CHAPTER 16 OPTIMIZED DZONGKHAG-WISE RURAL ELECTRIFICATION MASTER PLAN – THE RESULT OF THE MASTER PLAN –

16.1 Method for Developing the Optimized Phase Development Plan

Based on the work flow described previously in the Chapter 13, the rural electrification master plan was formulated as follows:

a) Firstly, as described in Chapter 14, the on-grid or off-grid status of every village was determined for the final target year of 2020 by evaluating benefits and costs of on-grid and off-grid electrification;

b) Secondly, as described in Chapter 15, an economic evaluation was carried out for every feeder. On-grid planned feeder construction was allocated to 10th Five Year Plan (FYP) and 11th FYP, so that implementation could start with feeders that have a high economic efficiency.

After determining the phase in which feeders will be implemented by using a genuine economic evaluation, it was found that there was a significant difference between the percentage of on-grid households in each Dzongkhag that would be electrified by the end of 10th FYP. For instance, Dzongkhags with larger populations tended to have a relatively high electrification percentage at the end of 10th FYP. This is partly because larger populations bring higher benefits, which makes the feeder IRR higher, so larger number of the feeders are included in 10th FYP. In addition, some Dzongkhags already have a high on-grid electrification percentage at the end of 9th FYP. However, some of the other Dzongkhags still have a lower electrification percentage, even at the end of 10th FYP. The RGoB regards equal rural development as the most important policy. For rural electrification, it is the country's policy to prepare the plan so that the electrified percentage of every Dzongkhag will become approximately equal by the end of 10th FYP.

Thus, the implementation plan that was described in Chapter 15 was modified according to the above policy, and an optimized on-grid phase development plan was prepared. This chapter (Chapter 16) describes the optimized master plan after the modification. It also explains the modification process. Here, factors of the consistency with other development sectors, as well as distance of the feeders from existing roads were considered. Furthermore, power flow analysis was performed for the optimized on-grid system and issues relating to the optimized distribution system were identified. Required countermeasures were presented.

In addition to the above, an off-grid electrification plan was also prepared. The final on-grid and off-grid electrification plans have been formulated to optimize the rural electrification master plan. These optimized plans comprise the final output of the study. The economic evaluations for the optimized on-grid and off-grid plans were explained, and finally the optimized Dzongkhag-wise electrification plan was presented.

Hereafter, 10th FYP (2007-2012) and 11th FYP (2012-2017) of the national development plan are also called Phase-1 and Phase-2, respectively in this master plan.

16.2 Modifications Required to Produce the Optimized On-grid Phase Plan

16.2.1 Method for Optimization

The modification was applied to the on-grid electrification plan that was described in Chapter 15 (original plan). The optimized on-grid electrification plan was formulated in accordance with the following procedure:

1) Calculate the on-grid electrification percentage in each phase that was determined by genuine economic evaluation for each Dzongkhag by the original plan.
2) In addition to apply the power sector policy, in order to enhance the efficiency of the development, and to have consistency with other development sectors, move particular feeders originally allocated to Phase-2 to Phase-1. The criteria used to identify which particular feeders would be moved from Phase-2 to Phase-1 are:
   a) Feeders close to or along to existing roads;
   b) Feeders located in areas of education sector development; and
   c) Feeders in areas where electricity is currently supplied by diesel generation.
3) Apply the following modification so that the electrification percentage of each Dzongkhag at the end of Phase-1 is as equal as possible:
   a) For Dzongkhags with a low electrification percentage at the end of Phase-1 in the original plan, move feeders that had a relatively high IRR in Phase-2 from Phase-2 to Phase-1;
   b) For Dzongkhags with high electrification percentage at the end of Phase-1 in the original plan, move feeders that had a relatively low IRR in Phase-1 from Phase-1 to Phase-2; and
   c) For Dzongkhags with a high electrification percentage at the end of Phase-1 in the original plan, for feeders of which branches are long, separate those into more than two feeders, and move sub-feeders that had a low IRR in Phase-1 from Phase-1 to Phase-2.
4) Every time a feeder was re-allocated to Phase-1 or Phase-2 in Step 2 or 3 above, check the balance of the electrification percentage in every Dzongkhag, and continue the work until the balance became more equitable.

Although the plan is prepared by phase and by Dzongkhags, when implementing the above procedure, it is important to note that some feeders pass through more than two Dzongkhags. In practical terms, firstly the source side of the feeder needs to be implemented in prior to the backward side of the same feeder. Secondly, it is necessary to separate the number of a

households connected to the feeder and the feeder length by Dzongkhag in order to calculate the Dzongkhag-wise construction cost and electrification percentage.

The number of feeders that will pass through more than two Dzonghags is eight (8), as shown in **Table-16.2.1** below. .

Table-16.2.1 Feeder Length and Number of Household that pass through More Than Two Dzongkhags

No.	Feeder Name	Feeder HH in 2007	Feeder Distance(m)	Source Dzongkhag			Extended Dzongkhag		
				Dzongkhag	HH in 2007	Distance(m)	Dzongkhag	HH in 2007	Distance(m)
1	MPB33F4-3	1797	134,879	Chukha	145	16,765	Ha	170	20,851
							Samtse	1,482	97,263
2	MPC33F3-1	431	54,720	Dagana	338	38,273	Chukha	93	16,447
3	MPI33F1-1	1154	101,859	Pemgatsel	55	16,840	Mongar	1,099	85,019
4	MPI33F3-2	520	46,577	Pemgatsel	367	26,976	Mongar	153	19,601
5	MPK11F2-4	929	80,692	Samdrup Jongkhar	912	79,910	Trashigang	17	782
6	MPM33F1-2	590	55,323	Sarpang	579	54,559	Dagana	11	764
7	MPR33F1-1	1251	70,144	Tsirang	907	39,505	Sarpang	344	30,639
8	MPR33F3-1	1691	107,719	Tsirang	845	54,983	Dagana	846	52,736

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16.2.2 Modification for the On-grid Optimization

Based on the above method, optimization of on-grid planning was carried out. The feeders for which the implementation phase was modified are shown in **Table-16.2.2**.

Table-16.2.2 Feeders of which the Phase was Changed

Feeders changed implementation period from Phasse 1 to 2					Feeders changed implementation period from Phasse 2 to 1				
Dzongkhag	Feeder Name	HH in 2007	Phase-1 IRR	Phase-2 IRR	Dzongkhag	Feeder Name	HH in 2007	Phase-1 IRR	Phase-2 IRR
Samdrup Jongkhar	MPK11F2-3	8	13.1%	13.8%	Bumthang	MPA11F2-1	168	11.1%	13.9%
Samdrup Jongkhar	MPK11F2-4	929	12.2%	13.8%	Dagana	MPC33F2-1	865	6.3%	9.7%
Trashigang	MPO11F1-8	244	20.3%	22.0%	Punakha	MPJ33F1-2	26	8.7%	10.3%
TrashiYangtse	MPP33F1-1	346	12.3%	13.8%	Punakha	MPJ33F1-5	45	11.2%	12.6%
					Punakha	MPJ33F1-6	12	8.3%	8.9%
					Punakha	MPJ33F1-9	84	12.0%	13.3%
					Sarpang	MPM33F1-2	590	10.3%	12.5%
					Zhemgang	MPT33F3-1	628	12.3%	13.8%
	TOTAL	1,527				TOTAL	2,418		

* Dagana includes 396 households connected to existing line to be replaced.

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Four (4) feeders were changed from Phase-1 to Phase-2, and the number of affected households is 1,527. Conversely, construction of eight (8) feeders was brought forward from Phase-2 to Phase-1, affecting a total of 2,418 households.

Many of the feeders located near existing roads were already included in Phase-1 by the genuine economic evaluation. In Chapter 14, priority areas identified as being close to existing roads were listed in **Table-14.1.3**. Of these only feeder MPA11F2-1 in Bumthang was allocated for Phase-2 construction by the genuine economic evaluation process. This particular feeder was changed to Phase-1.

Three (3) of the large feeders were divided into two, and the implementation phases were similarly divided. These feeders are listed in **Table-16.2.3** below.

Table-16.2.3 Divided Feeders with Revised Implementation Phases

Original Feeder						Separated Feeder (modified)						Note
Dzongkhag	Feeder Name	Phase	IRR	HH in 2007	Distance (m)	Dzongkhag	Feeder Name	Modified Phase	IRR	HH in 2007	Distance (m)	
Wongdue Phodrang	MPS33F3-1	2	13.2%	1,093	117,770	Wangduephodrang	MPS33F3-1	1	12.6%	734	71,565	Incorporation with the education sector program
						Wangduephodrang	MPS33F3-5	2	12.3%	158	18,449	
						Wangduephodrang	MPS33F3-4-2	2	11.5%	201	27,756	
Chukha	MPB33F4-3	1	13.5%	1,797	134,880	Chukha	MPB33F4-3	1	13.7%	1,401	109,533	Equal distribution
						Samtse	MPL33F1-5	2	15.2%	396	25,347	
Tsirang	MPR33F1-1	1	14.9%	1,251	70,144	Tsirang	MPR33F1-1	1	14.1%	907	39,505	Equal distribution
						Sarpang	MPM33F4-1	2	11.0%	344	30,639	

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Two sub-feeders were divided from MPS33F3-1 in Wangduephodrang with 1,093 households. The phase of the sub-feeders with a total number of household of 359 was changed from Phase-2 to Phase-1 in order to make accordance with existing road and development program in education sector. On the other hand, two sub-feeders in Samtse and Sarpang were modified from Phase-1 to Phase-2 after the divide. As for the part of divided feeders whose phases were changed from Phase-1 to Phase-2, the IRR increased than that of original phase. This is because the benefit in the later phase become more than the original phase. Usually, the IRR in Phase-2 becomes larger than that of in Phase-1.

By this feeder divide, the total number of feeders becomes 213, four (4) feeders are increased from the original plan.

16.3 Optimized On-grid Phase Development Plan

16.3.1 Optimized On-grid Phase-1 Plan (10th FYP)

Table-16.3.1 in the next page shows the list of feeders that are now planned to be constructed in Phase-1. Out of 213 feeders, 130 feeders will be implemented in Phase-1. The number of households that will be connected to these feeders is forecast to be 21,519 in 2007 . This number includes the 396 households (2007 forecast) connected to existing lines from the Dagana small hydropower generator that needs to be replaced. Therefore, the actual number of non-electrified households of the master plan target that will be connected to an electricity supply for the first time is 21,123.

The total line length for the optimized 10th FYP is 1,580 km and the investment cost is US$ 49.2 million. The highest IRR is 57.7%, for feeder MPF11F5 in Lhuntse. The lowest IRR is 6.3% for feeder MPC33F2-1 in Dagana. This particular feeder includes the additional cost for the replacing the lines from the existing small hydropower, which contribute to the low IRR. Dagana needed to increase electrification percentage in the original plan, so the phase of the feeder was changed from Phase-2 to Phase-1. In addition, there are five (5) feeders of which the IRRs are below 12%. They were evaluated to be Phase-2 in the original plan, but the phase was changed to Phase-1 during the process of modification for the optimization.

Table-16.3.1 Optimized Feeder List of Phase-1 Implementation (10th FYP)

No.	Feeder Name	HH 2007	Investment (1,000 Nu.)	Distance (m)	IRR	B/C	Note
	(A) Bumthang						
67	MPA11F1-3	7	967	818	17.6%	1.58	
107	MPA11F1-4	147	17,604	13,945	13.4%	1.23	
113	MPA11F1-1	126	17,081	12,659	12.8%	1.18	
122	MPA11F3-1	27	2,129	2,616	11.8%	1.11	
124	MPA11F2-1	168	26,825	34,415	11.1%	1.06	*
	(B) Chukha						
2	MPB11F1-1	42	2,290	609	41.2%	4.38	
4	MPB11F5-2	10	461	145	31.3%	3.12	
8	MPB11F5-1	7	379	128	30.8%	3.05	
9	MPB33F4-1	18	1,781	1,159	28.4%	2.68	
12	MPB11F3-3	13	544	117	23.2%	2.24	
18	MPB11F4-1	14	860	470	24.2%	2.26	
29	MPB33F4-19	9	677	418	20.1%	1.84	
44	MPB11F2-1	64	6,974	9,572	18.4%	1.60	
52	MPB11F4-2	15	1,018	457	16.1%	1.48	
53	MPB11F5-3	28	2,489	2,404	17.0%	1.52	
62	MPB33F4-6	750	65,542	44,819	14.7%	1.34	
70	MPB11F1-2	201	14,548	12,665	15.6%	1.41	
79	MPB33F4-3	1,401	135,219	109,533	13.7%	1.25	
84	MPB11F3-1	68	4,444	2,865	14.0%	1.29	
117	MPB33F2-1	38	3,060	1,595	11.4%	1.07	*2
	(C) Dagana						
59	MPC33F6-1	6	652	277	17.6%	1.63	
97	MPC33F6-2	3	631	361	13.1%	1.21	
129	MPC33F2-1	865	90,597	77,723	6.3%	0.72	*
	(E) Haa						
14	MPE11F2-1	12	753	73	23.5%	2.30	
	(F) Lhuntse						
1	MPF11F1-7	3	646	505	57.7%	6.05	
27	MPF33F6-4	17	1,271	46	19.0%	1.82	
40	MPF11F4-1	36	3,514	2,187	17.8%	1.62	
66	MPF11F1-5	64	7,019	3,824	16.5%	1.50	
78	MPF11F4-2	17	1,574	618	14.5%	1.34	
92	MPF33F6-3	8	587	28	14.7%	1.38	
100	MPF33F6-8	189	23,081	10,824	13.8%	1.27	
101	MPF11F3-4	43	3,951	2,053	13.5%	1.24	
110	MPF33F6-7	132	17,708	7,703	13.1%	1.21	
121	MPF11F5-2	312	36,829	25,587	12.3%	1.15	
	(G) Mongar						
11	MPG11F12-3	4	392	81	24.8%	2.41	
23	MPG33F5-1	85	10,263	4,144	21.2%	1.98	
43	MPG11F12-2	15	923	403	16.2%	1.49	
47	MPG11F2-1	8	479	46	17.7%	1.67	
48	MPG11F12-1	9	569	167	16.2%	1.50	
55	MPG11F12-5	6	427	39	15.1%	1.41	
56	MPG33F3-1	228	20,938	6,548	16.5%	1.53	
65	MPG33F7-1	31	3,416	965	16.2%	1.50	
73	MPG33F14-1	289	35,578	17,756	15.8%	1.45	
83	MPG11F1-1	84	10,400	8,792	15.0%	1.36	
96	MPG33F10-1	134	13,652	4,123	13.6%	1.26	
103	MPG33F14-3	11	872	191	13.1%	1.22	
	(H) Paro						
38	MPH11F2-2	16	973	126	16.7%	1.57	
69	MPH11F4-1	2	374	440	17.8%	1.57	
105	MPH33F3-1	13	918	731	12.4%	1.15	
106	MPH33F3-2	17	2,268	3,073	13.4%	1.22	
111	MPH11F1-3	9	914	1,208	13.0%	1.19	
	(I) Pemagatshel						
19	MPI33F2-3	96	7,641	4,007	24.3%	2.27	
85	MPI33F2-2	7	763	539	15.6%	1.42	
93	MPI33F3-2	520	61,289	46,576	14.8%	1.35	
	(J) Punakha						
125	MPJ33F1-9	84	13,168	14,975	12.0%	1.12	*
126	MPJ33F1-5	45	5,152	4,031	11.2%	1.06	*
128	MPJ33F1-2	26	2,414	1,990	8.7%	0.88	*
130	MPJ33F1-6	12	1,079	1,143	8.3%	0.86	*
	(K) Samdrup Jongkhar						
6	MPK33F3-1	20	1,713	808	31.5%	3.07	
25	MPK33F7-7	66	6,028	2,588	20.6%	1.91	
28	MPK11F7-2	274	20,073	16,375	20.7%	1.86	
41	MPK33F1-1	950	82,024	54,389	17.9%	1.62	
46	MPK33F3-2	103	7,362	2,937	17.1%	1.58	
58	MPK33F6-1	11	685	174	16.1%	1.50	
64	MPK33F7-1	115	14,899	12,188	13.6%	1.25	
89	MPK33F3-3	20	1,387	740	13.7%	1.26	
91	MPK33F3-4	438	50,263	35,827	14.4%	1.31	
102	MPK11F7-9	174	15,957	16,626	13.7%	1.25	
114	MPK33F3-6	41	3,099	1,533	12.5%	1.16	

No.	Feeder Name	HH 2007	Investment (1,000 Nu.)	Distance (m)	IRR	B/C	Note
	(L) Samtse						
20	MPL11F1-1	366	24,072	17,088	19.5%	1.77	
30	MPL33F2-6	9	487	101	18.3%	1.72	
34	MPL33F2-5	13	731	316	17.0%	1.57	
37	MPL11F1-4	50	2,972	1,775	17.5%	1.59	
42	MPL11F5-14	28	1,562	832	16.9%	1.55	
45	MPL11F5-5	519	34,548	28,176	16.9%	1.52	
86	MPL33F2-11	23	1,862	1,258	14.0%	1.28	
87	MPL33F2-10	32	2,227	1,081	13.5%	1.25	
104	MPL11F5-1	159	12,181	12,202	13.0%	1.20	
109	EXL15	1,144	87,509	93,735	12.4%	1.15	
112	MPL11F6-4	40	2,865	2,382	12.1%	1.13	
120	MPL11F1-2	189	13,953	12,360	11.5%	1.08	
	(M) Sarpang						
3	MPM33F3-1	35	5,400	6,675	41.0%	3.77	
5	MPM33F2-4	64	4,442	1,185	14.3%	1.33	
7	MPM11F2-3	260	16,217	6,474	29.5%	2.87	
10	MPM11F2-1	12	1,126	1,154	30.0%	2.71	
16	MPM11F1-2	41	1,764	477	22.6%	2.16	
17	MPM11F4-6	35	2,199	985	24.1%	2.27	
22	MPM11F4-7	10	527	175	18.6%	1.73	
24	MPM11F2-2	17	975	13	18.0%	1.72	
36	MPM11F4-5	35	2,057	635	16.8%	1.56	
54	MPM33F2-21	23	1,780	785	15.7%	1.45	
60	MPM33F1-1	34	2,265	443	15.1%	1.41	
63	MPM11F1-1	45	2,949	1,483	15.2%	1.40	
115	MPM11F4-1	195	17,088	17,604	11.9%	1.11	
127	MPM33F1-2	590	65,764	55,323	10.3%	0.99	*
	(O) Trashigang						
13	MPO11F3-1	17	932	37	24.8%	2.47	
15	MPO11F9-14	83	8,527	5,013	26.6%	2.50	
26	MPO11F9-2	317	33,372	16,629	20.9%	1.93	
31	MPO33F8-1	75	8,055	3,797	15.8%	1.45	
39	MPO11F1-3	400	43,078	28,396	18.7%	1.69	
50	MPO11F7-5	5	351	69	14.9%	1.38	
57	MPO11F9-1	18	2,201	2,911	18.4%	1.61	
71	MPO11F9-7	282	25,498	15,446	14.3%	1.31	
75	MPO11F7-2	8	868	519	15.2%	1.39	
76	MPO11F9-13	23	1,598	442	14.7%	1.36	
80	MPO11F9-15	23	1,820	966	14.8%	1.36	
82	MPO11F9-17	145	24,923	8,860	15.1%	1.38	
88	MPO11F3-2	5	1,366	2,034	15.1%	1.34	*
98	MPO11F1-1	121	12,235	11,077	14.2%	1.29	
108	MPO11F2-1	84	8,004	6,545	13.5%	1.23	
	(P) TrashiYangtse						
32	MPP33F1-13_2	35	4,485	1,858	19.2%	1.77	
35	MPP33F1-13_1	15	941	123	16.8%	1.57	
49	MPP33F1-18	336	35,425	15,950	15.6%	1.43	
72	MPP33F1-8	359	36,573	13,636	15.6%	1.44	
74	MPP33F1-14	63	7,491	3,747	15.4%	1.41	
90	MPP33F1-9_1	66	5,856	1,379	13.7%	1.27	
	(Q) Trongsa						
77	MPQ33F1-13	384	56,428	37,905	15.2%	1.38	
81	MPQ33F1-10	86	9,904	4,317	14.4%	1.33	
95	MPQ33F1-8	229	32,308	26,229	13.9%	1.27	
116	MPQ33F1-7	7	595	198	11.6%	1.09	
	(R) Tsirang						
21	MPR33F2-1	553	48,549	19,669	15.4%	1.42	
33	MPR33F1-1	907	85,579	39,505	14.1%	1.30	
51	MPR33F2-5	46	3,334	436	15.0%	1.40	
61	MPR11F2-1	42	2,743	1,153	15.0%	1.38	
68	MPR33F3-1	1,691	190,781	107,719	14.9%	1.36	
99	MPR11F1-1	30	2,224	1,482	12.4%	1.15	*2
	(S) Wangduephodrang						
94	MPS11F1-1	203	39,219	53,043	14.9%	1.33	
118	MPS33F3-1	734	89,466	71,565	12.6%	1.17	*2
	(T) Zhemgang						
119	MPT33F2-6	708	101,269	94,297	12.4%	1.15	
123	MPT33F3-1	628	87,217	68,784	12.3%	1.14	*
	TOTAL	**21,519**	**2,214,793**	**1,579,952**			

* The Phase was changed from 2 to 1 after genuin economic evaluation.
*2 The feeder was cut and part of the feeder was sent to Phase-2.
*3 The feeder was changed from 1 to 2 after genuin economic evaluation.
*4 Those were subfeeders cut from the feeder of *2 and sent to Phase-2.
Dagana MPC33F2-1 includes 396 households connected to existing line to be replaced.
Prepared by JICA Study Team

As for the feeders that pass through more than two Dzongkhags, those are included in Dzongkhag from which the source of the feeders start

16.3.2 Optimized On-grid Phase-2 Plan (11th FYP)

In Phase-2, which corresponds to 11th FYP, construction of the remaining 83 out of 213 feeders will occur. The on-grid electrification plan will be completed in Phase-2 without requiring Phase-3. Therefore, before the target year 2020, 100% electrification will be achieved by 2017.

