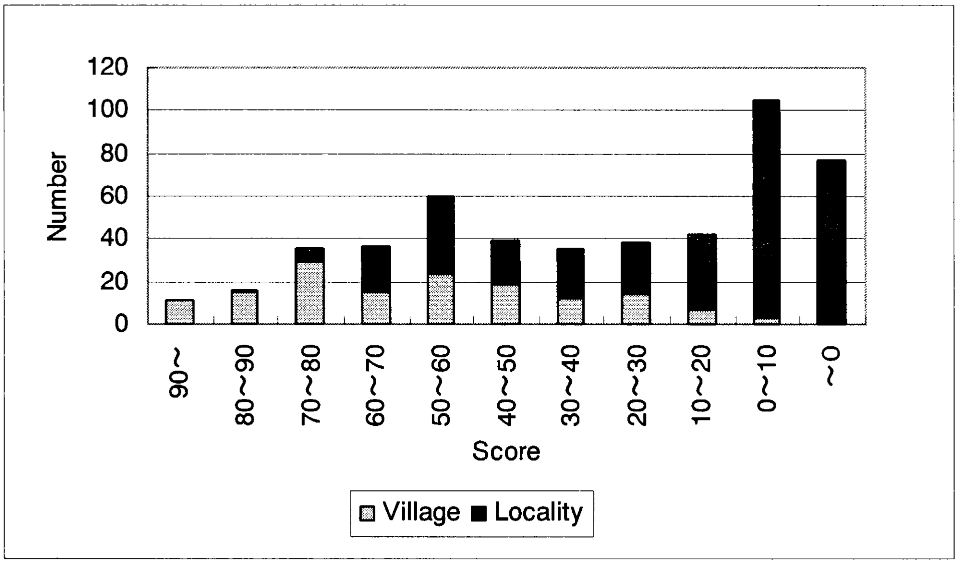

Figure 7.4-2 Number of Villages and Localities by Score

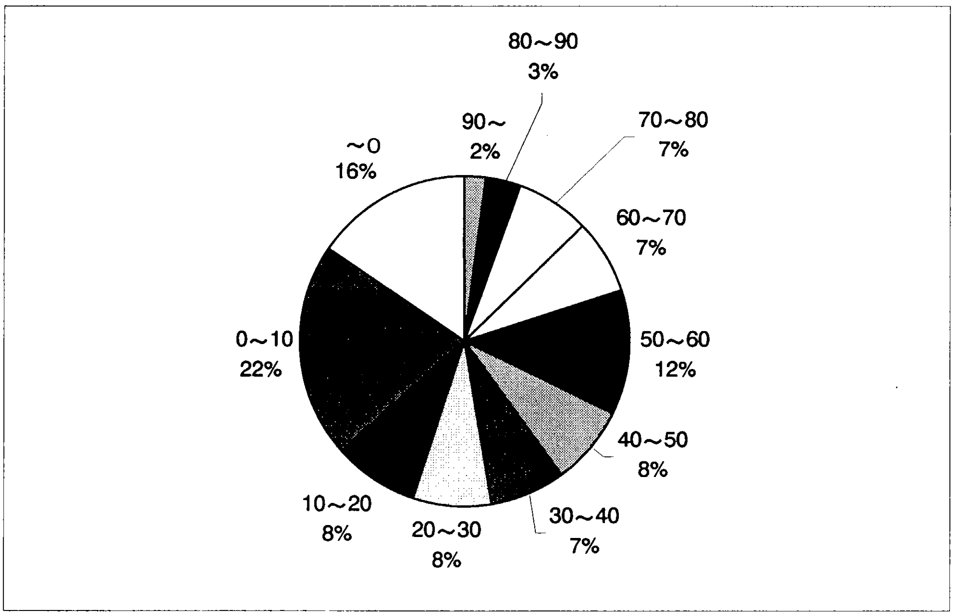

Figure 7.4-3 Percentage of No. of Villages and Localities by Score

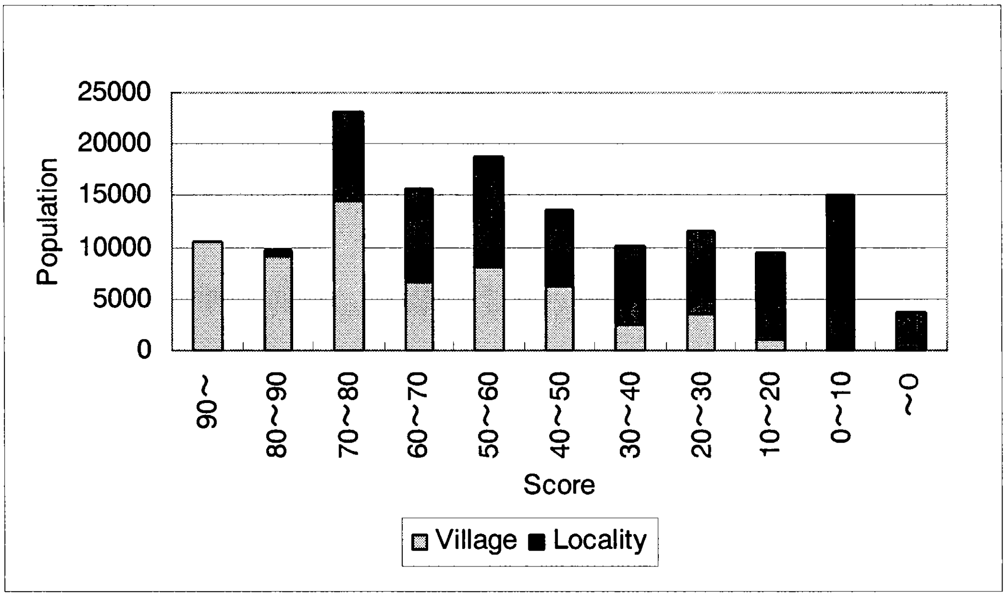

Figure 7.4-4 Population of Villages and Localities by Score

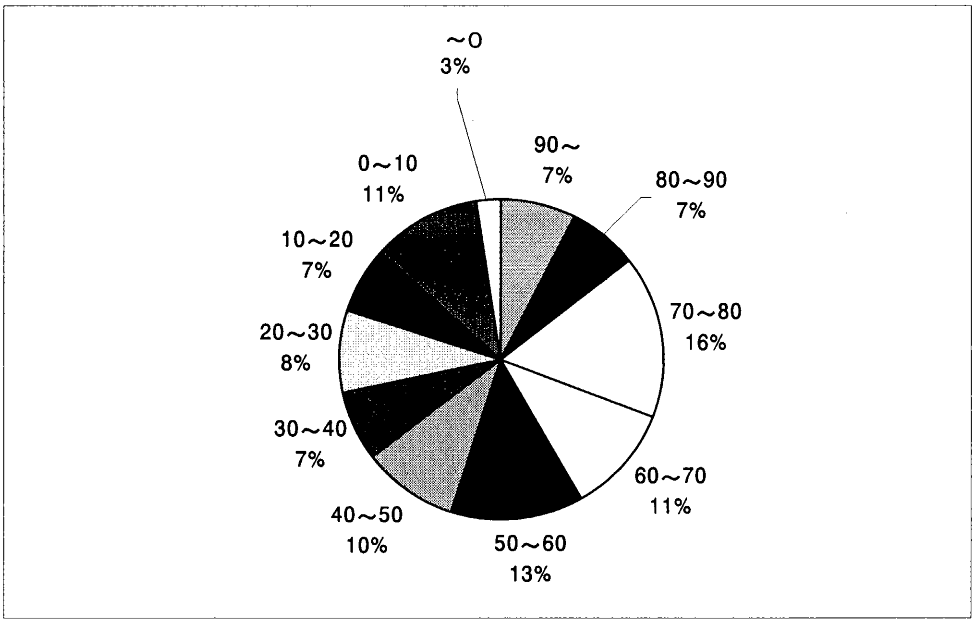

Figure 7.4-5 Percentage of Population of Villages and Localities by Score

Energy Master Plan dictates the access to electricity, both connected to the national grid and off-grid represented by PV to all households where it makes economic and social sense. Based on this policy, localities having population less than 200 (either in the year of 1991 or 2001) are excluded from PV electrification targets because such small localities have few sense in being electrified both economically and socially. (Refer to Section 7.4.2(1) "First Selection") In addition, villages and localities of which scores are less than 10 are excluded from PV electrification targets as well for the below reason.

The priority for PV electrification is proposed in Appendix Table 7.3-1. According to this Table, population of most villages and localities with a score less than 10 have decreased to less than 200 in the year of 2001 during 10 years since 1991, which conforms to the criteria mentioned in Section 7.4.2(1) "First Selection".

As the above, villages and localities with a score equal to 10 or more are selected as PV electrification targets. Low scored villages and localities will be PV-electrified at the later stage of the Mater Plan Period. Almost all villages and localities with a score 10 to 30 in Appendix Table 7.3-1 showed minus population growth from 1991 to 2001. If the trend is not changed, the said villages and localities may be scaled down to the size which will be not worth PV electrification when their turns come. Therefore, it is needed that eligibilities for PV electrification for low scored villages and localities are verified when the time comes.

Assuming that villages and localities that obtain the total score of 10 points or more are qualified for PV electrification, 145 villages (total population of 61,767) and 170 localities (60,666), totaling 315 (122,433 population), should be selected.