Table-16.3.2 shows the list of feeders that will be constructed in Phase-2. The IRR of Phase-2 is calculated from the demand and benefit forecast for 2012, when 11th FYP will start.

The total cost for the on-grid electrification in Phase-2 is US$22.1 million. The total Phase-2 line length is 742 km. The number of electrified households forecast for 2007 is 7,819. The feeders which have high IRRs are already electrified in Phase-1. Therefore, the IRRs in Phase-2 become relatively low. The highest IRR among the Phase-2 feeders is 22% for MPO11F1-8 in Tashigang, followed by 21.4% for feeder MPB33F2-7 in Chukha. Those were evaluated to be implemented in Phase-1 in the original plan, and changed to Phase-2 as a result of the optimization process. The lowest IRR is 7% for MPL33F2-12 in Samtse. In Phase-2, there are 47 feeders which have IRRs lower than 12%.

Figure-16.3.1 shows the distribution line extensions at the end of Phase-2. **Table-16.3.3** provides a summary of the number of households, number of villages, line length, and construction cost by phase. Approximately 70% of the electrification plan (number of households, number of villages, line length, and construction cost) will be implemented in Phase-1. As for the line length, 1,580 km will be constructed in the Phase-1, and 742 km will be constructed in Phase-2, bringing the total to 2,322 km. As for the investment cost, US$49.2 million will be expended in Phase-1 and US$22.1 million will be expended in Phase-2, which totals US$71.4 million.

Table-16.3.2 Optimized Feeder List of Phase-2 Implementation (11th FYP)

No.	Feeder Name	HH 2007	Investment (1,000 Nu.)	Distance (m)	IRR	B/C	Note
	(B) Chukha						
132	MPB33F2-7	111	10,144	6,929	21.4%	1.95	*3
138	MPB33F2-5	20	1,494	1,014	14.1%	1.29	
140	MPB33F3-1	4	389	41	13.8%	1.28	
167	MPB33F5-3	18	2,749	3,523	11.8%	1.10	
172	MPB33F2-4	4	435	139	11.6%	1.09	*4
203	MPB11F3-4	5	534	619	8.6%	0.89	
208	MPB33F2-2	24	2,573	2,663	8.1%	0.85	
	(C) Dagana						
182	MPC33F3-1	431	60,659	54,719	10.8%	1.03	
194	MPC33F1-2	73	8,093	3,284	10.1%	0.96	
206	MPC33F6-3	18	2,108	1,293	8.6%	0.86	
	(D) Gasa						
195	MPD33F1-1	184	30,255	32,039	9.6%	0.95	
	(E) Haa						
166	MPE11F1-2	10	1,276	1,436	12.0%	1.12	
191	MPE11F1-1	16	1,963	2,029	10.2%	0.99	
	(F) Lhuntse						
148	MPF11F3-3	86	10,342	6,650	13.5%	1.24	
169	MPF33F6-6	14	1,808	798	11.8%	1.10	
176	MPF33F6-5	37	4,636	2,170	11.3%	1.06	
183	MPF11F3-2	6	1,029	1,112	10.7%	1.03	
185	MPF11F3-7	25	2,897	2,103	10.6%	1.02	
198	MPF11F1-1	96	13,931	11,569	9.4%	0.93	
200	MPF11F5-1	26	3,253	2,592	9.3%	0.92	
212	MPF33F6-1	72	11,554	7,383	8.2%	0.84	
	(G) Mongar						
135	MPG11F2-3	177	24,881	24,269	14.6%	1.32	
188	MPG11F12-4	16	1,593	1,233	10.4%	1.00	
189	MPG33F11-1	18	1,966	642	10.6%	1.00	
	(H) Paro						
147	MPH33F1-5	4	694	768	13.7%	1.24	*4
168	MPH33F2-3	2	566	612	11.8%	1.10	
193	MPH33F2-2	12	1,558	1,747	9.8%	0.96	
202	MPH11F1-4	1	540	881	8.6%	0.91	
205	MPH33F2-1	11	1,628	1,571	8.7%	0.88	
207	MPH11F2-3	17	3,749	6,719	7.8%	0.86	
	(I) Pemagatshel						
152	MPI33F1-1	1,154	157,296	101,859	13.0%	1.20	
186	MPI33F3-5	4	407	38	10.8%	1.02	
190	MPI33F3-1	66	9,785	6,875	10.4%	0.99	*4
	(J) Punakha						
160	MPJ11F1-2	15	3,211	5,426	12.6%	1.16	
	(K) Samdrup Jongkhar						
144	MPK11F2-3	8	570	343	13.8%	1.27	
145	MPK11F2-4	929	143,273	79,483	13.8%	1.26	
146	MPK11F5-4	56	4,563	3,933	13.6%	1.25	*3
150	MPK33F7-4	148	14,085	9,435	13.2%	1.22	
163	MPK33F3-18	10	820	699	12.3%	1.14	
187	MPK11F5-3	43	5,810	7,547	10.5%	1.01	
192	MPK33F3-8	39	4,874	4,234	9.9%	0.97	
197	MPK33F3-10	5	977	1,281	9.2%	0.93	
	(L) Samtse						
134	MPL33F1-15	396	34,579	25,347	15.2%	1.38	
137	MPL33F2-7	223	17,853	12,388	14.1%	1.29	
139	MPL11F4-1	93	7,094	7,174	14.1%	1.28	
154	MPL11F3-1	42	3,164	3,418	13.0%	1.19	
157	MPL33F2-3	4	399	160	12.5%	1.16	
164	MPL11F6-1	51	4,039	4,409	12.2%	1.13	
179	MPL11F2-1	13	1,077	1,517	11.0%	1.05	
199	MPL33F2-4	6	550	447	9.3%	0.92	
201	MPL33F2-1	17	1,702	1,682	9.1%	0.91	
213	MPL33F2-12	7	750	722	6.8%	0.76	
	(M) Sarpang						
156	MPM33F2-5	763	84,891	67,112	12.7%	1.18	
170	MPM11F3-5	24	2,120	1,997	11.7%	1.10	
173	MPM33F2-1	78	7,365	4,878	11.4%	1.08	
175	MPM33F2-22	14	1,216	1,169	11.3%	1.07	*4
181	MPM33F4-1	344	38,980	30,639	11.0%	1.04	
	(N) Thimphu						
184	MPN33F2-1	14	1,604	1,482	10.7%	1.03	
	(O) Trashigang						
131	MPO11F1-8	244	27,338	15,981	22.0%	2.01	
133	MPO11F7-1	5	393	175	15.9%	1.46	
141	MPO11F2-4	30	2,798	1,627	13.9%	1.28	*3
149	MPO11F6-1	39	3,816	2,921	13.5%	1.24	
151	MPO11F7-7	62	5,800	4,139	13.2%	1.21	
159	MPO11F7-3	11	822	711	12.5%	1.16	
174	MPO11F10-1	4	435	237	11.4%	1.07	
177	MPO11F3-3	15	1,737	1,723	11.1%	1.05	
210	MPO11F9-11	14	2,065	2,014	8.1%	0.85	
211	MPO11F7-4	3	341	146	8.5%	0.84	
	(P) TrashiYangtse						
142	MPP33F1-1	346	51,063	28,448	13.8%	1.27	
158	MPP33F1-7	7	611	124	12.5%	1.16	
	(Q) Trongsa						
153	MPQ33F1-3	223	36,591	26,991	13.0%	1.20	
	(R) Tsirang						
204	MPR11F1-2	30	3,182	3,623	8.6%	0.89	
	(S) Wangduephodrang						
136	MPS33F3-24	4	378	98	13.9%	1.29	*3
155	MPS33F3-23	52	4,910	2,636	12.8%	1.19	
161	MPS33F3-37	13	1,486	1,111	12.5%	1.16	
162	MPS33F3-5	158	22,647	18,449	12.3%	1.14	
171	MPS33F3-31	18	3,753	3,538	11.6%	1.09	
178	MPS33F3-33	59	9,700	10,490	11.1%	1.05	
180	MPS33F3-4-2	201	29,382	27,756	11.0%	1.05	
196	MPS11F2-1	4	1,298	2,009	9.2%	0.94	
209	MPS33F3-34	17	4,325	5,280	8.0%	0.85	
	(T) Zhemgang						
143	MPT33F2-2	116	15,625	11,475	13.8%	1.27	
165	MPT33F1-3	40	3,488	1,938	12.1%	1.13	
	TOTAL	**7,819**	**996,217**	**741,885**			

* The Phase was changed from 2 to 1 after genuin economic evaluation.

*2 The feeder was cut and part of the feeder was sent to Phase-2.

*3 The feeder was changed from 1 to 2 after genuin economic evaluation.

*4 Those were subfeeders cut from the feeder of *2 and sent to Phase-2.

As for the feeders that pass through more than two Dzongkhags, those are included in Dzongkhag from which the source of the feeders starts.
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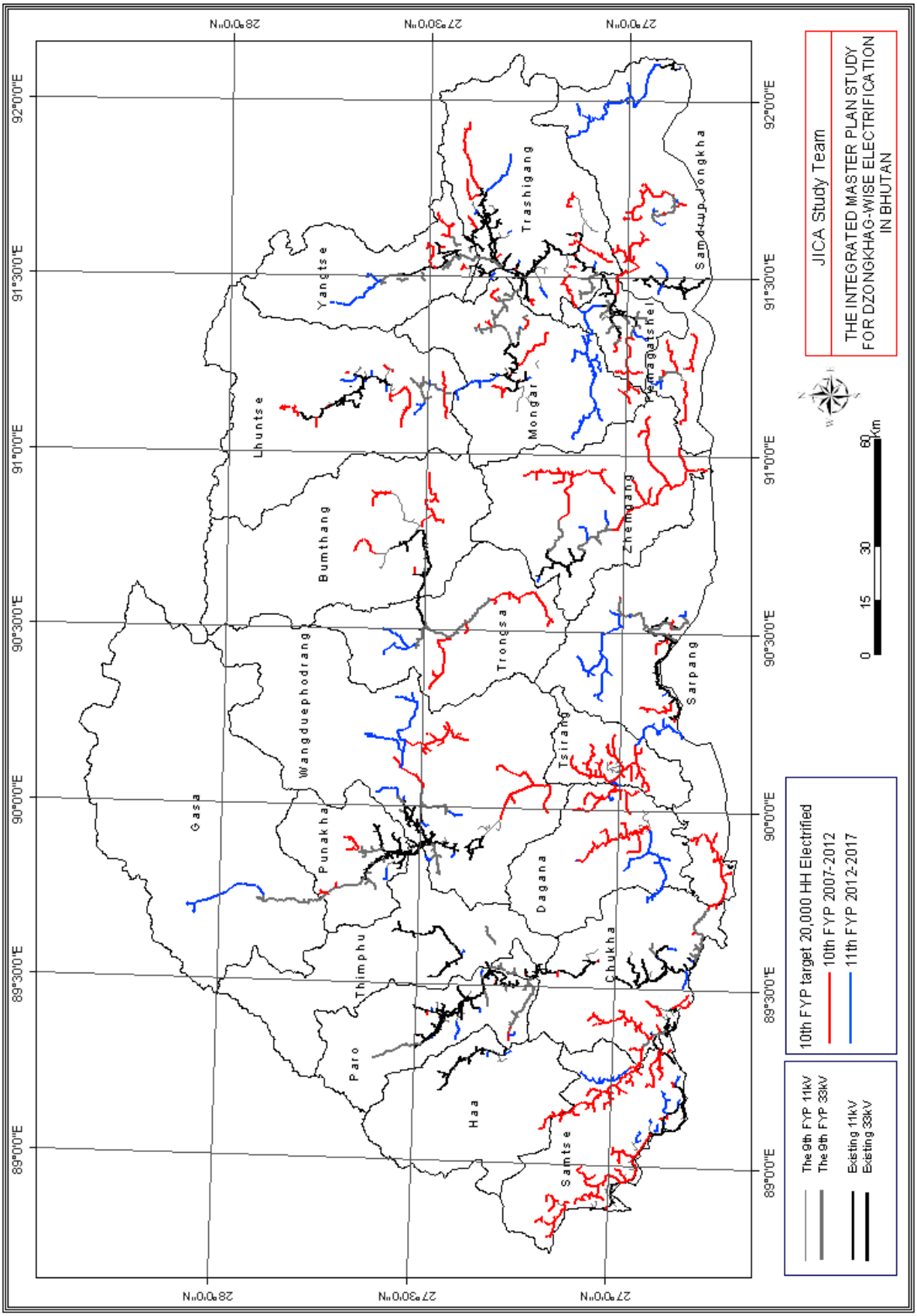

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Figure-16.3.1 On-grid Rural Electrification Plan by Phase

Table-16.3.3 Numbers of Households and Villages, Line Length, and Investment

Dzongkhag	On-grid Household Number*			On-grid Village Number			Line Length (m)			Investment (x US$1,000)		
	Phase-1	Phase-2	TOTAL	Phase-1	Phase-2	TOTAL	Phase-1	Phase-2	TOTAL	Phase-1	Phase-2	TOTAL
Bumthang	475	0	475	30	0	30	64,454	0	64,454	1,436	0	1,436
Chukha	1422	279	1701	63	15	78	94,186	31,376	125,562	2,718	699	3,416
Dagana	1731	429	2160	48	17	65	131,861	42,850	174,711	4,250	1,283	5,533
Gasa	0	184	184	0	7	7	0	32,039	32,039	0	672	672
Haa	182	26	208	8	2	10	20,925	3,465	24,389	519	69	588
Lhuntse	821	362	1183	46	27	73	53,376	34,379	87,755	2,137	1,099	3,236
Mongar	1057	1310	2367	44	82	126	62,856	111,164	174,019	2,651	3,843	6,494
Paro	57	47	104	5	6	11	5,577	12,297	17,874	121	194	315
Pemagatshel	470	125	595	16	10	26	31,521	23,752	55,273	1,074	511	1,585
Punakha	167	15	182	15	2	17	22,139	5,426	27,565	485	71	556
Samdrup Jongkhar	2212	1221	3433	83	45	128	144,186	106,173	250,358	4,522	3,860	8,382
Samtse	3658	852	4510	119	41	160	243,224	57,265	300,488	6,230	1,582	7,813
Sarpang	1385	1223	2608	59	64	123	92,646	105,796	198,443	2,744	2,990	5,735
Thimphu	0	14	14	0	1	1	0	1,482	1,482	0	36	36
Trashigang	1606	444	2050	67	15	82	102,740	30,457	133,197	3,841	1,041	4,881
TrashiYangtse	874	353	1227	31	20	51	36,694	28,571	65,265	2,017	1,148	3,165
Trongsa	706	223	929	33	11	44	68,650	26,991	95,641	2,205	813	3,018
Tsirang	2423	30	2453	69	1	70	117,228	3,623	120,851	5,220	71	5,291
Wangduephodrang	937	526	1463	65	37	102	124,608	71,367	195,975	2,860	1,731	4,590
Zhemgang	1336	156	1492	57	7	64	163,081	13,412	176,493	4,189	425	4,613
TOTAL	**21,519**	**7,819**	**29,338**	**858**	**410**	**1,268**	**1,579,952**	**741,885**	**2,321,837**	**49,218**	**22,138**	**71,356**
Percentage	73.3%	26.7%	100.0%	67.7%	32.3%	100.0%	68.0%	32.0%	100.0%	69.0%	31.0%	100.0%

*: The households are all forecast number in 2007, in order to apply it to calculate electrification percentage

* Dagana includes 396 households connected to existing line to be replaced.

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16.3.3 Results of Power Flow Analysis for the Optimized Phase Development Plan

The results of power flow analysis for optimized phase development plan (2012, 2015 and 2020) are shown in **Appendix B-II-1** and **Appendix B-II-3**.

The analysis identified the distribution lines that require countermeasures to be implemented, such as changing the conductor type or installing voltage regulators. Thee affected areas are as follows:

1) Hiley Gewog in Sarpan and Sakteng and Kangpara Gewogs in Trasigang

Electrification in these areas is going to be started in Phase-1. According to the power flow analysis, voltage regulators will need to be installed together with the extension of distribution lines in Phase-1 since the voltage drops for each area in 2012 will be 13%.

2) Lauri and Serthing Gweogs in Samdrup Jongkhar

Electrification in these areas is going to be started in Phase-2. According to the power flow analysis, since the voltage drop in 2017 is more than 50%, two voltage regulators need to be installed together with the extension of the distribution lines in Phase-2.

Taking environment/physical factors and source constraints into account, Micro Hydro would be a better option compare to Grid extension.

3) Namgyel Chholing Gewog in Samtse

Electrification of this area is going to be started in Phase-2 and the installation of two voltage regulators and replacement of 20 km of existing distribution lines are planned.

According to the power flow analysis, installation of two voltage regulators and replacement of 12 km lines are required in 2012. The other 8 km lines can be replaced in Phase-2.

Table-16.3.4 Power System Analysis Results for the Optimized Phase Development Plan

Dzongkhag	Gewog			2012	2017	2020
Samdrup Jongkhar	Lauri, Serthing	Countermeasure		---	1 SVR Installing	1 SVR Installing
		Voltage Drop	Before	---	Over 50%	Over 50%
			After	---	8%	10%
Samtse	Namgyel Chholing	Countermeasure		2 SVR Installing Re-conductor from Rabbit to Dog, 12km	2 SVR Installing Re-conductor from Rabbit to Dog, 20km	2 SVR Installing Re-conductor from Rabbit to Dog, 20km
		Voltage Drop	Before	37%	Over 50%	Over 50%
			After	8%	9%	10%
Sarpang	Hiley	Countermeasure		1 SVR Installing	1 SVR Installing	1 SVR Installing
		Voltage Drop	Before	13%	14%	15%
			After	8%	8%	9%
Trashigang	Sakteng	Countermeasure		1 SVR Installing	1 SVR Installing	1 SVR Installing
		Voltage Drop	Before	13%	16%	18%
			After	8%	8%	9%
	Kangpara	Countermeasure		1 SVR Installing	1 SVR Installing	1 SVR Installing
		Voltage Drop	Before	13%	14%	15%
			After	7%	7%	7%

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16.4 Off-grid Electrification Plan

The total number of non-electrified households in Bhutan is forecast to be 44,218 in 2020. This is the target of this master plan. The off-grid electrified villages is forecast to be 3,918 in 2007 and 5,133 in 2020.

Here, an off-grid system basically represents a solar home system. Mini/micro hydropower with high power source potential are defined as an optional implementation plan only when grants from donors can be secured. Accordingly, in the master plan, project cost calculations and economic evaluations apply to on-grid electrification by distribution line extensions and off-grid electrification by solar home systems. Project costs for mini/micro hydropower are not included in the master plan implementation cost.

The RGoB has a policy for the implementation budget of solar home systems to depend on grants from donors. Although the target off-grid electrification household number was formulated in 10th FYP, as presented below, implementation staging was not clearly identified as on-grid since the project implementation depends on receiving grant assistance. Project cost estimation and off-grid electrification household numbers used for the calculation of electrification percentages are summarized in 11th FYP in this master plan.

According to DOE policy, the target off-grid electrification household number was planned to be 2,000 for 10th FYP. Selection of target households will be village-wise based as a

realistic way of implementation. Here, the selection criteria for villages identified for off-grid electrification in 10th FYP are defined. Actual selection will be carried out in the Feasibility Study for 10th FYP.

The following selection criteria are for 10th FYP off-grid electrification villages:

1) Give priority to Dzongkhags that have low on-grid electrification percentages in 10th FYP.

2) Give priority to areas where it will be difficult to extend distribution lines, even after 2020.

Criteria (1) is applied in order to make the total electrification percentage with on-grid and off-grid of respective Dzongkhag as the same level as possible. Each Dzongkhag is allocated to be electrified by on-grid or off-grid, and the on-grid plan has already been formulated prior to off-grid. Therefore, it is suggested to increase the electrification percentage of the Dzongkhag for which the on-grid electrification percentage is low in 2020 by prioritizing the off-grid electrification. First, the target off-grid electrification percentage is compared to the on-grid electrification percentage at the end of 10th FYP, as shown in the **Table-16.4.1**. Here, the target off-grid electrification percentage is in proportion to the target off-grid households in 2020 by each Dzognkhags.

Table-16.4.1 On-grid Electrified Percentage and Target Percentage of Off-grid electrification

10th FYP On-grid Electrified %	10th FYP Target off-grid HH %
0-40%	100%
40-75%	95%
75-85%	60%
85-90%	10%

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Next, the Dzongkhags were arranged in ascending order of on-grid electrification percentage in 10th FYP, and the target off-grid electrification percentages were fixed according to the on-grid electrified percentages in every Dzongkhag. This allowed the target off-grid electrification households in 10th FYP to be determined for every Dzongkhag. The results of this carrying out this procedure are shown in **Table-16.4.2.**

Table-16.4.2 Off-grid Electrification Households in 10th FYP

Dzongkhag	10th FYP On-grid Electrified %	Total Off-grid HH Number	10th FYP Target off-grid HH %	10th FYP off-grid Electrified	10th FYP On + off grid Electrified %
Gasa	36.4%	178	100%	178	67.7%
Mongar	69.1%	498	95%	473	77.2%
Sarpang	69.9%	385	95%	366	77.0%
Samdrup Jongkhar	70.7%	401	95%	381	77.5%
Lhuntse	75.2%	294	50%	147	80.7%
Wangdue phodrang	78.7%	374	50%	187	83.1%
Dagana	78.9%	200	50%	100	82.3%
Zhemgang	81.9%	265	50%	133	87.6%
Trongsa	85.3%	32	10%	3	85.4%
Samtse	85.9%	255	10%	26	86.3%
TrashiYangtse	87.5%	35	10%	4	87.6%
Chukha	87.6%	284	10%	28	88.3%
Haa	92.1%	69	0%	0	92.1%
Thimphu	93.0%	121	0%	0	93.0%
Trashigang	93.1%	156	0%	0	93.1%
Pemagatshel	93.8%	48	0%	0	93.8%
Tsirang	95.0%	141	0%	0	95.0%
Punakha	95.5%	93	0%	0	95.5%
Paro	97.3%	70	0%	0	97.3%
Bumthang	99.1%	19	0%	0	99.1%
TOTAL	**84.1%**	**3,918**		**2,025**	86.5%

The household number applies the forecasted number in 2007

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In particular, the priority areas for installing the proposed off-grid systems are Dangana, Monogar, and Sarpang Dzongkhag, where the on-grid electrification percentage is low in 10th FYP. For the actual household selection, it is villages in the corresponding Dzongkhags that are to be selected, so that the number of off-grid electrification households becomes appropriate.

Criteria (2), as described above, comes from the policy that areas for which distribution line extension is almost impossible should be implemented in the early stage of off-grid electrification. Based on this policy, the areas for which geographic conditions are a problem, distances to distribution lines are long, and the numbers of households is small, were identified, as listed in **Table-16.4.3**.

Table-16.4.3 Off-grid Electrification Priority Areas

Off-grid Priority Dzongkhag	Priority Areas
Gasa	All Lunana Gewog
Mongar	Southern Saleng Gewog
Sarpang	Northern Lhamoizimkha, northern Deorali, central Dekil
Samdrup Jongkhar	Southern Langchenphu, western Orong Gewog
Lhuntse	Central and northern Khoma Gewog
Wangduephodrang	Southern Bjena, Southern and central Athang Gewog
Dagana	-
Zhemgang	Northen Phangkhar, Northen Bjoka Gewog
Trongsa	Northen Langthil Gewog
Samtse	Northen Namgyeltchholing Gewog
TrashiYangtse	-
Chukha	Northen Dungna Gewog

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16.5 Rural Electrification Percentage

The rural electrification percentage was calculated for the optimized plan as part of the master plan formulation. Here, the number of rural electrification households is defined as the sum of the accumulated target number of electrified households at the end of 9th FYP and the target number of electrification households in each FYP in this master plan, as was presented earlier in the Chapter 15, Section 15.4. The target number of rural electrification households in all Bhutan is 73,399. This number represents the sum of 40,536 households which are the target for electrification at the end of 9th FYP, and 32,863 households (forecast 2007) which are the target for electrification in this master plan.

Table-16.5.1 shows the accumulated number of electrification households and electrification percentages by Dzonghag. In addition, **Figure-16.5.1** shows a graph of the change of on-grid electrification percentage by Dzongkhags. Although off-grid electrification is planned in 10th FYP, the off-grid electrification percentage is summarized in 11th FYP since the implementation funding source is planned to be derived from financial assistance provided by donors, as explained above in Section 16.4.

The on-grid electrification percentage forecast was 55.2% in 2007, at the end of 9th FYP. It will be 84.5% at the end of 10th FYP, increase to 94.7% at the end of 11th FYP in the whole country. The target of 100% rural electrification will be achieved by the end of 11th FYP in this master plan. Approximately 95%[1] of rural households will be connected to the grid (on-grid) and remaining 5% will be electrified by off-grid means.

Table-16.5.1 Rural Electrification Percentage by Dzongkhags

Dzongkhag	Target nos of Electrifi-cation	At the end of 9th FYP		At the End of 10th FYP			At the End of 11th FYP			
		On Grid Electrified Households	% On-grid Electrified	On Grid Electrified Households	off + non-electrified Households	% On-grid Electrified	On Grid Electrified Households	Off-grid House-holds	% On-grid Electri-fied	Total % Eletrified
Bumthang	2,012	1,518	75.4%	1,993	19	99.1%	1,993	19	99.1%	100%
Chukha	4,550	2,565	56.4%	3,987	563	87.6%	4,266	284	93.8%	100%
Dagana	2,983	1,019	34.2%	2,750	233	92.2%	2,783	200	93.3%	100%
Gasa	569	207	36.4%	207	362	36.4%	391	178	68.7%	100%
Haa	1,203	926	77.0%	1,108	95	92.1%	1,134	69	94.3%	100%
Lhuntse	2,643	1,166	44.1%	1,987	656	75.2%	2,349	294	88.9%	100%
Mongar	5,851	2,986	51.0%	4,043	1,808	69.1%	5,353	498	91.5%	100%
Paro	4,387	4,213	96.0%	4,270	117	97.3%	4,317	70	98.4%	100%
Pemagatshel	2,772	2,129	76.8%	2,599	173	93.8%	2,724	48	98.3%	100%
Punakha	2,414	2,139	88.6%	2,306	108	95.5%	2,321	93	96.1%	100%
Samdrup Jongkhar	5,574	1,737	31.2%	3,940	1,634	70.7%	5,173	401	92.8%	100%
Samtse	7,879	3,114	39.5%	6,772	1,107	85.9%	7,624	255	96.8%	100%
Sarpang	5,093	2,100	41.2%	3,485	1,608	68.4%	4,708	385	92.4%	100%
Thimphu	1,933	1,798	93.0%	1,798	135	93.0%	1,812	121	93.7%	100%
Trashigang	8,752	6,546	74.8%	8,152	600	93.1%	8,596	156	98.2%	100%
TrashiYangtse	3,102	1,840	59.3%	2,714	388	87.5%	3,067	35	98.9%	100%
Trongsa	1,729	768	44.4%	1,474	255	85.3%	1,697	32	98.1%	100%
Tsirang	3,406	812	23.8%	3,235	171	95.0%	3,265	141	95.9%	100%
Wangdue phodrang	4,225	2,388	56.5%	3,325	900	78.7%	3,851	374	91.1%	100%
Zhemgang	2,322	565	24.3%	1,901	421	81.9%	2,057	265	88.6%	100%
TOTAL	**73,399**	**40,536**	**55.2%**	**62,046**	**11,353**	**84.5%**	**69,481**	**3,918**	**94.7%**	**100%**

All households were forecast number of the year 2007 to calculate electrified percentage, since existing electrified household in 9th fYP was only available in 2007.
* Dagana includes 396 households connected to existing line to be replaced.
Prepared by JICA Study Team

[1] The number includes existing and 9th FYP on-grid rural electrification household, whereas 88.4% on-grid electrification percentage descript in Chapter 14 is the number for only master plan target households.

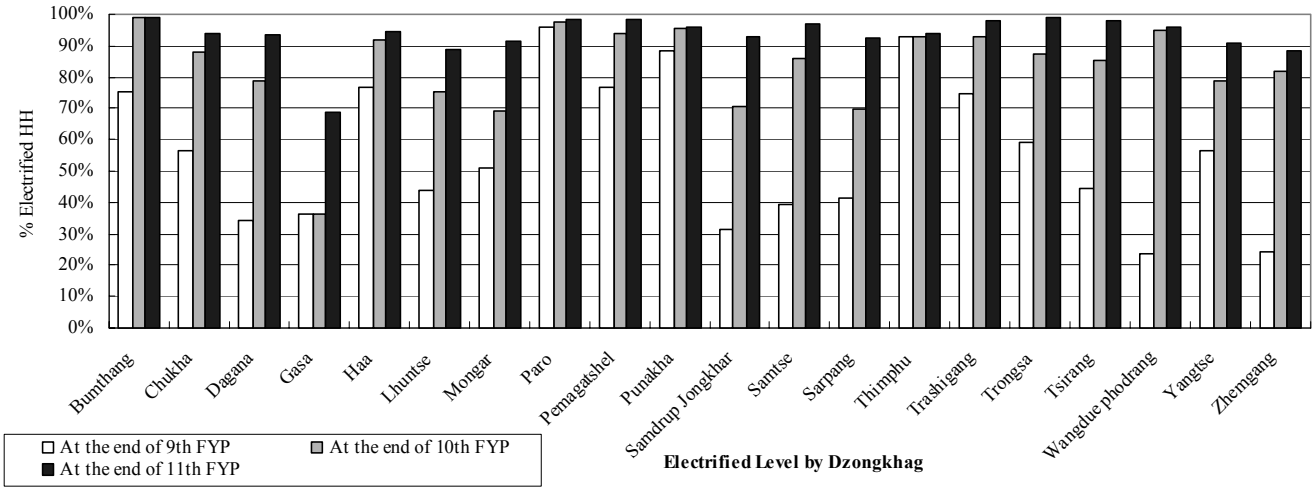

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Figure-16.5.1 On-grid Electrification Percentage at the End of Each FYP

16.6 Economic Evaluation of the Optimized Rural Electrification Program

16.6.1 Economic Evaluation of Optimized Grid Connection

This section shows the overall economic viability of the optimized rural electrification program by phase. **Table-16.6.1** shows the results of economic evaluations of on-grid electrification for each phase. 10th FYP (2007- 2012) requires expenditure of a total of US$49.2 million (2,214 million Nu.) with an IRR of 15%. 11th FYP (2012-2017) requires expenditure of a total of US$ 22.1 million (990 million Nu.) with an IRR of 13%. The average spending per year is equal to US$7.0 million. **Table-16.6.2** shows the cash flow tables for each phase of development. The overall return on investment shows a healthy investment viability of above 12%.

Table-16.6.1 Summary of Optimized Grid Extension Economic Analysis

	Unit	Phase-1	Phase-2
		2007-2012	2012-2017
Investment	Nu. million	2,215	996
	US$ million	49.2	22.1
Distance	km	1,580	742
Household	Nos	21,519	7,819
EIRR	%	14.6%	12.8%

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Table-16.6.2 Grid Extension Cash Flow Table by Phase

Stage-1 (2007-2012)		
Nos. of HH	21,519	
Investment	2,215	million Nu.
Distance	1,580	km
Nos. of Feeders	130	
IRR	14.6%	
B/C	1.19	

Stage-2 (2012-2017)		
No of HH	7,819	
Investment	996	million Nu.
Distance	742	km
Nos. of Feeders	83	
IRR	12.8%	
B/C	1.06	

Unit: Thousand Nu.

Year	Economic Benefit	Economic Cost	Net Flow
Year 0	0	2,280,547	-2,280,547
Year 1	136,393	55,145	81,248
Year 2	272,786	55,145	217,641
Year 3	454,643	55,145	399,498
Year 4	454,643	55,145	399,498
Year 5	454,643	55,145	399,498
Year 6	454,643	55,145	399,498
Year 7	454,643	55,145	399,498
Year 8	454,643	55,145	399,498
Year 9	454,643	55,145	399,498
Year 10	454,643	55,145	399,498
Year 11	454,643	55,145	399,498
Year 12	454,643	55,145	399,498
Year 13	454,643	55,145	399,498
Year 14	454,643	55,145	399,498
Year 15	454,643	55,145	399,498
Year 16	454,643	55,145	399,498
Year 17	454,643	55,145	399,498
Year 18	454,643	55,145	399,498
Year 19	454,643	55,145	399,498
Year 20	454,643	55,145	399,498
Year 21	454,643	55,145	399,498
Year 22	454,643	55,145	399,498
Year 23	454,643	55,145	399,498
Year 24	454,643	55,145	399,498
Year 25	454,643	55,145	399,498
Year 26	454,643	55,145	399,498
Year 27	454,643	55,145	399,498
Year 28	454,643	55,145	399,498
Year 29	454,643	55,145	399,498
Year 30	454,643	55,145	399,498

Unit: Thousand Nu.

Year	Economic Benefit	Economic Cost	Net Flow
Year 0	0	978,074	-978,074
Year 1	52,986	26,040	26,946
Year 2	105,972	26,040	79,931
Year 3	176,619	26,040	150,579
Year 4	176,619	26,040	150,579
Year 5	176,619	26,040	150,579
Year 6	176,619	26,040	150,579
Year 7	176,619	26,040	150,579
Year 8	176,619	26,040	150,579
Year 9	176,619	26,040	150,579
Year 10	176,619	26,040	150,579
Year 11	176,619	26,040	150,579
Year 12	176,619	26,040	150,579
Year 13	176,619	26,040	150,579
Year 14	176,619	26,040	150,579
Year 15	176,619	26,040	150,579
Year 16	176,619	26,040	150,579
Year 17	176,619	26,040	150,579
Year 18	176,619	26,040	150,579
Year 19	176,619	26,040	150,579
Year 20	176,619	26,040	150,579
Year 21	176,619	26,040	150,579
Year 22	176,619	26,040	150,579
Year 23	176,619	26,040	150,579
Year 24	176,619	26,040	150,579
Year 25	176,619	26,040	150,579
Year 26	176,619	26,040	150,579
Year 27	176,619	26,040	150,579
Year 28	176,619	26,040	150,579
Year 29	176,619	26,040	150,579
Year 30	176,619	26,040	150,579

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16.6.2 Economic Analysis of Solar Home System

Economic analyses of the two proposed systems for solar homes show two distinct results. The small scale system that only caters for lighting needs has an IRR of 25%, while the larger system of 550 Wp catering for both lighting and cooking needs shows a negative investment return of -9%. It is because of this discrepancy between the two systems that the on/off evaluation for grid connection described earlier shows 99.1% for grid connection when the larger solar home system is chosen as an alternative.

In calculating the economic costs, the replacement costs are added. It is assumed that batteries are replaced every four (4) years, and the inverter and charge controllers are replaced every eight (8) years. The solar panel is replaced after 25 years. The residual values are entered for year 30 include the assumption of straight line depreciation with the remaining life.

Table-16.6.3 Cash Flow Table for Solar Home Systems

Solar Home System-1
(Base Case)

No of HH	1	
Investment	13,304	Nu.
IRR	25%	
B/C	1.48	

Unit:Nu.

Year	Economic Benefit	Economic Cost	Net Flow
Year 0	0	14,634	-14,634
Year 1	4,922	450	4,472
Year 2	4,922	450	4,472
Year 3	4,922	450	4,472
Year 4	4,922	4,850	72
Year 5	4,922	450	4,472
Year 6	4,922	450	4,472
Year 7	4,922	450	4,472
Year 8	4,922	6,431	-1,510
Year 9	4,922	450	4,472
Year 10	4,922	450	4,472
Year 11	4,922	450	4,472
Year 12	4,922	4,850	72
Year 13	4,922	450	4,472
Year 14	4,922	450	4,472
Year 15	4,922	450	4,472
Year 16	4,922	6,431	-1,510
Year 17	4,922	450	4,472
Year 18	4,922	450	4,472
Year 19	4,922	450	4,472
Year 20	4,922	4,850	72
Year 21	4,922	450	4,472
Year 22	4,922	450	4,472
Year 23	4,922	450	4,472
Year 24	4,922	6,431	-1,510
Year 25	4,922	9,103	-4,181
Year 26	4,922	450	4,472
Year 27	4,922	450	4,472
Year 28	4,922	4,850	72
Year 29	4,922	450	4,472
Year 30	4,922	-9,067	13,989

Solar Home System-2
(Option-2)

No of HH	1	
Investment	196,215	Nu.
IRR	-9%	
B/C	0.29	

Unit:Nu.

Year	Economic Benefit	Economic Cost	Net Flow
Year 0	0	215,837	-215,837
Year 1	11,598	630	10,968
Year 2	11,598	630	10,968
Year 3	11,598	630	10,968
Year 4	11,598	29,670	-18,072
Year 5	11,598	630	10,968
Year 6	11,598	630	10,968
Year 7	11,598	630	10,968
Year 8	11,598	115,311	-103,713
Year 9	11,598	630	10,968
Year 10	11,598	630	10,968
Year 11	11,598	630	10,968
Year 12	11,598	29,670	-18,072
Year 13	11,598	630	10,968
Year 14	11,598	630	10,968
Year 15	11,598	630	10,968
Year 16	11,598	115,311	-103,713
Year 17	11,598	630	10,968
Year 18	11,598	630	10,968
Year 19	11,598	630	10,968
Year 20	11,598	29,670	-18,072
Year 21	11,598	630	10,968
Year 22	11,598	630	10,968
Year 23	11,598	630	10,968
Year 24	11,598	115,311	-103,713
Year 25	11,598	101,606	-90,008
Year 26	11,598	630	10,968
Year 27	11,598	630	10,968
Year 28	11,598	29,670	-18,072
Year 29	11,598	630	10,968
Year 30	11,598	-116,225	127,823

Prepared by JICA Study Team

16.7 Rural Electrification Master Plan by Dzongkhags

The Dzongkhag-wise rural electrification master plan is formulated in accordance with the result of the optimized plan. Detailed data and drawings for on/off-grid villages and the distribution expansion plan by phase in each Dzongkhag are included in **Appendix C-III-2**.

The forecast number of households in 2020 was applied as a base for the calculation of the percentage of affected households for the on/off-grid decision. In contrast, the electrification percentage is based on the forecast number households for 2007, which includes the planned number of households by the end of 9th FYP.

The master plan outline for each Dzongkhag is as follows:

(A) Bumthang

By the target year of 2020, 30 villages, corresponding 86% of non-electrified villages, are planned to be connected to the grid. This will provide on-grid electricity to 653 households, which is 96% of the non-electrified households. All grid extensions are to be implemented 10th FYP. There will be 28 off-grid households 5 villages.

The total route length of the planned 11 kV medium voltage line is 64 km. The electricity will be supplied from Jakar and the proposed Garpang transmission substations. Since 8 km of the feeder MPA11F1 will pass through a biological corridor, covered conductors will be installed fro this section of the feeder.

The on-grid electrification cost is 65 million Nu.and that of off-grid is 0.62 million Nu.

The on-grid electrification percentage is projected to be 75% in 2007, and will reach 99% in 10th FYP. The remaining 1% will be off-grid.

(B) Chukha

By 2020, 2,312 households in 78 villages, equivalent to 72% of the total number of non-electrified villages, will be connected the grid. A total of 387 households in 30 non-electrified villages will be off-grid.

The total route length of the planned medium voltage line is 126 km, with 74% being 33 kV and the rest being 11 kV lines. 94 km will be constructed in 10th FYP and 31 km will be constructed in 11th FYP. There are no environmentally protected areas in this Dzongkhag.

The on-grid electrification cost in 10th FYP is 122 million Nu., and that of 11th FYP is 32 million Nu. The off-grid investment is 8.7 million Nu.

The on-grid electrification percentage in 2007 will be 56%, and will increase to 88% in 10th FYP and 94% in 11th FYP. The remaining 6% will be off-grid.

(C) Dagana

On-grid connection to 3,033 households in 64 non-electrified villages, equivalent to 78% of the total of number of non-electrified villages, is the plan for 2020. This includes 545 households (forecast for the year 2020) connected to the existing 6.6 kV lines, for which

power is currently supplied by a small hydropower. The 6.6 kV lines will be replaced with 33 kV lines. In addition, 18 villages with a total of 280 households will be off-grid.

The total route length of the planned 33 kV medium voltage line is 175 km . For Dagana Dzongkhag, 132 km will be constructed in 10th FYP, including 45 km of existing 6.6 kV line replacement for the Dagana Small Hydropower. The remaining 43 km will be extended in 11th FYP. There are no environmentally protected areas in this Dzongkhag. Electricity will be supplied from the proposed Goshi substation, except for Lajab, Tsangkha and Drugelgang Gewog in the eastern areas, which will be supplied from Tsirang.

Total on-grid electrification cost in 10th FYP is 191 million Nu., and that for 11th FYP is 58 million Nu. Total investment for on-grid electrification is 249 million Nu. and the off-grid investment is 6.3 million Nu.

The on-grid electrification percentage in 2007 is projected to be relatively low at 34%. However, this will rise to 92% in 10th FYP and 93% in 11th FYP. The off-grid electrification will be 7%.

(D) Gasa

Half of the land in this Dzongkhag is covered by environmentally protected areas. By 2020, on-grid connection will be provided to 243 households in 7 villages, which is equivalent to 33% of the total number of non-electrified villages and 51% of the total of the non-electrified households. There is only one feeder, MPD33F1, which is 33 kV. This feeder, which will have a line length of 32 km, is planned to be extended in 11th FYP. Because of the environmental sensitivity of the route, feeder MPD33F1 was selected as the target for the draft TOR of an expected EIA study. This feeder extends in protected area and very steep mountains. Considering technical limitations anticipated especially over snow capped mountains during construction, as well as operation and maintenance and environmental issues, it would be recommended that small hydro be applied.