7.5 10-year PV Electrification Program

Assuming that the selected villages and localities will be electrified over a ten-year period, the program should proceed in the following sequence. (The detail study to be referred to Appendix 7.3)

- The entire country is divided into six zones, as shown below, and PV electrification will be carried out for selected villages and localities in each zone every year. The arrangement is designed to ensure that the project is carried out evenly throughout the country, considering a sufficient number of PV installation jobs to be conducted in each zone. It is expected that the equalized work volume of PV electrification will be contracted with PV installation contractors.

- Villages and localities will be PV-electrified each year according to the order of the rating scores. The following table shows the number of villages and localities to be selected in each zone and for each year.

Table 7.5-1-1 Preliminary Selection of Villages and Localities by Zone and Year

	PV year	1	2	3	4	5	6	7	8	9	10	Total
Zone 1	Ngwaketse	4	3	2	5	1	1	3	6	3	3	31
	Barolong	2	2	3	1	2	6	2	1	4	4	27
	Ngwaketse West	0	1	0	0	1	0	1	0	0	0	3
	South East	0	0	1	0	2	0	1	0	0	0	4
Zone 2	Kweneng East	0	1	3	2	5	2	3	3	4	3	26
	Kweneng West	5	3	2	2	0	1	2	1	1	1	18
	Kgatleng	0	1	0	1	0	2	0	1	0	1	6
Zone 3	North East	0	1	4	1	2	2	0	0	0	1	11
	Serowe/Palapye	2	3	1	3	2	2	2	4	4	1	24
	Bobonong	3	1	0	1	1	1	3	1	1	3	15
Zone 4	Mahalapye	1	2	3	2	3	0	1	0	1	2	15
	Boteti	0	0	2	0	0	0	1	1	0	2	6
	Tutume	5	4	1	4	3	6	4	5	5	3	40
Zone 5	Ngamiland East	0	3	5	3	3	4	3	1	3	3	28
	Ngamiland West	6	3	2	3	2	3	3	5	4	3	34
	Chobe	0	0	0	0	1	0	1	0	0	0	2
	Delta	0	0	0	1	1	0	0	1	0	1	4
Zone 6	Ghanzi	1	0	1	0	2	1	2	1	0	1	9
	Kgalagadi South	1	0	1	0	0	0	0	1	1	1	5
	Kgalagadi North	0	2	0	2	0	1	0	0	1	1	7
	Total	30	30	31	31	31	32	32	32	32	34	315

Table 7.5-1-2 Preliminary Selection of Villages, Localities and Population by Zone and Year

	Zone	Type	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Total
Zone1	No. of settlements	Vill.	6	5	3	2	2	6	3	2	6	2	37
		Local.	0	1	3	4	4	1	4	5	1	5	28
		Total	6	6	6	6	6	7	7	7	7	7	65
	Population	Vill.	4150	3196	1462	1084	673	2158	536	706	1483	253	15701
		Local.	0	621	1219	985	1038	309	1662	1409	238	1217	8698
		Total	4150	3817	2681	2069	1711	2467	2198	2115	1721	1470	24399
Zone2	No. of settlements	Vill.	4	4	0	1	0	4	2	3	2	0	20
		Local.	1	1	5	4	5	1	3	2	3	5	30
		Total	5	5	5	5	5	5	5	5	5	5	50
	Population	Vill.	2590	1637	0	464	0	1246	95	711	489	0	7232
		Local.	2585	559	2138	1379	1273	355	1113	736	982	1077	12197
		Total	5175	2196	2138	1843	1273	1601	1208	1447	1471	1077	19429
Zone3	No. of settlements	Vill.	5	5	3	3	5	1	0	0	0	1	23
		Local.	0	0	2	2	0	4	5	5	5	4	27
		Total	5	5	5	5	5	5	5	5	5	5	50
	Population	Vill.	3784	2146	1133	949	1363	318	0	0	0	182	9875
		Local.	0	0	661	641	0	1161	1669	1792	1388	959	8271
		Total	3784	2146	1794	1590	1363	1479	1669	1792	1388	1141	18146
Zone4	No. of settlements	Vill.	5	6	4	6	1	1	0	0	2	0	25
		Local.	1	0	2	0	5	5	6	6	4	7	36
		Total	6	6	6	6	6	6	6	6	6	7	61
	Population	Vill.	5400	3644	2186	3126	205	424	0	0	336	0	15321
		Local.	3052	0	1106	0	2562	2145	1497	2354	1372	1633	15721
		Total	8452	3644	3292	3126	2767	2569	1497	2354	1708	1633	31042
Zone5	No. of settlements	Vill.	5	2	5	2	2	0	2	3	1	2	24
		Local.	1	4	2	5	5	7	5	4	6	5	44
		Total	6	6	7	7	7	7	7	7	7	7	68
	Population	Vill.	2633	839	1512	332	684	0	696	650	194	253	7793
		Local.	732	1858	687	1398	1697	2425	1694	952	1817	1306	14566
		Total	3365	2697	2199	1730	2381	2425	2390	1602	2011	1559	22359
Zone6	No. of settlements	Vill.	2	2	2	2	2	2	1	1	1	1	16
		Local.	0	0	0	0	0	0	1	1	1	2	5
		Total	2	2	2	2	2	2	2	2	2	3	21
	Population	Vill.	949	835	762	659	667	890	331	405	175	172	5845
		Local.	0	0	0	0	0	0	245	224	233	511	1213
		Total	949	835	762	659	667	890	576	629	408	683	7058
Total	No. of settlements	Vill.	27	24	17	16	12	14	8	9	12	6	145
		Local.	3	6	14	15	19	18	24	23	20	28	170
		Total	30	30	31	31	31	32	32	32	32	34	315
	Population	Vill.	19506	12297	7055	6614	3592	5036	1658	2472	2677	860	61767
		Local.	6369	3038	5811	4403	6570	6395	7880	7467	6030	6703	60666
		Total	25875	15335	12866	11017	10162	11431	9538	9939	8707	7563	122433