As for 33 kV lines come from Lobesa 66/33/11 kV substation, only one 33 kV circuit breaker is installed for the supply to Punakha, Gasa, and Wangduephodraung. Thus, installation of separate 33 kV circuit breaker in each Dzongkhag needs to be examined in the F/S stage to enhance the reliability.

Lunana Gewog will be all off-grid. There will be 233 off-grid households, equivalent to 49% of the non-electrified households in Gasa Dzongkhag. This is by far highest percentage of off-grid in the master plan for Bhutan.

On the on-grid electrification investment is 30 million Nu. and the off-grid investment will be 5.2 million Nu.

The on-grid electrification percentage in 2007 is projected to be 36%. No change will occur in 10th FYP. However, the percentage will increase to 69% in 11th FYP. Accordingly, it is preferred to prioritize the implementation of off-grid electrification from 10th FYP, taking Dzongkhag equity into account. At 31%, the planned off-grid electrification percentage is the highest in the nation.

(E) Haa

A total of 302 households in 10 villages, equivalent to 75% of non-electrified households and 67% of the non-electrified villages, will be connected to the grid by 2020. Half of the Dzongkhag is covered by a national park. However, there are no target non-electrified villages found in the area. In Haa Dzongkhag, 100 households, representing 30% of the non-electrified households in 5 villages, will have off-grid electrification.

The total route length of the planned medium voltage line is 24 km. For this line, 85% will be 33 kV and the remaining 15% will be 11 kV. Most of this route (21 km) will be constructed in 10th FYP and 3 km will be constructed in 11th FYP. The starting point of the line will be Chukha in the southern part of the Dzongkhag, and the line will also pass through Samtse.

The on-grid electrification cost in 10th FYP is 23 million Nu., and that of 11th FYP is 3 million Nu., bringing the total to 27 million Nu. The off-grid investment will be 2.3 million Nu.

The on-grid electrification percentage in 2007 will be 77%, and increase to 92% in 10th FYP and 94% in 11th FYP. The remaining 6% is the off-grid electrification percentage.

(F) Lhuntse

By 2020, 73 villages with 1,484 households, equivalent to 71% of the total number of non-electrified villages and 80% of the non-electrified households, will be connected the grid. Off-grid electrification will be provided to 368 households in 30 villages, which represents 29% of the non-electrified villages and 20% of non-electrified households.

The total route length of the planned medium voltage line is 88 km. For this route, 33% will be 33 kV lines and the remaining 67% will be 11 kV lines. Construction of 53 km will be completed in 10th FYP and 34 km will be constructed in 11th FYP. Many areas of the Dzongkhag are environmentally protected areas. This will require covered conductors being installed for a total of 3.2 km of the distribution line, of which 1.8 km will be constructed in 10th FYP.

Currently, 132 kV transmission line from Kilikhar (Mongar) to Tangmachu (Lhuntse) is charged at 33 kV and 33 kV source for Autsho is directly tapped from 132 kV line. It is needed to include the study for the construction of substations in F/S.

It is preferable to introduce off-grid electrification for villages in environmentally protected areas that are far from the planned distribution lines. Khoma Gewog is the priority location for off-grid electrification.

The on-grid electrification cost in 10th FYP is 96 million Nu., and that of 11th FYP is 49 million Nu., bringing the total to 145 million Nu. The required off-grid investment will be 8 million Nu.

The on-grid electrification percentage in 2007 will be 44%, and increase to 75% in 10th FYP and 89% in 11th FYP. The off-grid electrification percentage will be 11%.

(G) Mongar

By 2020, 126 villages with 3,044 households, equivalent to 69% of the total number of non-electrified villages and 83% of the non-electrified households, will be connected the grid. There will be 642 off-grid households, which is the largest number of off-grid households in one Dzongkhag in Bhutan.

The total route length of the planned medium voltage line is 174 km. For this route, 80% will be 33 kV lines and the remaining 20% will be 11 kV lines. There will be 63 km of line constructed in 10th FYP and 111 km in 11th FYP. Electricity is provided from Pemagatshel in the southern part of the Dzongkhag. The feeder that extends to Lhuntse includes 17 km in environmentally protected areas. This section of the line will use covered conductors.

The on-grid electrification cost in 10th FYP is 120 million Nu., and that of 11th FYP is 173 million Nu., bringing the total to 292 million Nu. The off-grid investment will be 14 million Nu.

The on-grid electrification percentage in 2007 will be 51%, and increase to 69% in 10th FYP and 91% in 11th FYP. The off-grid electrification percentage will be 9%.

(H) Paro

Almost all the households in Paro (96%) will be electrified in 2007, as most already have electricity. By 2020, on-grid connection will be provided to 11 villages with 142 households, equivalent to 50% of non-electrified villages and 61% of non-electrified households. There will be 92 off-grid households.

The total route length of the planned medium voltage line is 18 km, of which 48% will be 33 kV lines and the remaining 17% will be 11 kV lines. For this route, 6 km will be constructed in 10th FYP and 12 km will be constructed in 11th FYP. There are some non-electrified villages in environmentally protected areas in the northern part of the Dzongkhag, and these will be off-grid.

The on-grid electrification cost in 10th FYP will be 5 million Nu., that of 11th FYP will be 9 million Nu., bringing the total to 14 million Nu. The off-grid investment will be 2 million Nu.

The on-grid electrification percentage in 2007 will be 96%, which is the highest in Bhutan. This is because most parts of the Dzongkhag are already connected to the grid. It will increase to 97% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2% by 2020.

(I) Pemagatshel

By 2020, 26 villages with 595 households, equivalent to 79% of the total number of the non-electrified villages and 93% of the non-electrified households, will be connected the grid. The number of off-grid households will be 48.

The total route length of the planned 33 kV medium voltage line is 55 km. 32 km will be constructed in 10th FYP and the remaining 24 km will be constructed in 11th FYP. There are no environmentally protected areas in this Dzongkhag.

The on-grid electrification cost in 10th FYP is 48 million Nu., and that of 11th FYP is 23 million Nu., bringing the total to 71 million Nu. The off-grid investment will be one million Nu.

The on-grid electrification percentage in 2007 will be 77%. This will increase to 94% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2%.

(J) Punakha

By 2020, 17 villages with 219 households, equivalent to 49% of the total number of non-electrified villages and 66% of the non-electrified households, will be connected the grid. The number of off-grid household will be 112.

The total route length of the planned medium voltage line is 25 km. For this route, 76% will be 33 kV lines and remaining 24% will be 11 kV lines. There will be 22 km constructed in 10th FYP and 3 km will be constructed in 11th FYP. In addition, 7 km of the distribution line passes through environmentally protected areas and covered conductors will be installed in this section. All of the line that is in the environmentally protected area will be constructed in 10th FYP.

As for 33 kV lines come from Lobesa 66/33/11 kV substation, only one 33 kV circuit breaker is installed for the supply to Punakha, Gasa, and Wangduephodraung. Thus, installation of separate 33 kV circuit breaker in each Dzongkhag needs to be examined in the F/S stage to enhance the reliability.

The on-grid electrification cost in 10th FYP will be 22 million Nu., and that of 11th FYP will be 3 million Nu., bringing the total to 25 million Nu. The off-grid investment will be 2.5 million Nu.

The on-grid electrification percentage in 2007 will be 89%, which is the third highest in Bhutan. It will increase to 95.5% in 10th FYP and 96.2% in 11th FYP. The off-grid electrification percentage will be 4%.

(K) Samdrup Jongkhar

There are 4,842 non-electrified households predicted for 2020, which is the second largest in Bhutan after Samtse. There are 4,335 households in 128 villages, equivalent to 72% of the total number of the non-electrified villages, that will be connected to the grid.

The total route length of planned medium voltage lines is 250 km. Of this, 50% will be 33 kV lines and the remaining 68% will be 11kV lines. Lauri and Serthing Gewog in the northeastern part of the Dzongkhag will be supplied from India. In addition, 14 km of feeder MPK11F2-4 passes through a national park. This is the longest length of line in a protected area. In addition, the source identified for grid extension is from Daifam which receives electric supply from India and this supply is known for its poor reliability. Therefore, the feasibility study of micro hydro is recommended for not only provide reliable supply of electricity to the Shingkhar Lauri villages but can also feed back the Daifam villages by our own supply in the future.

The on-grid electrification cost in 10th FYP is 203 million Nu., and that of 11th FYP is 174 million Nu., bringing the total to 377 million Nu. The off-grid investment is 11 million Nu.

The on-grid electrification percentage in 2007 will be quite low at 31%. However, it will become 71% in 10th FYP and 93% in 11th FYP. The off-grid electrification percentage will be 7%.

(L) Samtse

By 2020, 6,193 households in 160 villages, equivalent to 88% of the total number of the non-electrified villages and 95% of the non-electrified households, will be on-grid. This is the largest number of on-grid houses in a Dzongkhag in Bhutan. The number of off-grid households will be 348.

The total route length of the planned medium voltage lines is 292 km. For this route, 45% of the lines are 33 kV and the remainders are 11kV lines. Most of the route (234 km) is planned to be extended in 10th FYP, and the remaining 57 km will be extended in 11th FYP. There route does not pass through any environmentally protected areas.

Mayona, Dungtoe, Dorokha, Denchhukha and Tading Gewogs in the eastern part of the Dzongkhag are to be supplied from Chukha. Bara and Tendu Gewogs in the northwestern part of the Dzongkhag are to be supplied from Jaldhaka substation in India. This will require installation of two voltage regulators and replacement of 20 km of existing lines. As the demand and characteristics of the lines in India is not clear, it is needed that the design be examined measuring the voltage at the receiving point from India.

The on-grid electrification cost in 10th FYP is 280 million Nu., and that in 11th FYP is 71 million Nu., bringing the total to 352 million Nu. The off-grid investment will be 8 million Nu.

The on-grid electrification percentage in 2007 will be 40%. It will increase to 86% in 10th FYP and 97% in 11th FYP. The off-grid electrification percentage will be 3%.

(M) Sarpang

By 2020, there will be 3,791 on-grid electrified households in 123 villages, which is equivalent to 76% of the total of the non-electrified villages and 87% of non-electrified household. The number of off-grid households will be 555, which is the second largest number for a Dzongkhag.

The total route length of the planned medium voltage lines is 198 km. For this route, 82% of the lines will be 33 kV and the remaining lines will be 11kV. 92 km is planned to be extended in 10th FYP and 106 km is planned to be extended in 11th FYP. The electricity needs of Lhamnozinkha and Michula Gewogs are currently supplied by diesel generators. These Gewogs have been prioritized for 10th FYP implementation to save the cost diesel fuel. Lhamozinkha, Deorali, and Nichula Gewogs will be supplied from Chukha, while Senge and Hiley Gewogs will be supplied from Tsirang. Belkhola, Larpani and Hiley Gewogs will be supplied from the Golephu substation, and an installation of voltage regulator is required for these areas. In addition, currently, there is no 33 kV source at

Gelephu Substation. Therefore, it needs to examine to install either 132/33 or 66/33kV transformer at the substation in the F/S stage.

Four (4) feeders go through environmentally protected areas and these lines will have covered conductors within the protected areas. The total length of the lines in the protected areas is 32 km. Of this, 11.1 km is planned to be implemented in 10th FYP.

The on-grid electrification cost in 10th FYP is 123 million Nu., and that in 11th FYP is 134 million Nu., bringing the total to 258 million Nu. The off-grid investment will be 12 million Nu.

The on-grid electrification percentage in 2007 will be 41%. This will increase to 68% in 10th FYP and 92% in 11th FYP. The off-grid electrification percentage will be 8%.

(N) Thimphu

By 2020, just 16 households in one village, equivalent to 6% of the total of the non-electrified villages, will be on-grid. The total route length of the planned 33 kV medium voltage line is only 1 km. No village will be connected to the grid in 10th FYP and the 14 households will be connected in 11th FYP. 141 households in 15 villages will be off-grid.

The on-grid electrification cost in 11th FYP is 1.6 million Nu. and that of the off-grid electrification is 3.2 million Nu.

The on-grid electrification percentage in 2007 will be as much as 93%, as almost all the areas are already electrified. It will be the same in 10th FYP and finally increase to 94% in 11th FYP. The off-grid electrification percentage will be 6%.

(O) Trasigang

By 2020, there will be 82 villages with 2,471 households connected to the grid. This is equivalent to 78% of the total number of non-electrified villages and 93% of non-electrified households. The number of off-grid households will be 192.

The total route length of the planned 11 kV medium voltage line is 133 km. Of this, 102 km (97%) will be constructed in 10th FYP and 31 km will be constructed in 11th FYP. The 17 households in Merak Gewog will be supplied from Samdrup Jongkhar. An ABS will be installed in Sakten and Kangpara Gewogs. Lines in Sakten and Merak Gewogs pass through environmentally protected areas and will require covered conductors to be used in these areas Feeder MPO11F1-3 will be expanded in 10th FYP and there will be 18 km within protected areas.

One option for MPO11F1-3 is to apply 33 kV system instead of change the feeder from 11 kV system with voltage regulator. There is a technical merit for 33 kV including reduction of power loss, however, 11 kV has a cost merit. It is recommended to conduct additional examination from overall perspective in a feasibility study.

The on-grid electrification cost in 10th FYP is 173 million Nu., and that in 11th FYP is 48 million Nu., bringing the total to 220 million Nu. The off-grid investment is 4 million Nu.

The on-grid electrification percentage in 2007 will be 75%. It will increase to 93% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2%.

(P) Yangtse

By 2020, there will be 51 villages with the households of 1,632 connected to the grid. This is equivalent to 91% of the total number of the non-electrified villages and 97% of the non-electrified households. A total of 46 households will be off-grid.

The total route length of the planned 33 kV medium voltage line is 65 km. All electricity will be supplied from the Trashigang substation. There will be 37 km of line constructed in 10th FYP and 29 km constructed in 11th FYP. Covered conductors will be installed for 14 km of the distribution line, where it passes through environmentally protected areas.

The on-grid electrification cost in 10th FYP will be 91 million Nu., and that in 11th FYP will be 52 million Nu., bringing the total to 142 million Nu. The off-grid investment will be one million Nu.

The on-grid electrification percentage in 2007 will be 59%. It will increase to 87% in 10th FYP and 99% in 11th FYP. The off-grid electrification percentage will be only 1%.

(Q) Trongsa

By 2020, there will be 44 villages with 1,355 households connected to the grid. This is equivalent to 90% of the total number of non-electrified villages and 97% of the non-electrified households. There will be 49 off-grid households.

The total route length of the planned 33 kV medium voltage line is 96 km. Electricity will be supplied from the Trongsa substation. There will be 69 km of line constructed in 10th FYP and 27 km will be constructed in 11th FYP.

Three feeders pass through environmentally protected areas and covered conductors will be required where this occurs. There are 27 km (68% of total length) in protected areas. All of these lines will be constructed in 10th FYP.

The on-grid electrification cost in 10th FYP is 100 million Nu., and that of 11th FYP is 37 million Nu., bringing the total to 136 million Nu. The off-grid investment will be 1.1 million Nu.

The on-grid electrification percentage in 2007 will be 44%. It will increase to 85% in 10th FYP and 98% in 11th FYP. The off-grid electrification percentage will be 2%.

(R) Tsirang

By 2020, there will be 70 villages with 3,488 households connected to the grid. This is equivalent to 81% of the total number of non-electrified villages and 95% of the non-electrified households. There will be 198 off-grid households.

The total route length of the planned medium voltage line is 121 km. For this route, 95% of the lines will be 33 kV supplied from the Dhajay substation. The remaining 5% will be 11kV lines. The route will also provide electricity to Dagana. Most of the route (117 km) will be constructed in 10th FYP and the remainder (3 km) will be constructed in 11th FYP.

The on-grid electrification cost in 10th FYP will be 235 million Nu., and that in 11th FYP will be 3 million Nu., bringing the total to 238 million Nu. The off-grid investment will be 4.5 million Nu.

The on-grid electrification percentage in 2007 will be 25%, which is the lowest for a Dzongkhag. This will increase to 95% in 10th FYP and finally 96% in 11th FYP. The off-grid electrification percentage will be 4%.

(S) Wangduephodrang

By 2020, there will be 102 villages with 1,844 households connected the grid. This is equivalent to 66% of the total number of non-electrified villages and 80% of the non-electrified households. The number of off-grid households will be 461.

The total route length of the planned medium voltage line is 196 km. Of this, 72% will be 33 kV lines and the remaining 28% will be 11 kV lines. For this route, 125 km will be constructed in 10th FYP and 71 km will be constructed in 11th FYP.

A combined length of 58 km of covered conductors will be required for four feeders which go through environmentally protected areas. Two of these feeders, having a length of 45 km, will be constructed in 10th FYP. The other two feeders, having a length of 13 km, will be constructed in 11th FYP. The lines pass through protected areas in total of 60 km.

As for 33 kV lines come from Lobesa 66/33/11 kV substation, only one 33 kV circuit breaker is installed for the supply to Punakha, Gasa, and Wangduephodraung. Thus, installation of separate 33 kV circuit breaker in each Dzongkhag needs to be examined in the F/S stage to enhance the reliability.

The on-grid electrification cost in 10th FYP will be 130 million Nu., and that in 11th FYP will be 78 million Nu., bringing the total to 208 million Nu. The off-grid investment will be 10 million Nu.

The on-grid electrification percentage in 2007 will be 57%. It will increase to 79% in 10th FYP and finally reach 91% in 11th FYP. The off-grid electrification percentage will be 9%.

(T) Zhemgang

By 2020, there will be 64 villages with the 1,933 households connected to the grid. This is equivalent to 70% of the total number of non-electrified villages and 85% of the non-electrified households. The number of off-grid households will be 346.

The total route length of the planned 33 kV medium voltage line is 176 km. Two (2) feeders pass through environmentally protected areas. This will required covered conductors to be applied over a total length of 39 km. Both of these feeders are to be constructed in 10th FYP.

The on-grid electrification cost in 10th FYP will be 188 million Nu., and that in 11th FYP will be 19 million Nu., bringing the total to 208 million Nu. The off-grid investment will be 8 million Nu.

The on-grid electrification percentage in 2007 will be 24%, which is second lowest for a Dzongkhag. It will increase to 82% in 10th FYP and 89% in 11th FYP. The off-grid electrification percentage will be 11%.

CHAPTER 17 STRATEGIC ENVIRONMENTAL ASSESSMENT

17.1 Intention of Applying Strategic Environmental assessment

RGoB has set a significant electrification target, which is "100% rural electrification by the year 2020". On the other hand, RGoB aims at coexistence of the environment and development for sustainable development, as well as preservation of 60% forest coverage for the country. In the environmental legislation, the regulation on Strategic Environmental Assessment (SEA) in 2002 stipulates that SEA is required in preparation of national master plans. There has not been any case so far where SEA has been undertaken. However, in accordance with the SEA regulation, the concept of SEA was applied in the preparation of the Master Plan for rural electrification. The following definition is used for this undertaking:

- Environmental consideration in the master plan (M/P) stage enabling avoidance of significant impacts that may be caused by implementation of the proposed project.

In addition, the following items were set as basic strategies, after considering the existing SEA Regulation in Bhutan as well as the JICA Guidelines for Environmental and Social Considerations:

1) Consideration of the existing government policies and strategies in planning rural electrification.

2) Ensuring openness and transparency of decision making.

3) Conforming with the SEA Regulation in Bhutan.

The matters shown below were also taken into account. These things are to be achieved by the application of the SEA concept to preparation of the master plan:

- To enhance and apply the concept of sustainability in governmental decision making.
- To avoid significant and cumulative impacts on the environment through environmental consideration in the early stages of a project.
- To support and strengthen EIA in the implementation phase of projects.

The content of the case study is shown in **Table-17.1.1** below, which was finalized through discussions with the National Environmental· Commission (NEC). The table also shows which of the strategies mentioned above would be applied to each item.

Table-17.1.1 Scope of the Case Study for Strategic Environmental Assessment (SEA)

Contents	Basic Strategy
1. Review of policy, strategy, plans and programs regarding rural electrification and the environment.	1)
2. Hold meetings for discussion on policy/strategy at the governmental level.	1) & 2)
3. Qualitatively analyze of the cumulative environmental effect of rural electrification projects.	3)
4. Hold a stakeholder meeting in the workshops of the Study.	2)
5. Publicity of potential of environmental impacts, and environmental consideration in M/P	2)
6. Hold public hearings (through letters) on predicted environmental impacts and environmental considerations in the master plan study.	3)
7. Prepare an Environmental Statement.	

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17.2 Rural Electrification and National Environmental Strategy

(1) National Strategy on Environment and Rural Electrification

In national environmental strategies of Bhutan, sustainable development is stated consistently and the developments that incorporate appropriate environmental consideration are promoted. As for rural electrification, 100% electrification by 2020 is envisaged as a target, which is the basis of the master plan prepared in this Study.

"The Middle Path, National Environment Strategy for Bhutan" (1998, NEC) adopted the expanding hydropower as one of three main avenues for sustainable economic development. The strategy also mentions the necessity for contribution to the promotion of watershed maintenance which is crucial for hydropower, not only by the forestry sector, but also by others. In advancing rural electrification by grid extension, the goal is not only to supply clean renewable energy produced by hydropower, but also to improve living conditions for villagers, and produce positive environmental effects such as reduction of deforestation due to firewood harvesting are highlighted as merits of the project. Accordingly, it is regarded that both rural electrification and environmental conservation can occur simultaneously as they both have similar objectives in terms of sustainable development.

Although rural electrification is considering a sustainable development in its purpose, it is recommended that certain conditions for the rural electrification project implementation should be discussed and agreed upon at higher levels of decision-making within the government. The points shown as "mile stones" in the document "Bhutan 2020" (Bhutan Planning Commission, 1999) for both fields are highlighted. It is recommended that discussion on the issues that are shown below should be continued in order to attain the national target considering the circumstances of both sustainable development and rural electrification. Measures for achieving the required goals should be advanced based on agreement among the stakeholders.

- Necessity for 100% electrification. Can all villagers afford to pay for electricity and to buy appliances?
- Quality of electricity to be supplied to non-electrified villages. How or how much electricity will they use?
- Validity of development in protected area. It is recommended to prepare proper zoning in the protected area resulting in useful information for environmental conservation as well as development.
- Possibility of expansion of environmental impacts owing to the growth of villages in remote areas or the protected areas. Electrification may cause villages to expand in the future, which could result in increased environmental impacts. Will the nation accept increased impacts, or try to control the activity of people in the area to be conserved?

(2) Discussion on Policy/Strategy at the Governmental Level

In the second site work of the preliminary survey stage of the Study, a meeting was held to discuss policy and strategy, which is one of requirements for SEA. The participants of this meeting included people from Department of Energy (DOE) of the Ministry of Trade and Industry (MTI), the Planning Department of the Ministry of Finance, the National Environmental Commission Secretariat (NECS), the Department of Forestry, the Ministry of Information and Communication, Bhutan Power Corporation (BPC), and the JICA Study Team. In the meeting, it was discussed how the rural electrification should be promoted, considering national policies and strategies for environmental protection.

The opinions that were expressed in the meeting are summarized as follows:

- Conservation of forests is a very important task, but in order to provide electricity by a grid extension, there is no other option other than to allow clearing of certain areas.
- Further discussions are required about who will be responsible for bearing the cost of environmental conservation.
- One hundred percent of electrification is a target decided by the highest level of government. Since electrification contributes to improve the quality of life and alleviate poverty, especially in the rural areas, each agency should be driven by achieving positive impacts.
- Proper adoption of vegetation management in the vicinity of power lines should be observed as applicable in order to avoid complete clearing of the right-of-way area.
- Though grid extension provides the most reliable electrification, adoption of renewable energy sources can be a better solution to avoid damage to protected areas.
- Projects of rural electrification must meet and comply with government requirements, such as EIA and other related aspects. Environmental clearance is a requisite prior to implementation. NECS may require rural electrification projects that traverse protected areas to conduct EIA.

Rural electrification improves the quality of life and mitigates poverty in target areas, and reduces the felling of trees for fuel wood. But, it is certain that implementation of the project will have some negative impact on the environment.

The RGoB has set the "Middle Path" and "sustainable development" as national policies. Environmental conservation has a high priority in the minds of the Bhutanese people. Judging from the situation that local people have resided in protected areas (PAs) before these areas were designated, it is inevitable to discuss the validity of felling, use, and alteration of these areas when promoting the provision of electrification to all people of the country. Nevertheless, in practice, the decision on the validity of a project in protected areas depends on each case. There are not any definite criteria for making the decision.

Further discussion on rural electrification and environmental conservation is required at the decision makers' level. Environmental conservation mainly covers conservation of protected area and forest that provide a habitat for animals and plants. The discussions should be held in the course of realization of the proposed electrification project.

17.3 Examination of Environmental Factors to be Considered

(1) Current Environmental Situation of Project Site

The current situation of the environment was surveyed and by means of reviewing information available from existing materials (Refer to **Appendix C-1-1, I-2**).

Regarding the social environment, in addition to gathering information on the ethnic composition and sanitary conditions, the fact that electricity is currently supplied to less than 40% of the population was found. However, in contrast, it was also found that electric power sales are the biggest foreign exchange source for Bhutan. For the natural environment, it was found that that the national forest cover is currently more than 70% and that 26% of the country is incorporated into the nature conservation system.

Table-17.3.1 Items Surveyed for the Current Environmental Situation Study

Social Environment	People and ethnic groups Land use and utilization of local resources Public facilities/social institutions Economy Public health and sanitation
Natural Environment	Topography and geology Flora and fauna, and their habitats Lakes, river system, coast Climate
Pollution	Present Pollution Complaints which people have utmost concern Measures taken for pollution

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(2) Environmental Impact due to On-grid/off-grid Electrification

The characteristics in environmental point of view of grid extension, that is on-grid electrification, and means of off-grid such as micro hydropower generation are described in

Table-17.3.2. The anxiety of negative impact caused by micro hydropower is regarded as more serious than that caused by solar PV system among off-grid measures.

Accordingly, as described in chapters before, solar PV system for lighting was applied in the base-case proposed in master plan as means for off-grid electrification considering not only environmental aspect but also practical and economic aspects.

Table-17.3.2 Impact on the Environment caused by On-grid/off-grid Electrification

		Positive Impact	Negative Impact
On-grid Electrification	Grid Extension	➢ The electricity generated by hydropower has been abundant in Bhutan. Grid extension promotes utilization of it that exist locally without additional development for power generation. ➢ Electricity is generated by hydropower which is renewable energy. Utilization of hydropower accords with national strategy. ➢ The reliability of electricity supplied by grid is much expected to restrain the use of other energy such as firewood.	➢ It might require deforestation of ROW for construction and safety reason in operation. The longer the line is drawn, the wider the area for clearance becomes. ➢ The deforestation and site clearance might result in alteration of habitat of animals and plants. Negative impact on the nature is worried. ➢ Distribution lines and structure of power poles might give impact on the scenery in rural area
Off-grid Electrification	Solar PV	➢ Significant impact on the environment are assumed not to be caused by solar PV system that supply electricity to each household ➢ Utilization of renewable and clean energy	➢ Existence of PV panel might give impact on the scenery in rural area. ➢ Lead battery used in PV system is afraid to cause heavy metal pollution and change of soil pH by sulfuric acid in case it might not be treated and disposed of properly
	Wind Power	➢ Utilization of renewable and clean energy	➢ The existence of structure of windmill might give impact on the scenery in rural area. ➢ Lead battery disposal problem may happen as well as solar PV.
	Micro Hydropower	➢ As the reliability of electricity supplied by micro hydropower generation is equivalent to that of grid extension, the use of other energy is expected to be restrained. ➢ Utilization of renewable and clean energy	➢ It needs alteration of river even in small scale. It might cause impact on river flow. ➢ Distribution line will be drawn to the houses, which may require deforestation for clearance of ROW. ➢ In construction, access road will be required to transport generator and other materials for the facility. The activity might cause negative impact on the environment.
	Biomass	➢ Utilization of renewable and clean energy ➢ Firewood consumption is expected to be reduced.	➢ Collected and stored materials might cause offensive odor to circumstances

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(3) Environmental Impact of the Proposed Project

Environmental impacts caused by the proposed electrification project were analyzed by considering the current environmental situation and characteristics of the project. **Table-17.3.3** summarizes the results of scoping to identify anticipated environmental impacts by the project implementation.

It was concluded that the proposed projects might cause significant local impacts on flora, fauna and biodiversity. There are the following two reasons of significant local impact.

- Establishment of distribution lines will be accompanied by deforestation, alteration of land surface, construction of facilities in and around the power line rights-of-way.
- The proposed project may include feeders which traverse the protected areas.

Table-17.3.3 Anticipated Environmental Impact by Proposed Electrification Master Plan (Result of Scoping)

Project Component			The Integrated Master Plan Study for Dzongkhag-wise Electrification in the Kingdom of Bhutan													
				Planning Phase		Construction Phase				Operation Phase						
	No.	Likely Impacts	Overall Rating	Land acquisition	Change of Land use plan, Water Use for the construction	Forest clearance for the site	Alteration of topography	Construction work and operation of construction equipment and vehicles	Restriction of economic and other activities around the site	Presence of the distribution line, solar PV panels and relevant facilities.	Management of vegetation under distribution lines	Increasing influx of settlers	Maintenance of distribution lines and relevant facilities	Disposal of replaced batteries for the solar PV	Reduction of Consumption of kerosene, LNG and firewood
Social Environment	1	Involuntary resettlement	-C	-C	-C										
	2	Local economy, such as employment and livelihood, etc.	+B					+B	-C		+B				
	3	Land use and utilization of local resources	-B		C	-B				-B					
	4	Social institutions such as social infrastructure and local decision-making institutions	-C					-C		-C					
	5	Existing social infrastructures and services	-C						-C	-C					
	6	Underprivileged, remote rural people	-C	-C											
	7	Misdistribution of benefit and damage													
	8	Cultural heritage	-C	-C		-C									
	9	Local conflict of interests	-C		-C										
	10	Water usage or water rights and rights of common access	-C		-C										
	11	Sanitation													
	12	Hazards (risk), including infectious diseases such as HIV/AIDS													
Natural Environment	13	Topography and geographical features	-B				-B								
	14	Groundwater													
	15	Soil erosion	-B				-B	-B			-B				
	16	Hydrology	-B					-B							
	17	Coastal zone													
	18	Flora, fauna and biodiversity	-A			-A	-B				-A	-B	-B		
	19	Weather													
	20	Landscape	-B			-B				-B					
	21	Global warming	+B												+B
Pollution	22	Air pollution	-B					-B							
	23	Water pollution	-B				-B	-B						-B	
	24	Soil contamination	-B											-B	
	25	Waste	-B					-B							
	26	Noise and vibration	-B					-B							
	27	Ground subsidence													
	28	Offensive odor													
	29	Bottom sediment													
	30	Accidents	-B					-B		-B					

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Rating:

+ : Positive impact -: Negative impact

A: Serious impact is expected. B: Some impact is expected. C: Extent of impact is unknown (Impacts may become clear in implementation stage.)

No Mark: No impact is expected. IEE/EIA is not necessary. Example: -B: Some negative impact is expected.

17.4 Mitigation Measures and Analysis of Environmental Impact

(1) Policy of Environmental and Social Consideration

As described in Chapter 9, the following two policies were adopted when considering environmental and social impacts, as well as the mitigation of environmental impacts.

Prioritization of the Protected Area and Biological Corridor in Environmental Consideration

- The protected areas, and the biological corridors which are provided to enable wild animals to move from one protected area to another, were defined as priority areas in the environmental consideration. This was done because the proposed projects were anticipated to have significant local impact on "flora, fauna and biodiversity"

Consideration of Cumulative Impacts on the Environment

- Cumulative impact assessment contains the two factors shown below:

  1) The site affected by the rural electrification project is usually undeveloped. Therefore, the cumulative impact on such a site can not be determined without sufficient information about every development sector that may also affect the same site.

  2) Cumulative impacts can be reduced by coordination with other sectors (e.g. the forest road construction department and the power line construction department).

In the master planning work done for the Study, road projects were considered in terms of factor 2) above.

(2) Mitigation Measures in the Preparation of the Master Plan

The measures shown below were adopted for environmental mitigation in master planning and these follow the policies of environmental and social consideration mentioned above:

Locating distribution lines along roads

- Constructing of distribution lines in locations that have already been altered artificially (i.e. adjacent to existing roads) can avoid changing the land use as well as topography. (The Road Act requires securing 50 ft of clearance from the edge of main roads. Many of existing road have width less than 50 ft. In considering this fact the effectiveness of requirement by the act should be discussed by the point of view of environmental conservation.)

Avoiding protected areas and corridors as much as possible

- The protected areas include national park were designated as area to be preserved by the RGoB. In the master planning phase, the protected areas and biological corridors were defined as the highest priority for nature conservation in order to minimize alteration of these areas and to maintain continuity of the habitat of plants and animals.

Application of covered conductors for grid extension that must be located in the protected

areas. This allows a narrower width to be cleared for the right-of-way.

- In cases where traversing a protected area can not be avoided, covered conductors shall be adopted. Using covered conductors allows the width of the right-of-way to be reduced from 12 m down to 4 m. The right-of-way is required for safety clearance of the distribution line. The area to be cleared for the right-of-way, as well as any impact on the protected area, will therefore be minimized.

(3) Consideration of Alternatives

Three alternatives were considered in the evaluation of the Master Plan: (i) Base Case. (ii) Option-1, and (iii) No Action. The Base Case and Option-1 are described in the economic analysis section 13.1 in Chapter 13. The No Action case is "the case that the proposed project will not been implemented". The results of a comparison of these 3 alternatives are described in **Table-17.4.1** below.

- Base Case: master plan for on/off-grid allocation, based on the economic evaluation
- Option-1: All on-grid electrification
- No Action: The proposed rural electrification projects will not be implemented

Table-17.4.2 below shows the area to be cleared for safety reasons for the first and second alternative listed above. The Base Case needs a clearance area that is 160 ha less than Option-1. In addition, for Base Case, adoption of covered conductors will reduce the area of clearance in protected areas by 297 ha, compared to the area that would need to be cleared if bare conductors were used.

For the No Action alternative, where no project proposed in the master plan will be implemented (except for those that are already on-going), the electricity supply in Bhutan would stop at the level of servicing less than 40% of the population. Deforestation for distribution lines would be stopped, but felling for firewood that required for living in non-electrified villages would continue. The national electrification target would not be realised. As the Base Case consists of many feeders, actually the case of "No Action" seems unlikely.

In the implementation stage of the master plan up to 2017, introduction of other methods such as Option-2, Option-3 (described before in Chapter 13) may be possible, based on further examination. It is necessary to examine and evaluate environmental impacts and effects for the mitigation of environmental impact considering the characteristic of measures including the solar PV having a large capacity, as well as mini-hydro power stations.

Table-17.4.1 Comparison of Alternatives

Alternatives	Description
No Action (No project is implemented)	The electricity supply in Bhutan will stop at the level of servicing less than 40% of the whole population. Most people in non-electrified village will not enjoy the benefit of electrification. Deforestation for distribution lines will not occur, but felling for firewood required for living in non-electrified village will continue.
Base Case (Proposed On/Off-grid electrification Master Plan)	The plan proposed in the Master Plan is based on the on/off-grid evaluation by a program developed to determine the economic benefit and cost of the further extension of the electricity grid. The evaluation was made by comparing the benefit and cost of electrification to the cost of a small scale solar home system for lighting. Costs considered in the program include the cost for the mitigation measures adopted for the grid extension into protected areas, which requires the use of covered conductors. Use of covered conductors enables the width of right-of-way clearing to be reduced from 12 m down to 4 m. The right-of-way is required to provide safety clearance for the distribution line.
Option-1 (All on-grid electrification)	Option-1, provides 100% electrification by grid extension (all on-grid). This was studied for comparison with the cost of the Base Case. Although other options, such as small hydro and SHS were studied in the course of the study, these options were not evaluated as being more cost effective than the proposed plan (i.e. the Base Case). The electricity supply by grid extension is stable, but the implementation is technically difficult in some sites that have steep terrain. Besides, more deforestation is required than Base Case. The distance of distribution lines in the protected areas will be longer than that required for the Base Case. Therefore, the area of deforestation will be wider. (Refer to Table-17.4.2 below.)

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Table-17.4.2 Comparison of the Area to be Cleared for the Distribution Line

Dzongkhag	Option-1 [All on-grid] (m^2)			Base Case (m^2)			Difference between Option-1 and the Base Case (m^2)		
	Normal Areas	PA	TOTAL	Normal Areas	PA	TOTAL	Normal Areas	PA	TOTAL
Bumthang	668,637	73,367	742,004	645,681	42,590	688,271	22,956	30,777	53,733
Chukha	2,262,947	0	2,262,947	1,506,739	0	1,506,739	756,209	0	756,209
Dagana	2,763,744	0	2,763,744	2,096,529	0	2,096,529	667,215	0	667,215
Gasa	0	511,691	511,691	0	128,156	128,156	0	383,536	383,536
Haa	451,081	0	451,081	292,671	0	292,671	158,409	0	158,409
Lhuntse	1,269,130	280,024	1,549,155	961,113	30,649	991,762	308,017	249,375	557,392
Mongar	3,244,068	168,756	3,412,824	2,005,507	27,574	2,033,081	1,238,561	141,181	1,379,743
Paro	499,528	66,426	565,955	214,492	0	214,492	285,036	66,426	351,462
Pemagatshel	861,336	0	861,336	663,282	0	663,282	198,055	0	198,055
Punakha	506,908	105,033	611,941	244,812	28,657	273,469	262,096	76,377	338,472
Samdrup Jongkhar	3,791,577	131,908	3,923,485	2,838,404	55,298	2,893,702	953,173	76,610	1,029,783
Samtse	4,357,077	0	4,357,077	3,605,861	0	3,605,861	751,216	0	751,216
Sarpang	2,997,137	182,602	3,179,739	1,980,640	133,558	2,114,198	1,016,497	49,044	1,065,541
Thimphu	86,910	235,763	322,673	17,785	0	17,785	69,125	235,763	304,888
Trashigang	1,619,527	178,609	1,798,136	1,176,150	140,738	1,316,889	443,377	37,870	481,247
TrashiYangtse	728,719	57,546	786,265	610,544	57,546	668,091	118,174	0	118,174
Trongsa	760,387	166,920	927,307	646,932	166,920	813,852	113,455	0	113,455
Tsirang	1,888,313	0	1,888,313	1,450,216	0	1,450,216	438,097	0	438,097
Wangduephodrang	2,232,587	540,535	2,773,122	1,634,873	238,943	1,873,816	597,714	301,592	899,306
Zhemgang	2,343,481	256,738	2,600,219	1,647,204	156,905	1,804,109	696,277	99,833	796,110
TOTAL	33,333,096	2,955,918	36,289,014	24,239,436	1,207,534	25,446,970	9,093,660	1,748,384	10,842,044
Percentage (%)	91.9%	8.1%	100%	95.3%	4.7%	100%	N/A	N/A	N/A

Note: PA = Protected area and bioligical corridor N/A = Not Applicable

Prepared by JICA Study Team

(4) Consideration of the Cost of Environmental Conservation

In order to take environmental aspects into account in the economic evaluation, a part of the internal cost required for environmental mitigation measures was added to the project cost. Namely, increased costs due to the use of covered conductors for distribution lines in environmentally prioritized areas were added to the project cost. On the other hand, costs related to external environmental affects, such as the value of biodiversity and the impact on communities of construction work, etc. were not included. These external effects can not be traded in actual markets. Therefore, these costs were not included in the economic evaluation because conversion of such costs into a monetary value contains uncertainty.

The internalization of environmental mitigation costs brought about a reduction in distance of on-grid extensions proposed in the master plan. This resulted in weghting of environmental consideration in the planning process. Before implementation of construction work, especially in the environmentally prioritized areas, the actual environmental situation should be checked. A detailed environmental examination should be conducted.

In addition, the cost increase for use of covered conductors in Base Case of the master plan has a monetary value of US$0.60 million. This expenditure will be required in order to reduce the area to be cleared for the on-grid extension.

Regarding benefits from environmental aspects, the reduction of firewood and other energy source consumption was counted as a part of internal benefit of the project. Based on the analysis of the Village Baseline Survey data, it was estimated that the reduction of firewood consumption by on-grid electrification would be 167 kg/month/household. This reduction of expense for energy equates to 263 Nu./month/household. (Refer to Chapter 13.)

(5) Qualitative Analysis of Cumulative Environmental Impacts

The target area of the project proposed in the master plan contains areas where distribution lines have not yet been introduced. These areas include forests that have not been developed. Accordingly, it is not assumed that the impacts caused only by the rural electrification project are cumulative to impacts resulting from other developments. Besides, it was difficult to consider the impact caused by projects of other sector because there is not enough information about other sectors. This was explained earlier in relation to obtaining data on the location of existing trafficable roads.

Based on the characteristics of rural electrification mentioned above, it was concluded that reducing the impact on undeveloped and protected areas, e.g. by using covered conductors, will enable the overall environmental impact caused by this project to be minimized.

In general, the cumulative impact should be carefully examined in the case of multiple large scale projects that exist close to the power line construction sites where the impact caused by these projects is cumulative. It was regarded that considering and coodinating power line construction work along with road construction projects would decrease the cumulative impact. As a mitigation measure, “locating distribution lines along roads” was adopted in the master plan. Accordingly, the area required to be altered for the project implementation

would be reduced, and the impact caused by people doing line maintenance work would be minimized.

One additional measure for environmental mitigation can be incorporated into preparation of the master plan. This additional measure can contribute to further reduce the environmental impact of the project. If information about future large scale projects, including road projects, could be considered in the master plan, environmental assessment of these other projects could be done together with assessment of work that is proposed in the master plan. Therefore, it is important to exchange and share information between other sectors before the implementation phase of the projects.

(6) Environmental Statement

The environmental statement reflects the conduct and results of the SEA case study. (Refer to **Appendix C-I-1**.) The SEA guidelines in Bhutan stipulate that the preparation of the environmental statement is to be done for SEA. The contents list of the environmental statement is shown in **Table-17.4.3** below. Regarding the environmental management plan (item 7 in the list) that is consists of mitigation measures and environmental monitoring plan, this is to be prepared in the master plan stage. Because of this, the environmental management plan should consider the actual situation of the definite project site again for managing construction work effects and the effects occurring during operation of the proposed project.