(1) PV electrification system

In the Dissemination Project, the Battery Charging Station (BCS) system, details of which is mentioned in Chapter 8 and 13, was installed in Lorolwana only. The BCS system requires higher equipment and operation costs, while generating less income than the SHS system, and is not commercially viable in terms of pure financial feasibility. On the other hand, the system can provide a significant social benefit for the poor people who cannot afford to use the SHS system with a higher user charge. As the SHS system alone is expected to achieve the electrification rate of 30% - 40%, the BCS system can benefit far more people with PV electrification, contributing greatly to the objective of providing electricity throughout the country.

It is therefore recommended to install the BCS system in parallel with the SHS system for villages and localities with 500 or more population. For smaller settlements, only the SHS system will be installed as the BCS system becomes inviable in terms of complexity and cost.

As 43 villages (total population of 30,507) and 19 localities (16,449 persons), totaling 62 settlements (46,956 persons), have 500 or more residents and will be installed with both SHS and BCS systems.

The total population of villages and localities grew 25% between 1991 and 2001, with an annual average growth rate of 2.3%. According to the 2001 Population Census, the average family size per household is 4.48.

Assuming that the target SHS electrification rate is 40% of all the households and BCS users account for 20% of total households in villages and localities where the BCS system is installed, the installation of PV systems will proceed during the ten-year period, as follows.

Table 7.5-2 PV System Installation Plan

Project Year		1	2	3	4	5	6	7	8	9	10	Total
SHS	No. of households in 2001	5,776	3,423	2,872	2,459	2,268	2,552	2,129	2,219	1,944	1,688	27,330
	Population growth rate	1.069	1.093	1.118	1.143	1.169	1.195	1.222	1.25	1.278	1.307	
	No. of households in the PV installation year	6,176	3,743	3,211	2,811	2,651	3,051	2,603	2,774	2,485	2,206	31,711
	No. of households to install the PV system	2,470	1,497	1,284	1,124	1,060	1,220	1,041	1,110	994	882	12,682
BCS	No. of villages/localities for PV installation	25	15	6	7	0	4	3	2	0	0	62
	Population in 2001	21,404	11,950	3,681	4,152	0	2,508	1896	1,365	0	0	46,956
	No. of households in 2001	4,778	2,667	822	927	0	560	423	305	0	0	10,482
	Population growth rate	1.069	1.093	1.118	1.143	1.169	1.195	1.222	1.25	1.278	1.307	
	No. of households in the PV installation year	5,109	2,916	919	1,060	0	669	517	381	0	0	11,571
	No. of households to install the PV system	1,022	583	184	212	0	134	103	76	0	0	2,314

In addition, the PV system size requirements need to be determined. The results of the socio-economic surveys indicated an average electricity demand of 122Wp per household, while actual demand confirmed in the dissemination project amounted to 68Wp on average. (Refer to Chapter 6)
For the Master Plan for the ten-year installation program, the latter (based on the Dissemination Project) should be used.

As for public facilities, 1,650Wp per village and 350Wp per locality are assumed.

Finally, the desirable timing of system installation varies between the results of the socio-economic surveys (see Table 6.2-9) and those estimated from the results of the Dissemination Project (see Table 6.4-22). Again, for the Master Plan for the ten-year installation program, the latter is considered to be more reliable and should be used:
First year - 35% of target users in villages and localities
Second year - 40% of target users
Third year – 25% of target users

PV installed capacity for SHS, public facilities, BCS and total capacity during 10 years Master Plan period are shown in Figure 7.5-1 and 7.5-2 in case the target SHS electrification rate is 40% of all the households and BCS users account for 20% of total households in villages and localities where the BCS system is installed. Grand total installation capacity reaches 1,200kWp in Master Plan period.