Table-17.4.3 Contents of the Environmental Statement

1. Proposal and objectives
2. Background
3. Proposed activity
4. Anticipated adverse environmental impact analysis
5. Environmental benefit of the proposal
6. Alternatives to the proposal
7. Environmental management plan

Prepared by JICA Study Team

17.5 Publicity of the Master Plan Study

(1) Holding Stakeholder Meeting

In the course of the Study, three workshops were held for discussing the project and for giving information about the project to stakeholders. Environmental consideration, as well as environmental examination in rural electrification, was one of the items presented and discussed in all three workshops. Based on the discussion in the workshops, it is concluded that the participants recognized that rural electrification should be promoted in accordance

with environmental conservation objectives. In addition, it was recognized that the project would contribute to the reduction of firewood consumption in rural areas.

Table-17.5.1 Outline of Workshops

	Date	Venue	Participants	Organizations	Main Subjects
1st	30 Jan, 2004	Thimphu	66	Dzongkhag, MOF, DOE, BPC, UNDP, JICA	Methodology of the master plan study. (Including the methodology of the environmental impact analysis.) Overview of rural electrification program
2nd	26 Oct, 2004	Thimphu	85	Dzongkhag, MOF, MOA, MOIC, NEC, DOE, BPC, EOJ, JBIC, JICA	Progress of the master plan study. (Including policy of the strategic environment assessment [SEA]) Request to master plan study team by Dzongkhag representatives
3rd	9 Jun, 2005	Thimphu	70	Dzongkhag, MOF, MOA, MOIC, NEC, DOE, BPC, JBIC, JICA	Draft result of master plan study. (Including environmental consideration in the master plan)

Note: Dzongkhag = Dzongkhag representatives
MOF = Minsirty of Finance
DOE = Department of Energy, Ministry of Trade and Induxtry (MOTI)
BPC = Bhutan Power Corporation
UNDP = United Nations Development Programme…
JICA = Japan International Cooperation Agency
MOA = Ministry of Agriculture
MOIC = Ministry of Information & Communications…
NEC = National Environmental Commission
EOJ = Embassy of Japan
JBIC = Japan Bank for International Cooperation

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In the 2nd workshop, a survey on the awareness of participants of environmental considerations in the rural electrification project was conducted through a questionnaire. **Table-17.5.1** shows a summary of the results. It is believed that people understood that there was a strong need for rural electrification, though the project might cause some adverse impacts on the environment.

Table-17.5.2 Awareness of Participants on Environmental Impact due to Rural Electrification

Number of respondents: 29 people who participated in the 2nd workshop

Q1. 1. Do rural electrification projects have environmental impacts?

Yes	No	No response	Total
27 (93%)	1 (3%)	1 (3%)	29

Q2. 3. Do you feel RE projects in protected area and conservation area should be avoided?

Yes	Relatively yes	No	Total
4 (14%)	12 (41%)	13 (45%)	29

Justification of reply as "No" to Q2: (summary)

- Electricity is one of the basic needs. People living in protected areas should also have access to it.
- It should be implemented with consideration of minimizing damage to the environment.
- To achieve the national target that is electricity for all by2020.

Q3. Opinion regarding environmental consideration in rural electrification of projects (summary):

- Felling of trees, impact on flora and fauna should be minimized
- We should follow the policy of "Middle Path". Development and environment should balance.
- Forest, land use, scenery, religious and historical sites should be considered.

Prepared by JICA Study Team

(2) Publicity of the Draft Master Plan and Environmental Examination

It believed that as a result of holding the three workshops, the study team enhanced the publicity and information transfer related to the master plan process, such as the methodology that was being used, progress of the plan, and an outline of draft of master plan.

In the 3rd workshop, the draft master plan was introduced. In addition, questions about the draft master plan were collected from the Dzongkhag representatives. The questions about the draft master plan were collected from Gewogs through the mail too. In addition, not only the output of planning but also the results of environmental consideration were provided through a letter sent to Dzongkhags, Gewogs, the concerned governmental organizations and NGOs. This was done to maintain transparency in master plan process.

It is quite difficult to attract participants from remote districts in Bhutan. However, rather a lot of people participated in the three workshops that were held in the capital, Thimphu. Information about the rural electrification master plan was sent out at a national level to those people who could not come to the workshops, and who usually had not been involved in the planning. It is concluded that that these people realized they had access to information that that they had not known about, and that they had the opportunity to give their opinion as feedback on the draft master plan.

17.6 Environmental Effect Mitigation Measures in the Implementation of Project

The master plan was prepared at a nation-wide scale aimed at all territories in Bhutan. In the examination, the protected areas were defined as the highest priority areas for nature conservation. The environmental effect mitigation measures were selected to avoid or minimize the alteration and usage of the high priority areas, and to mitigate cumulative environmental impacts. In the implementation stage, detailed circumstances will become clear. Therefore, environmental effect mitigation measures will need to be considered again according to the actual situations that are encountered. Directions for identifying and considering environmental impacts in implementation of the rural electrification project are shown in **Table-17.6.1** below.

In preparation of the master plan, it was recommended to utilize existing and planned roads to advance the rural electrification project. It is desirable to share and utilize the accumulated data and information with not only the road sector, but also other sectors. This will encourage the effective conduct of SEA for road and city development projects, as well as for EIA of each project.

Table-17.6.1 Directions for Identifying and Considering Environmental Impacts in the Implementation of the Rural Electrification Project

Natural Environment		Social Environment		Pollution, others.	
Impact	Direction for Consideration	Impact	Direction for Consideration	Impact	Direction for Consideration
Deforestation, Impact on Ecosystems	The consideration of the prioritized areas of PAs is important in nature conservation. The minimization of clearing forest areas.	Impact on Cultural Property and Heritage	Suggestion for practical consultation in project implementation. Suggestion for avoidance of impact on cultural heritage etc.	Electric Shock	To ensure the implementation of measures for safety.
Scenery	Decrease impact on scenery by minimization of distribution lines. Consideration of the impact by solar PV panels and windmills.	Disturbance of Infrastructure	The examination of the possibility of disturbance to existing microwave facilities, and the obstruction of traffic, and their countermeasures.	Construction	The restoration of area altered by temporary roads etc. The measures for soil erosion control.
		Impact on Land Use	Suggestion for site selection in implementation.	Environmental Monitoring	Monitoring planning, based on practical effects.

Prepared by JICA Study Team

17.7 Preparation of a Draft TOR for EIA

(1) Purpose of Preparation of a Draft TOR for EIA

The EA Act (2000) stipulates that if a project is evaluated as giving rise to significant environmental impacts according to the information described in the application for environmental clearance, the proponent would have to conduct EIA. The proponent would have to submit Terms of Reference (TOR) for EIA to NEC before implementation. The TOR should include methods for site surveys for various environmental features, prediction and evaluation of environmental impact, etc. The TOR should be proposed before conducting an EIA because there have not been any case so far of EIA being done based on EA Act (2000).

Though the necessity for an EIA for the proposed project is incorporated into the master plan, the environmental assessment procedure in Bhutan is not clear at present. Therefore, the relevant legal procedures should be followed in the course of the project realization. Simultaneously, the actual environmental situation of definite project sites will need to be surveyed and checked again. The project proposed in the master plan includes care for the environment and social considerations. It is understood that where power line routes fall within protected areas because they are needed to supply electricity to people living in those areas, an EIA study might be required. This is because some deforestation will be necessary for constructing and maintaining the distribution lines.

Therefore, the information about preparation of a draft TOR for EIA is intended to be used when making the actual draft TOR in the master plan project implementation phase. The draft TOR can be referred to when it is necessary to conduct an EIA in the future.

(2) Selection of Targeted Feeders for Draft TOR Preparation

During the fifth site work, one project was selected to be the target for preparation of a TOR for EIA. The construction of this feeder should be regarded as being subject to EIA. Depending on currently available information, the criteria 1) and 2) were applied to select the feeders which is recommended to be subject to EIA. The criteria 3), then, was used for selection of the target feeder which might cause significant impact on the environment:

1) The feeder site had to include part of a protected area.

2) The feeder, and its length in the protected area, had to be relatively longer.

3) The feeder had to be located in the northern highland part of Bhutan, where the ecosystem is regarded as being vulnerable.

Table-17.7.1 below shows the feeders that go through PAs, ordered by length within the PA. The feeder located in Jigme Dorji National Park (JDNP) was selected as the target feeder by following the criteria listed above. In order to select the feeder, meetings with NEC and the Nature Conservation Division (NCD) were held.

Table-17.7.1 Selection of the Target Feeder for Preparation of a Draft TOR for EIA

Unit of number: m

No	Feeder Name	Dzongkhag	Distance in normal area	Distance in Area to be Considered			Total Distance of Feeder	Phase
				Distance in Biological Corridor	Distance in PA	Sub-total Distance		
1	MPD33F1-1	Gasa	0	0	32,039	32,039	32,039	2
2	MPQ33F1-13	Trongsa	8,671	3,655	25,579	29,234	37,905	1
3	MPS11F1-1	Wangduephodrang	24,355	14,319	14,369	28,688	53,043	1
4	MPT33F2-6	Zhemgang	66,364	0	27,933	27,933	94,297	1
5	MPS33F3-1	Wangduephodrang	51,598	17,992	1,976	19,967	71,565	1
6	MPO11F1-3	Trashigang	10,793	0	17,603	17,603	28,396	1
7	MPM33F2-5	Sarpang	51,697	4,072	11,344	15,415	67,112	2
8	MPP33F1-1	TrashiYangtse	14,061	0	14,387	14,387	28,448	2
9	MPK11F2-4	Samdrup Jongkhar	65,658	0	13,825	13,825	79,483	2
10	MPT33F3-1	Zhemgang	57,491	11,293	0	11,293	68,784	1
11	MPQ33F1-8	Trongsa	17,069	5,910	3,250	9,160	26,229	1
12	MPS33F3-4-2	Wangduephodrang	19,044	8,712	0	8,712	27,756	2
13	MPA11F1-1	Bumthang	4,684	7,975	0	7,975	12,659	1
14	MPM33F1-2	Sarpang	48,271	0	7,052	7,052	55,323	1
15	MPM33F4-1	Sarpang	23,723	6,917	0	6,917	30,639	2
16	MPG11F2-3	Mongar	17,375	0	6,894	6,894	24,269	2
17	MPJ33F1-5	Punakha	0	0	4,031	4,031	4,031	1
18	MPM33F3-1	Sarpang	2,669	0	4,005	4,005	6,675	1
19	MPQ33F1-10	Trongsa	981	0	3,336	3,336	4,317	1
20	MPF11F1-5	Lhuntse	550	3,274	0	3,274	3,824	1
21	MPA11F1-4	Bumthang	11,273	2,673	0	2,673	13,945	1
22	MPS33F3-5	Wangduephodrang	16,080	2,369	0	2,369	18,449	2
23	MPO11F1-8	Trashigang	13,924	0	2,057	2,057	15,981	2
24	MPJ33F1-2	Punakha	0	0	1,990	1,990	1,990	1
25	MPF11F5-2	Lhuntse	23,808	1,779	0	1,779	25,587	1
26	MPF11F3-3	Lhuntse	5,335	1,315	0	1,315	6,650	2
27	MPJ33F1-6	Punakha	0	0	1,143	1,143	1,143	1
28	MPF11F3-2	Lhuntse	0	1,112	0	1,112	1,112	2
29	MPF11F3-7	Lhuntse	1,922	181	0	181	2,103	2

Prepared by JICA Study Team

Feeder recommended to be subject to EIA Target Feeder for preparation of TOR for EIA

(3) Draft TOR for EIA

The contents list for the draft TOR for EIA is shown in **Table-17.7.2** below. (The actual draft TOR is attached as **Appendix C-I-3**).

When conducting the EIA, it might be required that the detail description of the EIA procedure should be examined further through discussion with the relevant organizations as well as considering the actual situation at a project site. Nevertheless, the draft TOR prepared in the Study will be useful for the discussion of EIA implementation at early stage of the implementation phase of the master plan project.

Table-17.7.2 Contents of Draft TOR for EIA

1. Introduction
2. Objectives of the environmental assessment
3. The area to be covered in the EIA
4. Scope
4.1 Preparatory work
4.2 Collection of existing data and information
4.3 Field work
4.4 Impact assessment
4.5 Analysis of alternatives
4.6 Development of EMP (Environmental Management Plan)
4.7 Public consultation
4.8 Preparation and submission of environmental assessment reports
5 Work schedule

Prepared by JICA Study Team

CHAPTER 18 EXPANSION PLAN FOR THE INFORMATION AND COMMUNICATIONS NETWORK

18.1 Expansion Plan for the Information and Communications Network

In this master plan, the information and communications network is planed to be expanded by installing fiber optic cables along with power lines that are constructed for the electricity distribution network. Therefore, expansion planning for the information and communications network must be done simultaneously with planning for the electricity distribution network. This part is expected to be done in 10th and 11th Five Year Plan.

The target end points of the fiber optic information and communications network proposed in the master plan will be 193 on-grid Gewog centers out of a total of 201 Gewogs.

Fiber optic cable on existing and ADB/RE-3 distribution lines also must be considered to construct nationwide network. Installation plan of such cables should be planed, considering whole budget for the project and requests/needs from local. This part is expected to be done by 2020 in 12th Five Year Plan.

An overview of the plan is shown in **Table-18.1.1** below.

Table-18.1.1 Overview of the Information and Telecommunications Plan

Target Area	· Fiber optic cable: 193 out of 201 Gewogs (on-grid)
Target Population	· 750,000 (almost all of the population - RGoB does not publish any statistics of Gewog-wise population and current address-based population data.)
Target Facilities	· Gewog Centers - 193 for fiber optic cables (8 for standard telephone lines) · Bhutan Telecom Ltd. and Bhutan Broadcasting Corporation Service · Health service institutions as beneficiaries only; the cost of the network connection to these facilities is not included in the master plan
Available Services	Gewog Centers · Improvement of governmental/public services · Better efficiency of officer's and staff work · People can get certificates easily. Bhutan Telecom Ltd. (BTL) · Development of the communications network · BTL can offer better services for people. Bhutan Broadcasting Services Corporation (BBSC) · BBSC can provide services to more people. · BBSC can send program material from local/rural areas to the central office. School and Health Service Centers · Better education services · Teachers/students in rural areas can be trained/study by distance education systems. · Some of teachers will be willing to be assigned schools in rural areas thanks to better information infrastructure, including telephone and TV. · Better health services · Health service centers in rural areas can use videophone to ask questions to doctors in the main hospital in Thimphu or in Dzongkhag hospitals. · Staff can access to the Internet to get information or study materials.

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18.2 Demand and Benefit for Expansion of the Information and Communications Network

Table-18.2.1 below shows a summary of comments on the needs and expected benefits that were received from RGoB and related agencies.

Table-18.2.1 Summary of Comments and Plans of Ministries and Agencies

ICT Policy in General: Department of Information Technology (DIT), Ministry of Information and Communications (MOIC)	Optical fiber network is very important as an infrastructure for the information and communications network. Therefore it will/should be expanded as a national infrastructure. DIT is in the process of deciding policies of information and communications technology (ICT) like communications, broadcasting, education and remote health services. BTL's idea is that fiber optic cables to Gewog centers should be installed from around 2017, which is not too late to meet future demand.
Communications: Bhutan Telecom Ltd. (BTL)	Optical fiber networks are important as stable trunk lines. Additionally, optical fiber network is essential in branch networks, when converting the present exchange system to an IP system. This is because it will be difficult to maintain present digital exchange system. BTL will install telephone lines for all 201 Gewogs by 2007 as part of their rural telecommunication project. However, the facility cannot meet the demand for broadband communications. Fiber optic cable to be installed with the electrification master plan is expected to be a replacement for the facilities installed under the rural telecommunication project. Therefore, BTL hopes that fiber optic cable will be installed from 2017. (The life span of the standard telephone lines is ten years.) BTL has invested in several projects for a few years, e.g. the rural telecommunication project and GSM mobile phone service, so it is difficult for BTL to extend the fiber optic network at present. However, BTL understands the benefits to plan information and communication network along with power distribution lines.
Broadcasting: Bhutan Broadcasting Service Corporation (BBSC)	BBSC will borrow trunk network capacity from BTL. BBSC wants to cover areas where people cannot receive microwave transmissions; using the optical fiber network will allow BBSC to distribute TV programs to these areas. Owning a network is important for keeping security, and is beneficial for improving skills and to maintain. Additionally two-way communications are available, e.g. for sending program materials from Gewogs to the central office. This facility is not available in the case of broadcasting satellite systems.
Education Services: Ministry of Education (MOE)	MOE has a plan to use the optical fiber network for distance education to upgrade teachers and their qualifications. Actually, MOE is in the process of developing a distance education system using broadband Internet connection. MOE is eager to use the optical fiber network. At present, distance education is done through schools during the school holidays and huge volumes of handouts are processed. MOE understands that distance education and computer training in primary education or rural areas is difficult because of limitations in the existing electricity and communications network. Most of teachers don't want to be assigned to schools in rural areas because of a lack of electricity and communications facilities. It is said that the problem is not matter of money, like allowances, but a matter of loneliness. On this point also, availability of the fiber optic information and communications network is expected to encourage teachers to accept rural postings.
Health Services: Ministry of Health and JDW National Referral Hospital	MOH has tried to provide best service by existing facilities. However the service level is not enough, especially in rural areas, because of a lack of facilities. Telemedicine systems installed by Japanese Grass Roots Grant Aid are also not working so well because of lack of proper network and experienced staff. It will be great step forward to be able to use the standard telephone network in rural areas by 2007. For the future, fiber optic cable can bring much greater possibilities for providing better health services with videophone and the Internet. Such new facilities can help to improve health services because MoH is facing a lack of human resources such as doctors, and expensive equipment.

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Considering the comments above, and other studies undertaken for the rural electrification master plan, the demands on the fiber optic network that can be expected have been determined. The information and communications network is expected to be a national infrastructure and various ministries and agencies are eager to use it for delivering their services to the people. These demands are summarized in **Table-18.2.2** below. Result of quantification of benefit is shown in Section 18.4.

Table-18.2.2 Expected Demand and Benefit

Public Services by the Government	· Efficiency of Public Services and Promotion of the RGoB Policy of Decentralization. · Better Service for People · Better Database System of Government Ministries and Agencies
Communications Service	· Stability of Backbone Network with Large Capacity · Rural Network with Large Capacity · Ready to IP-based Network · Low Maintenance Cost and Long Life Span · More Profit/Business Chance for BTL
Broadcasting Service	· Expansion of Service Area · Better Program Production · Real Time Program Delivery
Education Service	· Better Quality of Education Service in Rural Areas · Training Opportunity for Teachers in Rural Areas by Distance Training · Possibility of Distance Education and ICT Education for Students
Health Services	· Better Communications Facility · Videophone Service for Better Consultation · Internet to Get Necessary/Useful/Important Information.

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18.3 Cost of the Expansion Plan for the Information and Communications Network

The Study Team estimated the cost of expanding the information and communications network. This estimate was prepared on the basis that the optical fiber cables are connected to Gewog centers that the distribution lines reaches; further extension was not considered. Expansion of the information and communications network is supposed to be done in conjunction with the expansion of the electricity distribution network to reduce the installation cost. In addition, the fiber optic cable should be installed on the existing electricity distribution network in the master plan to complete the national information and communications network.

Distribute the total estimated cost into 10th, 11th and 12th Five Year Plan (FYP) in the ratio 40%, 30% and 30% respectively. The total cost shown in **Table-14.3.4** includes the cost of installation and materials for the information and communications network, both on the new and existing electricity distribution lines. As the electricity distribution line project is scheduled to be completed in 11th FYP, the fiber optic work in 12th FYP will not be synchronized with the work of electricity distribution lines during this phase. The reason of the difference in the implementation schedule is mentioned in Chapter 19.

The total cost was estimated in the following steps:

1. Estimate the route length of communication lines, and quantity the equipment and materials.
2. Determine standard unit prices.
3. Apply an equipment cost decrease of 10% for 11th FYP and 20% for 12th FYP.
4. Distribute the total estimated cost into 10th, 11th and 12th FYP in the ratio 40%, 30%, and 30% respectively.
5. The following items were not included in the estimation:
   - OPGW network and its associated facilities (BTL will independently plan in an another project.)
   - Telephones, facsimiles and computers for Gewog centers
   - Equipment for broadcasting services, education and health care institutions

The quantity of materials was estimated using the planning map of electricity distribution line. For estimation purposes, the line was terminated at Gewog centers. However, the location of some Gewog centers could not be identified. Therefore, some of the locations were estimated by the Study Team.

The total length of the required sections of the electricity distribution line was estimated to be 2,239 km. This total length is 20% more than the route length that was measured on the map (1,866 km) to have a marginal length when the cables are installed. The total includes the cable required for the existing and ADB/RE-3 distribution line (1,224 km) and the new lines for the master plan rural electrification (1,015 km).

Dzongkhag-wise cable lengths for both the existing and ADB/RE-3 power line network and the new power lines required to extend the network to Gewog centers are shown in **Table-18.3.1** below. The existing power line distances and the new cable length (shown in parentheses) indicate the length of the planned power lines that was measured with map prepared in the master plan distribution line design.