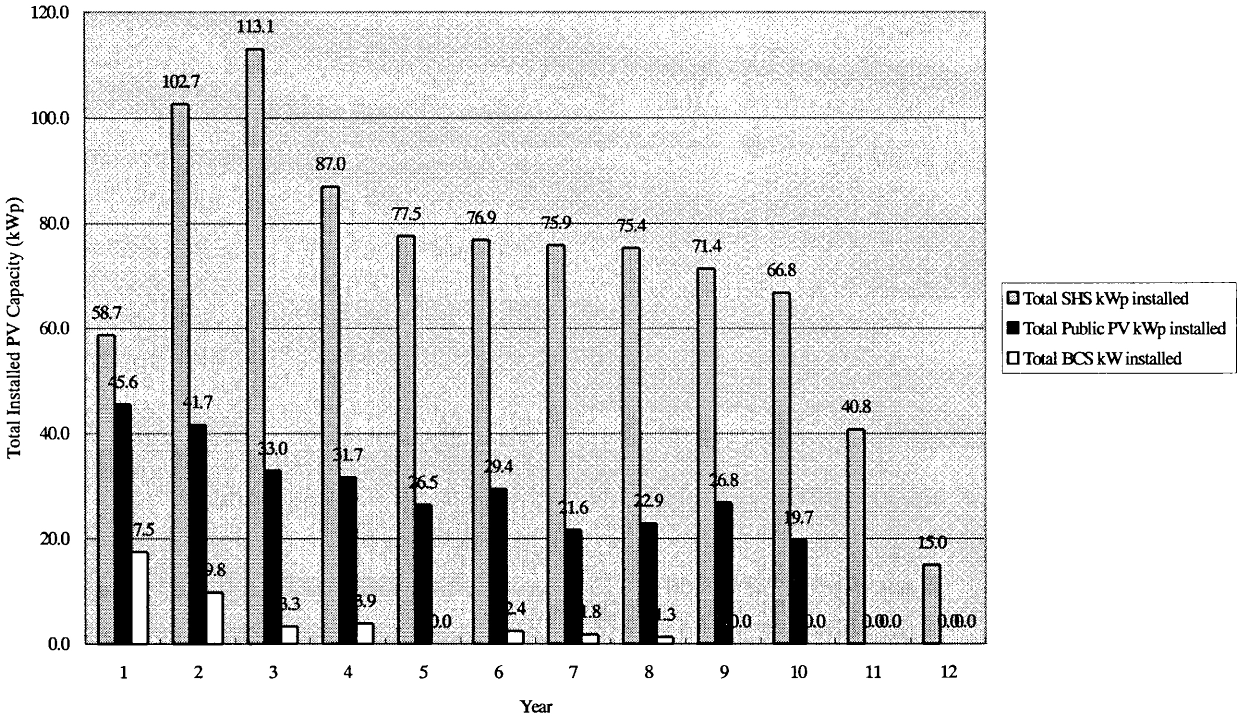

Figure 7.5-1 PV Installed Capacity (SHS, Public, BCS)

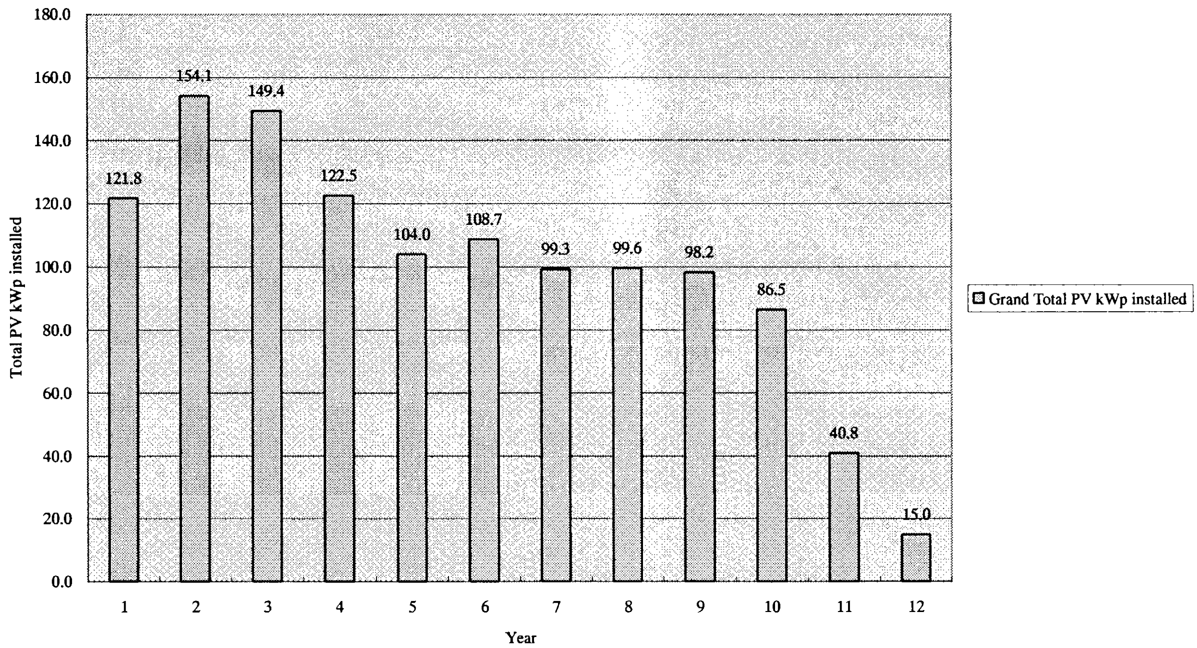

Figure 7.5.2 Total PV kWp Installed

7.6 Total Electrification Rate achieved

Total electrification rate achievable in the year of 2012 for all villages and localities (excluding cities, towns) is summarized in Table 7.6-1. It will be 49.6% in case of grid electrification rate 60% and PV electrification (SHS/BCS: 40%/20%) and will be 42% if grid electrification rate stays around 50%.

Table 7.6-1 Total Electrification Rate by means of Grid and PV Electrification

Year		Census 2001	2,012
Villages			
	No.	462	462
	Population	1,023,878	1,279,848
	No. of Households	228,544	285,680
Localities			
	No.	5,660	5,660
	Population	281,208	351,510
	No. of Households	62,770	78,463
Total Population (village+ locality)		1,305,086	1,631,358
Total No. of Households (village+ locality)		291,314	364,143
Villages/Localities which have been and planned to be grid-electrified by 2009			
	No.	290	290
	Population	939,721	1,174,651
	No. of Households	209,759	262,199
Villages/Localities where grid electrification is considered to be economical			
	No.	59	59
	Population	49,575	61,969
	No. of Households	11,066	13,832
Villages/Localities to be grid electried			
	No.	349	349
	Population	989,296	1,236,620
	No. of Households	220,825	276,031
Villages/Localities to be electrified by SHS/BCS			
	No.	315	315
	Population	122,433	153,041
	No. of Households	27,328	31,711
Total Electrification Rate (in case of grid electrification rate 60%)			
	No. of Households electrified by grid		165,619
	No. of Households electrified by SHS/BCS (40%/20%)		14,996
	Total Electrified Households		180,615
	Total electrification Rate		49.6%
Total Electrificatio Rate (in case of grid electrification rate 50%)			
	No. of Households electrified by grid		138,016
	No. of Households electrified by SHS/BCS (40%/20%)		14,996
	Total Electrified Households		153,012
	Total electrification		42.0%
Percentage of households in villages/localities where grid or PV are catered for versus total number of households in villages/localities			
	Total number of households in villages/localities where grid or PV are catered for		307,742
	Percentage of households in villages/localities where electricity are catered for versus to total number of households in villages/localities		84.5%

Chapter 8 PV System Design and Environmental Measures

Chapter 8　PV System Design and Environmental Measures

8.1 Current State of PV Related Technologies and Their Commercial Availability

As discussed in Chapter 2, Botswana has ample experience in PV system operation as a variety of PV systems have been operated in a number of pilot projects, as listed below.

- Solar home system (SHS)	:	Manyana Pilot Project National PV Rural Electrification Program (NPV-REP)
- PV mini-grid system	:	Motshegaletau Pilot Project
- PV systems for village offices, clinics and schools	:	A number of places
- Pump system	:	Projects of Department of Water Affairs
Telecommunications system	:	Projects of Botswana Telecommunication Corporation

PV modules are available from a number of manufacturers in Europe, the U.S., and Japan. They can be imported through South Africa or by local contractors who purchase them directly from manufacturers.

Charge controllers and inverters are mainly imported from Europe or the U.S.

There are more than ten local contractors capable of installing PV systems. They are relatively small and are expected to improve technical capabilities as the PV electrification project becomes full-fledged.

8.2 Adequate Technology for PV Rural Electrification

(1) System configuration

① On the basis of the evaluation results in Chapter 7, The PV system used for the project is primarily of Solar Home System (SHS) type.

② The centralized PV system will be installed at important public facilities, including a local government office, a police office and a meeting hall.
The centralized system will also be installed at schools, medical clinics and other public facilities not electrified.