Table-18.3.1 Dzongkhag-wise Fiber Optic Cables Lengths

Dzongkhag	Existing Power Line Length (km)	New Power Line Length (km)	Dzongkhag	Existing Power Line Length (km)	New Power Line Length (km)
Thimphu	23	(0)	Bumthang	64	(23)
Chukha	131	(50)	Sarpang	193	(112)
Haa	32	(11)	Zhemgang	147	(86)
Paro	51	(0)	Trongsa	66	(30)
Samtse	149	(94)	Lhuntse	92	(21)
Tsirang	62	(56)	Mongar	134	(74)
Dagana	83	(44)	Pemagatshel	70	(31)
Punakha	59	(0)	Samdrup Jongkhar	93	(58)
Gasa	40	(20)	Trashigang	195	(51)
Wangduephodrang	115	(61)	Yangtse	67	(24)

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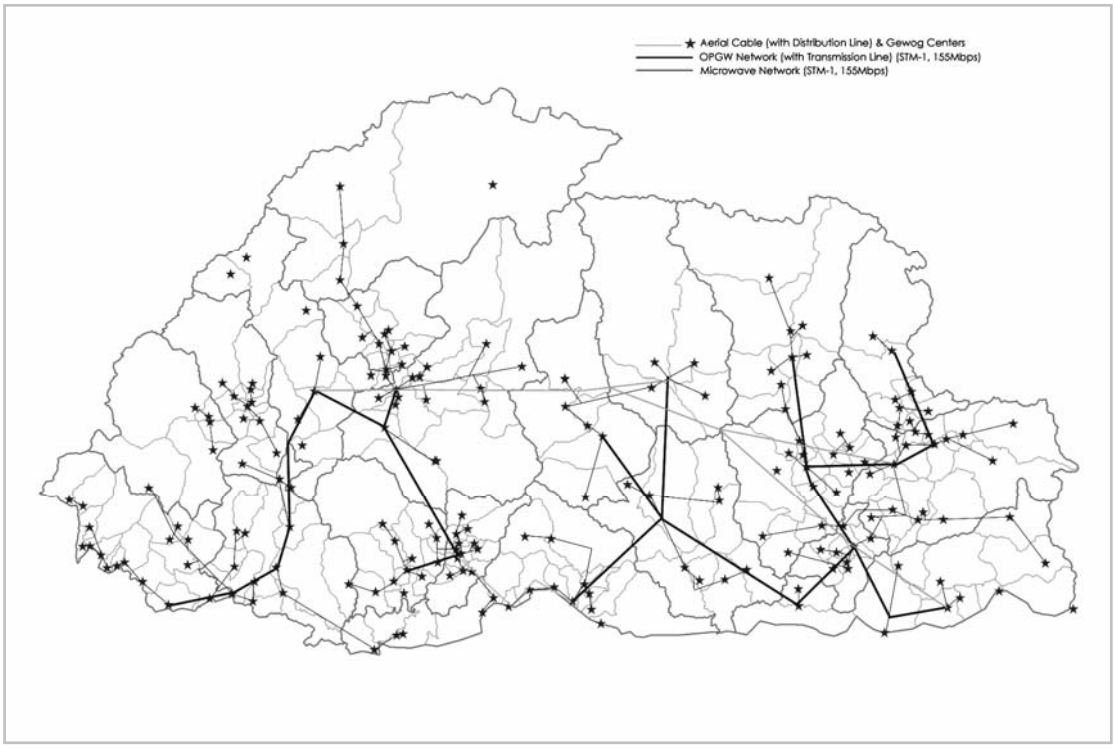

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Figure-18.3.1 Locations of Gewog Centers and Networks

If optical terminating equipment (OTE) was installed at all Gewog centers, the capacity will be too high and the equipment too costly. The Study Team therefore reduced the project cost by sharing one OTE with a number of Gewogs. In this master plan, the Study Team intends to install an OTE in 40 Gewog centers. Repeaters will be used for the other Gewog centers, if necessary. Regarding the number of fiber cores bundled in one fiber optic cable, eight cores were selected, as the capacity is considered to be enough for the future demand.

Table-18.3.2 shows the necessary equipment and materials, with the estimated quantities.

Table-18.3.2 Necessary Equipment for the Information Network Expansion

Item	Quantity	Note
Fiber Optic Cable (SSF[1] 8 Core Cable)	1,015 km	It will be installed with the new electricity distribution line of the Master Plan.
	1,224 km	It will be installed with the existing and ADB/RE-3 power lines.
Optical Terminating Equipment (OTE)	40	
Subscriber Premises Terminating Equipment (SPTE)	193	
Repeater	80	

Prepared by JICA Study Team

For the cost estimation, the Study Team adopted unit prices for materials and installation work as shown in **Table 18.3.3** below. Because there are only a few examples of optic fiber

[1] Self Support Fiber

cable in Bhutan, the unit costs were estimated from data taken from the examples in Bhutan and other countries like Nepal.

Table-18.3.3 Standard Unit Prices

Item	Unit Price	
SSF 8 Core Cable	US$2,160/km	This unit price includes necessary accessories. Installation cost is also included.
OTE	US$15,000/Unit	This is required at the connection point of OPGW-SSF and each exchange. BTL will cover this equipment for the connection point by another project. Therefore only the equipment for the exchange was considered. The installation and transportation cost is estimated to be an additional 10% of the unit price (US$15,000).
SPTE	US$1,600/Unit	This equipment is required per subscriber (Gewog center). Installation and transportation cost is estimated to be an additional 10% of the unit price (US$1,600).
Repeater	US$800/Unit	A repeater will be used where the length between the OTE and SPTE is around 10 km or more.

Prepared by JICA Study Team

The overall cost estimate and cost estimate by each FYP for the information and communications network project is shown in **Table-18.3.4** and **Table-18.3.5** below. The total project cost is estimated at US$5.4 million including as shown in **Table-18.3.3**. Transportation and installation are included in the material costs.

Table-18.3.4 Overall Cost Estimate

Item	Quantity	Unit Price	Subtotal	Note
SSF 8 Core Cable	1,015 km	US$2,160/km	US$1,974,456	With new electricity distribution line of the master plan.
	1,224 km	US$2,160/km	US$2,380,968	With existing / ADB/RE-3 power lines.
OTE	40	US$18,000/Unit	US$648,000	
SPTE	193	US$1,920/Unit	US$333,696	
Repeater	80	US$800/Unit	US$57,600	
Total			US$5,394,720	

Note: Unit prices mentioned above are for 10th FYP only, and do not include a price decrease in 11th and 12th FYPs. Therefore, the quantity multiplied by unit price is not equal to the subtotal.

Prepared by JICA Study Team

Table-18.3.5 Cost Estimate of Each Five Year Plan

	10th FYP			11th FYP			12th FYP			Total	
	Unit Price	Quantity	Subtotal	Unit Price	Quantity	Subtotal	Unit Price	Quantity	Subtotal	Quantity	Total
SSF 8 Core Cable (Unit: US$, km)	2,160	783	1,691,280	1,944	686	1,333,584	1,728	770	1,330,560	2,239	4,355,424
OTE (Unit: US$, Unit)	18,000	14	252,000	16,200	12	194,400	14,400	14	201,600	40	648,000
SPTE (Unit: US$, Unit)	1,920	67	128,640	1,728	60	103,680	1,536	66	101,376	193	333,696
Repeater (Unit: US$, Unit)	800	28	22,400	720	24	17,280	640	28	17,920	80	57,600
Total (Unit: US$)			2,094,320			1,648,944			1,651,456		5,394,720

Prepared by JICA Study Team

18.4 Economic Evaluation of the information and Communications Network

18.4.1 Overview

The plan to install optical fiber network utilizing the electricity distribution system enables savings in both investment and operation costs of the telecommunication system. The proposed optical fiber network provides broadband capacity enabling new and faster communication functions. However, the extension of the current telecommunication system up to all Gewog centers by the year 2007 is already planned and underway. Thus, immediate investment would create a double investment.

From a viewpoint of security of the nation, the information and communications system has a vital value beyond mere economy. However, this redundancy of the proposed network limits the economic evaluation within the narrowly-defined benefit of cost-saving and demands for better and added functionalities. The results of the economic analysis show that the expected return on investment will be 1.8% for 10th FYP. However, the return on investment improves for the later phases; 6.2% for 11th FYP and 24.0% for 12th FYP, indicating the delayed implementation will improve the economic viability of the project. Sensitivity analyses show that the return on investment drops to 1.6% for 20% investment cost increase scenario and to -0.3 % in the case of 20% demand reduction for 10th FYP, using factors for a cost escalation (20% up) and target demand reduction (20%). In the case 100% Internet demand capture, the EIRR increases to 9.0 % but in the case of 0% realization, the EIRR drops to -2.5%.

The use of the new data communication system depends on many additional factors. These need to be developed beyond construction of the telecommunications infrastructure. For example, software, client-level investment for PCs and other digital equipment, software and the digital and audio-visual content that is to be delivered. Another critical element in rural areas is people who are proficient in using these new technologies. Among all factors, the most critical is the institutional resolve to bring new services on line, either by the private or public sector for the realization of the benefits. Whether the initiatives and investments will be undertaken in a timely manner to justify the investment in a small country like Bhutan itself is a matter for speculation. The broader societal demand should be investigated further before deciding the immediate implementation. The progresses of decentralization, human resource development and possibilities which can be realized these progresses are to be surveyed in feasibility study stage to grasp detail benefits and realizability.

18.4.2 Scope of Analysis

The range of investments that is required for the new telecommunications system to function is more than just that required for the optical fiber network. Digital-optical equipment is needed and also the receiving and transmitting equipment at the user level. Depending on the use of the telecommunications functionality, additional facilities and personnel may be needed. Here, for the simplicity of analysis the Study Team assumed two broad categories of services: (i) conventional telecommunications functions, and (ii) broadband services. There could be a number of broadband services, but since the first line connections will be limited to Gewog centers and public facilities, the Study Team considered two services that

may have broad impact on the living standard of the rural population; one is remote education and the other is remote medicine. Project life is set at 20 years. According to the phase development plan, the implementation takes place 40% in 10th FYP, 30% in 11th FYP, and 30% for 12th FYP respectively. The estimated nation-wide benefit is assumed to be distributed according to these implementation shares as well.

18.4.3 Economic Benefit and Cost Estimation

The benefits and costs are firstly estimated on a full-scale nation-wide basis first and secondary allocated in proportion to the share of the phase development coverage.

- Telephone

  For telecommunication needs, analysis of the willingness-to-pay questionnaire survey (WTP Survey) conducted in conjunction with Gewog's was analyzed using questionnaire to villagers. As a result, villagers are willing to pay 100-200 Nu. per call. Without an access point in their own Gewog, villagers are estimated to travel around 20 km on foot or by car to make a call. The cost of travel alone would be 100-300 Nu. per trip including the lost time. The phone call rate in Bhutan is relatively inexpensive; 10 Nu. or so for a 1- 2 minute call to Thimphu from a local city. Besides, the villagers would have to pay the same rate or more for a call made from a Gewog center as well. A willingness to pay up to 350 Nu. per call would be quite acceptable to assume. The estimation of the call frequency is difficult to make. The average frequency derived from questionnaire appears to be overstated for a household. Three times per year per household is estimated to be a good number. The coverage of households is tentatively 30,000, which is about 90% of the total number of rural households.

  The WTP interview shows that the annual budget at Gewog offices is between 3,500 and 5,000 Nu. Therefore, the Study Team assumed that a benefit 4,000 Nu. per year for the Gewog administration, and thus 772,000 Nu. per year will be generated nation-wide.

- Cable TV

  As discussed in Chapter 13, the average willingness-to-pay for the transmission of TV program content through the digital network is as much as 10,000 Nu. per month per company. There are currently 17 companies, and that potentially represents 2.04 million Nu. per year in total.

- Distance Education

  The quantification of such benefits is rather arbitrary. The potential for remote education is assumed to represent the addition of one teacher in each Gewog. Given an average remuneration of US$2,500 per year per teacher, the cost saving is equal to US$2,500 per Gewog, multiplied by 193 on-grid Gewogs, i.e. US$482,500 or 21.7 million Nu. At the same time, the cost of production of the digital content and education material needs to be taken into account. Such production costs would require a minimum professional group of 50 staff and 100% production and overhead cost. The cost is estimated to be US$300,000. Thus, the net benefit would be US$0.183 million or 8.24 million Nu.

- Tele-medicine / Health Services

  Currently, medical services in Bhutan have a hierarchical system based on the three main hospitals, Basic Health Units (BHU's) and Out-reach Clinics (ORC's). The quality and specialization of personnel and equipment intensifies as one goes up the ladder.

  The benefit of obtaining medical information is again very arbitrary. Thus, again the Study Team assumed some cost saving benefits related to seeking information on medical care. Assuming that one day in one month is consumed for information gathering by the medical experts in rural areas, e.g. by traveling directly to contact the source of the information. The provision of the Internet would eliminate such traveling expenses, so the cost saving in each BHU or out-reach clinic is assumed as follows:

  Cost saving = (Traveling cost: 300 Nu./trip + Wage cost: 200 Nu./trip) = 500 Nu./trip x 12 trips = 6,000 Nu./year

  Since there are 200 BHU's and outreach clinics, the total saving is estimated to be 1.2 million Nu./year.

  The cost of running such a medical knowledge base is assumed to be 0.81 million Nu./year with 5 professionals: US$300/month x 5 x 12 = US$18, 000 (= 810,000 Nu.)

18.4.4 Uncertainties and Expected Value

Besides simple use of the telecommunications network as communication device, the potentials described above for remote education and medicine depend on the premise that the associated institutional setup is created by some public initiatives, adequate investment in procuring equipment and hiring professionals takes place, and other needed factors are all aligned to bring the project into reality. Without such initiatives, the potentials would be no more than dreams. On the other hand, unexpected opportunities may arise with the provision of a new telecommunications network. There is no denying that there may be better agricultural marketing information or extension services, handcraft production marketing, or tourism promotion. The potentials are limitless, but there is no way of quantifying the potential at this point.

Therefore, the benefits of remote education and medicine are treated as representative potentials. However, in order to assign some uncertainty value to associate with these projects, the probability of 0.3 will be adopted for both. The expected economic benefits would be 0.3 times assumed benefits for both the educational and medical sectors.

Another factor is the potential and actual demand. For instance, it would be impractical to assume that all the Gewogs will have a remote education system from the start of the telecommunications system operation. Realistically, the actual penetration would be a gradual process. Therefore, in a simple manner, it is assumed that 20% of the potential demand will become actual demand over the first five years after the system is implemented.

- Growth of Benefit

  5% annual growth is assumed for the telecommunications component, and 10% for the digital communications component (Cable TV and Internet) for 20 years since the beginning of the year 1 and thereafter to be without any growth.

- Economic Cost

  For the investment component of the project, it is assumed that the conversion factor is 1.1 for imported materials, which is the same as for the distribution project. For convenience, the import ratio is assumed to be 90% for the telecommunications network investment and 50% for operation and maintenance cost.

- Replacement Cost

  The need to replace the equipment is assumed to take place every 10 years. The cost is assumed to be 30% of the total initial investment cost.

- With/Without Assessment

  For the first 10 years, the newly installed conventional analog telecommunication system will be operational. Therefore, the benefits from fiber optic (digital) telecommunications are assumed to be zero for the first 10 years. The digital communication component is assumed to capture all such benefits from the outset.

18.4.5 Results of the Economic Analysis

Table-18.4.2, **Table-18.4.3** and **Table-18.4.4** below and show the results of the economic analysis for each phase. The Economic Internal Rate of Return (EIRR) is calculated to be 1.8% for 10th FYP, 6.2% for 11th FYP and 24.0% for 12th FYP. There would be no financial return on investment, and the quality improvement is not taken into account. Progress improvements of EIRR according to phases indicate the delayed implementation is the major contributor to the economic viabilities for this project.

- Sensitivity Analysis

  The demand for Internet access (remote education, and remote medicine) is a market that may happen or may not happen. Following the principles of posterior analysis, the sensitivity analysis was undertaken for the cases of no Internet demand and full Internet demand (i.e. 100% instead of 30% probability).

  The results of this analysis are shown in **Table-18.4.1** below.

Table-18.4.1 Sensitivity Analysis for 10th FYP

Case	EIRR
A) Full Internet Demand	9.0%
B) No Internet Demand	-2.5%

Case	EIRR
C) 20% Cost Up	1.6%
D) 20% Demand Down	-0.3%
C)+D)	-0.9%

Prepared by JICA Study Team

Table-18.4.2 Cash Flow for Optical Fiber Network (10th FYP)

Unit: 1,000 Nu.

Year	Benefit						Cost		Net Cash Flow
	Telecommunication		Cable TV	Internet		Total	Invest-ment	O & M	
	local admin	general household		Tele-Education	Tele-medicine				
0	0	0	0	0	0	0	102,726	14,310	-117,036
1	0	0	163	521	29	713		16,365	-15,651
2	0	0	359	1,146	63	1,505		16,365	-14,859
3	0	0	592	1,892	105	2,484		16,365	-13,881
4	0	0	869	2,774	153	3,643		16,365	-12,721
5	0	0	1,195	3,815	211	5,009		16,365	-11,355
6	0	0	1,314	4,196	232	5,510		9,210	-3,699
7	0	0	1,446	4,616	255	6,061		9,210	-3,148
8	0	0	1,590	5,077	281	6,668		9,210	-2,542
9	0	0	1,749	5,585	309	7,334		9,210	-1,875
10	0	0	1,924	6,144	340	8,068	30,818	9,210	-31,960
11	101	4,105	2,116	6,758	373	13,080		6,825	6,255
12	211	8,620	2,328	7,434	411	18,593		6,825	11,769
13	333	13,577	2,561	8,177	452	24,648		6,825	17,823
14	466	19,007	2,817	8,995	497	31,285		6,825	24,461
15	611	24,947	3,099	9,894	547	38,552		6,825	31,727
16	642	26,194	3,409	10,884	602	41,129		6,825	34,304
17	674	27,504	3,749	11,972	662	43,900		6,825	37,075
18	708	28,879	4,124	13,169	728	46,881		6,825	40,057
19	743	30,323	4,537	14,486	801	50,090		6,825	43,265
20	780	31,840	4,991	15,935	881	53,545		6,825	46,721

E.I.R.R = 1.8%

Note: 0) The first year of the project is equal to the demand estimated for the 10th year in the base case.

1) Assumptions for the growth rates:telecommunicaiton demand (5%), Cable TV and Internet (10%)

2) initial demand for the Internet will be low due to slow penetration among users.
It is assumed that the initial year market capture remains 20% of the potential, with the increment of 20% till reaching 100%.

3) The operation and maintenance costs for optical fiber network is 2% of the initial investment and include stage-wise equal share of the cost of 13.5 million Nu. for remote education and 0.81 million Nu. for tele-medicine.

4) implementation probability of 30% is assumed for the Internet uses.

5) The initial investment is calculated as follows;

Conversion factor is calculated by assuming as following;
Foreign & Local currency component of investment: 90% & 10%
Shadow exchange rate for Nu./US$: 1.1
Thus Conversion factor: 0.9 x 1.1 +0.1 =1.09
Initial investment: 1.09 x US$2,094,320 x 45 Nu./$ = Nu.102,726,396

6) There is a need for re-investment of 30% of the initial investment every 10 year.

7) The exchange rate is set at 45 Nu./US$.

Prepared by JICA Study Team

Table-18.4.3 Cash Flow for Optical Fiber Network (11th FYP)

Unit: 1,000 Nu.

Year	Benefit						Cost		Net Cash Flow
	Telecommunication		Cable TV	Internet		Total	Invest-ment	O & M	
	local admin	general household		Tele-Education	Tele-medicine				
0	0	0	0	0	0	0	80,881	7,155	-88,036
1	0	0	263	839	46	1,148		8,773	-7,624
2	0	0	578	1,846	102	2,425		8,773	-6,348
3	0	0	954	3,046	168	4,001		8,773	-4,772
4	0	0	1,399	4,468	247	5,867		8,773	-2,905
5	0	0	1,924	6,144	340	8,068		8,773	-705
6	151	6,157	2,116	6,758	373	15,183		6,388	8,795
7	158	6,465	2,328	7,434	411	16,385		6,388	9,998
8	166	6,788	2,561	8,177	452	17,693		6,388	11,305
9	175	7,128	2,817	8,995	497	19,114		6,388	12,727
10	183	7,484	3,099	9,894	547	20,661	24,264	6,388	-9,991
11	193	7,858	3,409	10,884	602	22,343		6,388	15,956
12	202	8,251	3,749	11,972	662	24,175		6,388	17,788
13	212	8,664	4,124	13,169	728	26,170		6,388	19,782
14	223	9,097	4,537	14,486	801	28,343		6,388	21,956
15	234	9,552	4,991	15,935	881	30,712		6,388	24,324
16	234	9,552	4,991	15,935	881	30,712		6,388	24,324
17	234	9,552	4,991	15,935	881	30,712		6,388	24,324
18	234	9,552	4,991	15,935	881	30,712		6,388	24,324
19	234	9,552	4,991	15,935	881	30,712		6,388	24,324
20	234	9,552	4,991	15,935	881	30,712		6,388	24,324

E.I.R.R = 6.2%

Note: 0) The first year of the project is equal to the demand estimated for the 10th year in the base case.

1) Assumptions for the growth rates:telecommunicaiton demand (5%), Cable TV and Internet (10%)

2) initial demand for the Internet will be low due to slow penetration among users.
It is assumed that the initial year market capture remains 20% of the potential, with the increment of 20% till reaching 100%.

3) The operation and maintenance costs for optical fiber network is 2% of the initial investment and include stage-wise equal share of the cost of 13.5 million Nu. for remote education and 0.81 million Nu. for tele-medicine.

4) implementation probability of 30% is assumed for the Internet uses.