③ The battery charge station (BCS) will be provided. For users who cannot afford to pay for the SHS system, the battery will be leased and recharged at the BCS.

(2) System design

1) Sizing

System design should take into account the customer's capacity to pay the monthly fee and requirements (customer needs). Important design conditions are summarized as follows.

① The SHS system should be configured on the basis of the standard 50Wp panel to allow capacity increase according to the user's request by installing an additional panel.
In principle, the PV-SHS system capacity should be determined according to electricity generation capacity of the PV panel, as follows.

- SHS-50Wp
- SHS- 100Wp
- SHS-150Wp
- Above SHS-150Wp, capacity can be increased adding module of 50 Wp.

To reserve grid connectivity in the future, the 240V-AC system is used for the system size of over 150Wp, while 12V-DC for less than 150Wp.

② The centralized PV system capacity (generation capacity) should be 500Wp as standard, but the actual capacity should be determined for each village according to actual demand. The centralized PV system for public facilities (CPS) should also have design flexibility in terms of capacity, while standard capacities should be 500Wp or 1,000Wp.
The centralized PV system should be designed to provide electricity to streetlights in the locality center and water supply pumps of schools and medical clinics but in that case the system size would be larger.

③ The capacity of the BCS should be determined according to actual demand (user's request), while standard design capacities are 500Wp, 1,000Wp or 1,500Wp.

2) System design should give consideration to the streamlining of maintenance work and prevention of system failure due to incorrect operation by the customer.

   SHS system

   - The system should integrate batteries, a battery box, a battery charger controller into one unit (box).

3) Pre-paid card system

   To facilitate collection of the electricity charge, it is recommended to use the pre-paid card system, which should be incorporated into the above one unit system.

8.3 Environment and Health Protection

8.3.1 Environmental Benefits of Solar Home Systems

Not only are PVs environmentally superior to kerosene and dry cells, they also have advantages over other electricity supply options. PV modules generate electricity without emitting gases that cause global warming, local air pollution or acid rain, or causing water pollution or noise. The modules are typically roof-mounted or require very little ground space, so PV-based rural electrification also avoids the disruptive land use impacts associated with power lines and some methods of electricity generation (such as large-scale hydropower).

Since stand-alone PV systems provide electricity without power lines, their use in protected forest areas and buffer zones can be particularly valuable for ecosystem preservation. Power-line corridors can open access for the development of forested areas, change the diversity of species within ecosystems, and cause ecosystem fragmentation. Furthermore, power-line construction and maintenance activities themselves can be quite disruptive.

In many developing countries, migration from rural to urban areas is creating tremendous social and ecological problems. People move to the city for jobs and to gain access to electricity and other modern amenities. But urban infrastructure often has not kept pace with population growth. While it is unlikely that electricity alone will stem the tide of rural to urban migration, it is possible that solar electrification in rural areas can help by improving the quality of life there.

Based on the report on the study covering villages in the country, entitled "Urban and rural energy in Botswana: needs and requirement", EAD, July 2001), it is estimated that 193kg of CO_2 discharge per year can be cut off for each 50Wp SHS system, which is calculated on the basis to replace household consumption of paraffin used for lighting purpose. If the PV system is installed according to the business plan in Chapter 13, 4,780 tons of CO_2 discharge can be eliminated each year.

Table 8.3-1 Greenhouse Gas Generation Reduction

	Unit	Baseline Scenario	CO_2 Offset
		continue to use kerosene for lighting	change to electricity generated by SHSs (50Wp)
Kerosene consumption per household	l/m/HH	6.0	0.0
Electricity generation	kWh/y/HH	0.0	72.0
Sp. Gravity	kgf/m^3	850	
Kerosene consumption	kgf/y/HH	61.2	0.0
Calorific value	GJ/t	44.75	
Kerosene consumption	GJ/y/HH	2.74	0.00
Carbon emission factor	tC/TJ	19.60	
Carbon emission	tC/y/HH	0.0526	
CO_2 emission	tCO_2/y/HH	0.19	
CO_2 emission reduction	kg CO_2/kWh		2.68
CO_2 emission reduction	kg CO_2/50Wp/y		193
Total kWp installed	kWp		1,239
Total CO_2 reduction	t/y		4,780

8.3.2 Negative Environmental Impact

A negative environmental impact from SHS dissemination can result from the improper disposal of lead-acid batteries. While careful recycling of lead-acid batteries is the best way to prevent this, current recycling practices vary substantially by country. As SHSs become widespread, it will be important to encourage well-managed battery recycling programs.

8.3.3 Recycling Required by Environmental Law

(1) Recycling

Lead usually tops the list of substances classified as hazardous in environmental legislation. Strict legal control should be imposed to protect the environment from harm caused by the use or transportation of lead and products containing it.

In Botswana the responsible organization is the Department of Sanitation and Waste Management of the Ministry of Lands, Housing and Environment established as a result of split of the Ministry of Local Government Land and Housing.
It was reported that Denmark offered expert consultancy in building of dangerous and toxic chemical handling regulations in Botswana.

The Ministry of Trade, Industry, Wildlife and Tourism endeavors to develop national standards to address the need for safe and environmentally friendly goods and services in the country.
For "dead" batteries that will be produced from the project, it is recommended to establish and operate a proper recycling and proposal system that involves battery manufacturers and suppliers, as shown in Figure 8.3-1.

Refer to Appendix 8 for the details related to Article 8.

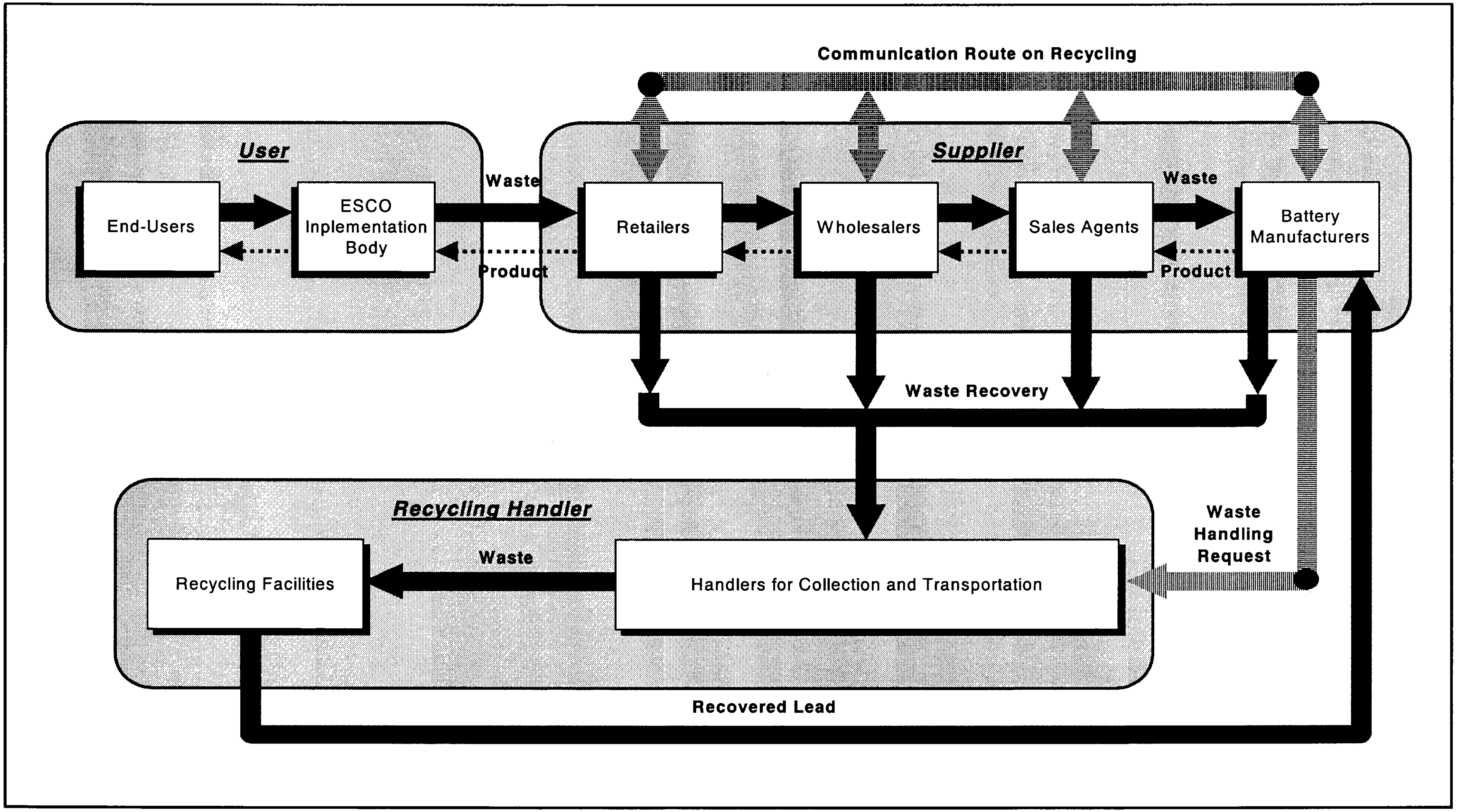

Figure 8.3-1 Proposed Recycling Route for Waste Lead-Acid Batteries