5) The initial investment is calculated as follows;

Conversion factor is calculated by assuming as following;
Foreign & Local currency component of investment: 90% & 10%
Shadow exchange rate for Nu./US$: 1.1
Thus Conversion factor: 0.9 x 1.1 +0.1 =1.09
Initial investment: 1.09 x US$1,648,944 x 45 Nu./$ = Nu.80,880,703

6) There is a need for re-investment of 30% of the initial investment every 10 year.

7) The exchange rate is set at 45 Nu./US$.

Prepared by JICA Study Team

Table-18.4.4 Cash Flow for Optical Fiber Network (12th FYP)

Unit: 1,000 Nu.

Year	Benefit						Cost		Net Cash Flow
	Telecommunication		Cable TV	Internet		Total	Invest-ment	O & M	
	local admin	general household		Tele-Education	Tele-medicine				
0	0	0	0	0	0	0	81,004	4,770	-85,774
1	101	4,105	423	1,352	75	6,055		6,390	-335
2	211	8,620	931	2,974	164	12,736		6,390	6,346
3	333	13,577	1,537	4,906	271	20,352		6,390	13,962
4	466	19,007	2,254	7,196	398	28,923		6,390	22,533
5	611	24,947	3,099	9,894	547	38,552		6,390	32,162
6	642	26,194	3,409	10,884	602	41,129		6,390	34,739
7	674	27,504	3,749	11,972	662	43,900		6,390	37,510
8	708	28,879	4,124	13,169	728	46,881		6,390	40,491
9	743	30,323	4,537	14,486	801	50,090		6,390	43,700
10	780	31,840	4,991	15,935	881	53,545	24,301	6,390	22,854
11	780	31,840	4,991	15,935	881	53,545		6,390	47,155
12	780	31,840	4,991	15,935	881	53,545		6,390	47,155
13	780	31,840	4,991	15,935	881	53,545		6,390	47,155
14	780	31,840	4,991	15,935	881	53,545		6,390	47,155
15	780	31,840	4,991	15,935	881	53,545		6,390	47,155
16	780	31,840	4,991	15,935	881	53,545		6,390	47,155
17	780	31,840	4,991	15,935	881	53,545		6,390	47,155
18	780	31,840	4,991	15,935	881	53,545		6,390	47,155
19	780	31,840	4,991	15,935	881	53,545		6,390	47,155
20	780	31,840	4,991	15,935	881	53,545		6,390	47,155

E.I.R.R = 24.0%

Note: 0) The first year of the project is equal to the demand estimated for the 10th year in the base case.

1) Assumptions for the growth rates:telecommunicaiton demand (5%), Cable TV and Internet (10%)

2) initial demand for the Internet will be low due to slow penetration among users.
It is assumed that the initial year market capture remains 20% of the potential, with the increment of 20% till reaching 100%.

3) The operation and maintenance costs for optical fiber network is 2% of the initial investment and include stage-wise equal share of the cost of 13.5 million Nu. for remote education and 0.81 million Nu. for tele-medicine.

4) implementation probability of 30% is assumed for the Internet uses.

5) The initial investment is calculated as follows;

Conversion factor is calculated by assuming as following;
Foreign & Local currency component of investment: 90% & 10%
Shadow exchange rate for Nu./US$: 1.1
Thus Conversion factor: 0.9 x 1.1 +0.1 =1.09
Initial investment: 1.09 x US$1,651,456 x 45 Nu./$ = Nu.81,003,917

6) There is a need for re-investment of 30% of the initial investment every 10 year.

7) The exchange rate is set at 45 Nu./US$.

Prepared by JICA Study Team

18.5 Operation and Maintenance Plan

18.5.1 Implementation Body

At present, only BTL and BPC are judged to be candidates for becoming the implementation body for installation, and subsequent operation and maintenance work of the information and communications network. Even through the series of discussion with BTL, DIT of MOIC and BPC during the master plan study, the Study Team could not determine which of them would become the implementation body. However considering the concept of the master plan, which is information and communication network developed along with power distribution network, the ideal implementation body is in power sector. Initiative of communication sector in planning and technical matter of information and communication network is essential and the minister for information and communication agreed the necessity of initiative.

The important thing to consider when thinking about the implementation body, and operation and maintenance framework is to set criteria to reduce the capital investment cost and avoid the duplication of operation and maintenance costs. There are many options to consider and in feasibility study phase, further study and discussions must be held with various groups to reach a conclusion like cost estimation by using latest criteria, possibility of funding considering directions of donors and operation and maintenance scheme considering human resource and institution.

Operation and maintenance cost of information and communication network to rural area is expected to be higher than OPGW as trunk line because of total length. It is inefficient to operate and maintain distribution lines by BPC and the network by BTL separately. Additionally BTL is ready to pay 'reasonable' fee to any body if other body implements the plan or maintains the facilities of the network. As a result of doing the master plan study, the Study Team recommends that:

- BPC be the implementation body and take all responsibility for installation, operation and maintenance, however initiative by communication sector is mandatory;
- Installation work be included in the contract of the electricity distribution line extension project in 10th and 11th FYP to reduce the capital investment cost;
- Funding source is extected to be same as distribution network for information and communication network installed along with new lines. The rest of information and communication network along with existing distribution lines and necessary equipment at end user side to utilize the network are expected to be funded by budget of RGoB or donors those are interested in ICT sector in Bhutan;
- Operation and maitenance work, including tariff collection, be entrusted to BPC to avoid the duplication of work in rural areas related to the electricity supply operation. Regular inspection of the network is expected to be done with electricity lines' inspection done by BPC. More technical inspection is expected to be done by BTL; and
- BTL pays 'reasonable' rental and maintenance fee to BPC. BTL is expecting lower

percentage of maintainance fee of OPGW, which is 3% of material cost per year. It's realistic persentage if required inspection items are simple.

18.5.2 Implementation Schedule

The information and communications network project will be implemented so that it is synchronized with the electricity distribution line project in 10th and 11th FYP. However, installation work of fiber optic cable on existing/ADB/RE-3 distribution lines will be implemented in 10th, 11th and 12th FYP. The reason is described in Chapter 19. The target completion time is the year 2020. The schedule expected at present is show in **Table-19.5.1**.

CHAPTER 19 IMPLEMENTATION PLAN

19.1 Project Package

In order to secure a conclusive realization of the master plan, it is effective to split the total master plan into appropriate project packages. This will allow various donors to focus on them up and carry them out easily. In addition, there is a need for software assistance, like technical support and capacity building to accompany the project packages for effective project implementation and promotion.

Table-19.1.1 below shows the project packages and their associated software assistance requirements, along with the expected donors.

Table-19.1.1 Project Packages and Software Assistance, with Expected Donors

Project Package	Expected Donors/Scheme
Project Package	
1 Distribution Line Extension	JBIC loan, ADB loan
2 Solar Electrification	Japan general grant and grass roots grant, NGO and NPO, grant scheme from donor countries
3 Small Hydro Electrification	Japan general grant, UNDP, grant scheme from donor countries
4 Biogas Energy Supply	Japan grass roots grant, World Bank, NGO and NPO, grant scheme from donor countries
5 Information and Communication Network Extension	JBIC loan, ADB loan, Japan general grant
6 Distance Education	Japan general grant and grass roots grant, UNDP, grant scheme from donor countries
7 Telemedicine	Japan general grant and grass roots grant, UNDP, grant scheme from donor countries
8 TV Broadcasting Improvement	Japan general grant and grass roots grant, UNDP, grant scheme from donor countries
Software Assistant	
9 Feasibility Study for Distribution Line Extension	JBIC/SAPFOF*, JICA/Development study, ADB/Technical assistant, and other donors
10 Feasibility Study for: Solar Electrification Mini/Microl Hydropower Electrification Biogas Energy Supply Information and Communication Network Extension Distance Education Telemedicine TV Broadcasting Improvement	JICA/Development study and other donor's scheme
11 Technical Cooperation for: Solar Electrification Mini/Micro Hydropower Electrification Biogas Energy Supply Information and Communication Network Extension Distance Education Telemedicine TV Broadcasting Improvement	JICA/Expert and other donor's scheme

* SAPROF: Special Assistance for Project Formation

Prepared by JICA Study Team

Needless to say, at some future time RGoB will need to implement the projects and afterwards Bhutan's people will need to operate them in a sustainable way within Bhutan's own budget. Until that time, the packages shown in **Table-19.1.1** above is useful for both Bhutan and donors; Bhutan needs some donors to assist with implementation of the projects and donors are looking for suitable projects that meet their budget and assistance policies.

In the power sector, there are four project packages:

a) Distribution line extension,

b) Solar electrification,

c) Small hydropower,

d) Biogas energy supply.

The distribution line extension project is the biggest of the project packages, and the necessary funding scale seems able to be satisfied with loans; being impossible to meet grants. The other three packages suit grant based assistance. As the solar electrification project consists of aggregates of small solar home systems, the project can be arranged in any size. Consequently, any small donors can apply their assistance programs to this project. Similarly, the biogas energy supply project can be implemented in the form of various small-scale projects and funding for these projects seem able to be met by assistance from NGO, NPO, and Japan's Grass Roots Grant scheme.

For the information and communications sector, the Study Team recommends that a feasibility study be carried out. In the master plan study, the information and communications sector is seen as an associated development that augments the master plan by increasing the economic benefit of the rural electrification. After the feasibility study, it is recommended that the information and communications project be implemented as a part of distribution line project under a JBIC or ADB loan. However, the possibility of being implemented by a grant still remains open because the project cost is not so high. Through the feasibility study, distance education, telemedicine and TV broadcasting improvement projects will be evaluated. For the time being, Study Team has determined that these projects will be small packages, each of which will be suitable for grant assistance.

Regarding the software assistance for the various project packages, feasibility studies are needed before starting their implementation. Technical cooperation, such as sending experts to Bhutan, will be effective for the software project implementation, operation and maintenance.

19.2 Funding Plan for On-grid Electrification

The funding source for the on-grid electrification and distribution extension project will be JBIC and ADB.

JBIC is already in the process of the preparation of the loan for this project. JBIC has carried out research on debt management in Bhutan during May, 2004 and held a JBIC ODA Management Seminar on October 25, 2004 in Thimphu. On the other hand, on May 24, 2005, RGoB officially submitted a loan request to the Embassy of Japan for the

electrification of 13,000 households in 10th FYP. The total of 13,000 households includes 3,000 household that are still waiting to be electrified under 9th FYP. The total requested amount of the loan is US$26 million. In reply to the request, as of October 2005, JBIC decided to conduct a Special Assistance for Project Formation (SAPROF) study from November 2005. It is expected that the loan will be pledged soon after SAPROF.

ADB has been major financier for the rural electrification in 7th, 8th and 9th FYPs, and has the intention to continue offering loans for rural electrification in 10th FYP.

The Study Team visited JBIC's New Delhi office, the Embassy of Japan and JBIC's Tokyo headquarters after each site visit study to report the results of the study and to exchange information. In addition, the Study Team visited ADB Manila headquarters and presented the study outcomes to the Program Officer on February 24 and September 14, 2005. The Study Team believes that this kind of coordination will help the project to proceed well.

As mentioned above, it is understood that funding for the on-grid electrification project in 10th FYP is almost arranged via the loans from JBIC and ADB. It is also understood that JBIC and ADB will continue to advance loans for the on-grid electrification project in 11th FYP; in this FYP, the on-grid electrification is to be completed according to the master plan.

19.3 Funding Plan for Off-grid Electrification

In this section, the funding sources for off-grid electrification are identified and proposals for off-grid electrification funding are described.

As a result of the master plan studies described earlier in the Chapters 14 and 16, the scale of off-grid electrification has been determined to be approximately 12%, or 5,129 households. RGoB plans to electrify 2,000 off-grid households in 10th FYP.

Off-grid electrification includes subsidies for capital installation, operation and maintenance as well as for planning, advertisement, capacity building, monitoring, and promotion by the private sector. To finance off-grid electrification, RGoB has the policy that Bhutan will not apply a loan to off-grid electrification, but will make use of grant aid from foreign donors and provide some assistance from the government budget. As described in the Section 19.2, donor grant assistances are expected to provide the fund source for off-grid projects. However, the funding source for the sustainable off-grid electrification and operation still has to be determined to cope with the needs that can not be covered by grant assistances.

In order to support the off-grid electrification program, it is proposed to set up and prepare a framework for an Off-grid Rural Electrification Fund (OFF-REF) to support installation, operation and maintenance, capacity building, monitoring, and promotion by the private sector. The candidate funding sources and proposed issues relevant to OFF-REF are listed in the **Table-19.3.1** below.

Table-19.3.1 Possible Fund Source of OF-REF

Item	Contents	Issues
Allocation of electricity export income	Allocate a certain ratio of electricity export income from India to the off-grid electrification fund.	The income by electricity export is allocated to all sectors in Bhutan. It requires agreement of the Ministry of Finance.
Carbon tax	To add a tax (a certain ratio) to the consumer price of fossil fuels such as gasoline and diesel oil.	A new tax regulation, which will affect the environment and road sector, needs to be prepared.
Loan for on-grid electrification	To add the equipment subsidy, management, and capacity building cost of off-grid electrification to the components of the loan for the grid extension.	Repayment is needed, and low economic returns have to be covered by other components.
Income from tariff on grant projects	To provide a grant for mini/micro hydropower and solar installation through a finance package, and provide off-grid electrification fund from the electricity tariff after subtracting operation and maintenance costs.	The scale is small. After subtracting the operation and maintenance costs, there may not be any surplus. This will depend on the electricity tariff that is set.
GEF (Global Environment Facility)	The program is implemented by UNDP, UNEP, and World Bank. It includes programs to support the establishment and operation of renewable energy funds. It covers dispatching specialists, undertaking studies for preparation of implementation institutions and regulations, capacity building, and income generation activities.	The fund is a support program. It is not aimed at covering all installation and operation and maintenance costs.

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The Renewable Energy Division (DOE-RED) of DOE will take responsibility of management and operation of the fund. In addition, it is proposed to establish a regulatory authority with members from the Bhutan Electricity Authority, MTI, and MOF. The regulatory authority will carry out the preparation of a constitution, approval of planning, subsidy program, specification of equipment, and evaluation of monitoring. In addition, it is important for the fund to have external audit to attract donors.

19.4 Institutional Framework for the Rural Electrification Project Implementation

19.4.1 Current Structure

(1) Overview

Figure-19.4.1 below shows the current organization of the power sector in Bhutan. The Department of Energy (DOE) in the Ministry of Trade and Industry is in charge of formulation of macro-level national plans, policies, development programs, techno-economics, plans for project fund mobilization with budgetary clearance, and the coordination of energy sector activities.

Each Hydro-Power Corporation (HPC) is responsible for hydropower generation at its major power station. As of 2005, Chukha HPC (CHPC), Kurichhu HPC (KHPC), and Basochhu HPC were organized and functioning.

Export of electricity to India is directly dealt by individual HPCs (CHPC and KHPC). BPC is responsible for maintenance of transmission line. In addition, BPC undertakes some electricity imports for supplying to isolated systems such as in Daifam in Samdrup Jongkhar.

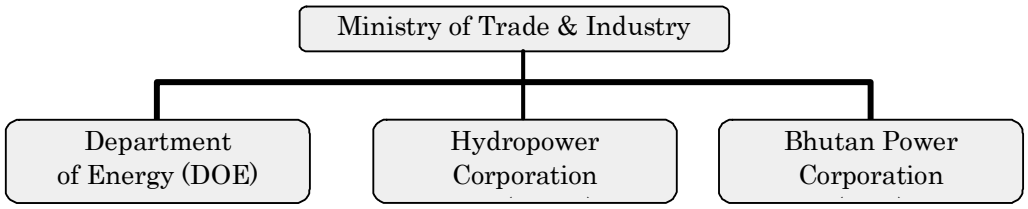

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Figure 19.4.1 Present Organization of Ministry of Trade and Industry

(2) Functions of DOE Relevant to Rural Electrification

For rural electrification, the major functions of the Department of Energy (DOE) are the body of the formulation of macro expansion plans and implementation plans for electrification, monitoring of the implementation of projects, and rural electrification fund mobilization. The Planning and Coordination Division (PCD) is responsible for rural electrification. This division, with 16 staffs, has charge of not only rural electrification, but also of national level plan formulation in the fields of generation, transmission systems, and power communications network. Planning, F/S, fund mobilization and implementation of small/micro hydro projects are carried out by PCD. Rural electrification is materialized by either on-grid or off-grid electricity supply. For off-grid electrification, the Renewable Energy Division (DOE-RED), with 19 staff, is responsible for the investigation of resources, introduction of new technology, strengthening of professional capacity, formulation of plans for energy conservation and efficiency improvement, in addition to formulation of off-grid electrification plans and implementation of facilities. The Hydromet Services Division is the largest group with 120 staffs, and is responsible for collection of data related to hydrology and metrology.

(3) Functions of BPC Relevant to Rural Electrification

Figure-19.4.2 below shows the current organization of Bhutan Power Corporation (BPC). Departments directly related to rural electrification projects are the Procurement and Stores Department, Development and Construction Department, Customer Services Department, and the Planning and Monitoring Division.

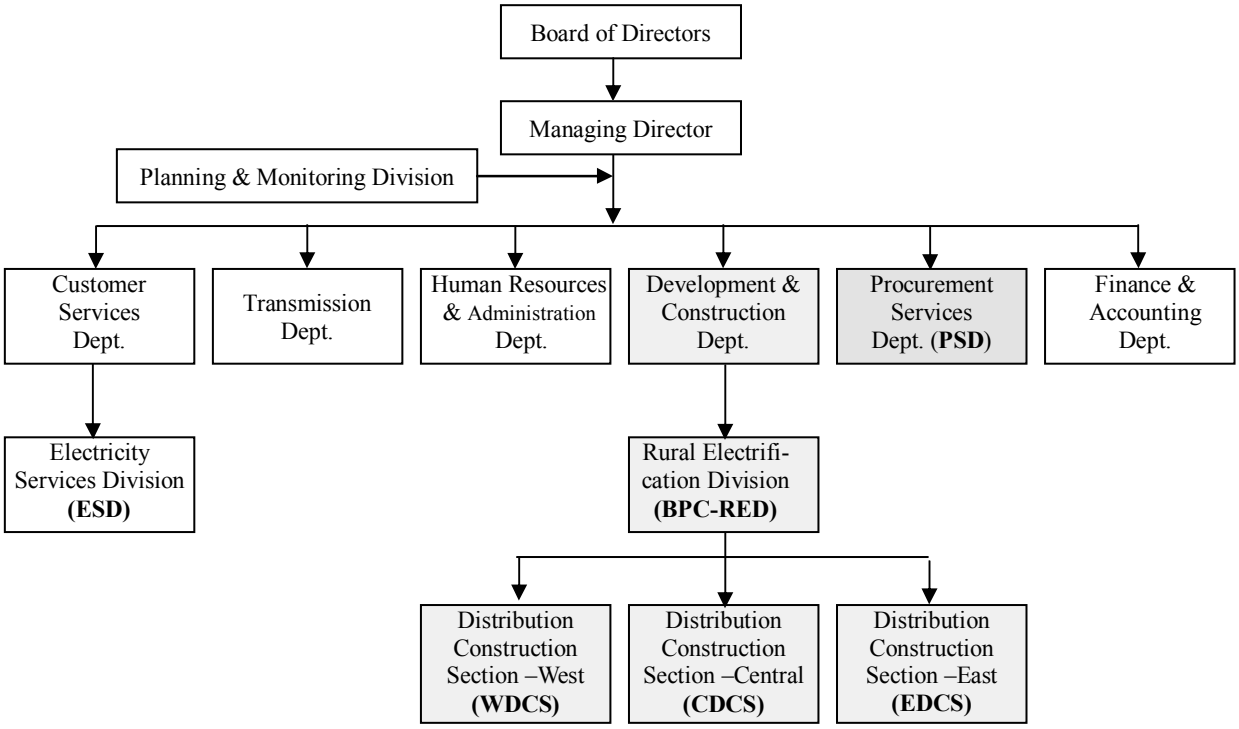

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Figure-19.4.2 Current Organization of Bhutan Power Corporation

The Planning and Monitoring Division is responsible for reporting of all BPC projects to various agencies. The Procurement Services Department (PSD) is in charge of procurement of materials and equipment for projects. Construction of all HV transmission lines and substations and MV facilities, including distribution networks, are managed by the Development and Construction Department. The Rural Electrification Division (BPC-RED) in this department is a core section for rural electrification projects. During implementation of the past and current rural electrification projects, several staff from BPC-RED have been assigned for supervising contractor's work, together with the project consultants. Operation and maintenance work for MV and LV distribution networks, as well as construction of LV lines and minor distribution facilities, are executed by 19 Electricity Services Divisions (ESDs) (at present, here is an ESD office in each Dzongkhag, except for Gasa Dzongkhag) and 16 Electricity Services Sub-Divisions (ESSDs) under the Customer Services Department. Billing to and collection of payments from customers are also duties of the ESDs and ESSDs. Operation and maintenance work for HV transmission lines and substation facilities are the responsibility of the Transmission Department.

(4) Rural Electrification Contracts and Construction

The ADB/RE-1 and ADB/RE-2 projects have been implemented in such a way that BPC (DoP, at that time) procured equipment and materials for the projects through international competitive bidding (ICB). Local contractors, selected through local competitive bidding (LCB), and/or BPC constructed the distribution network (site transportation, pole erection, and conductor stringing) using the equipment and materials supplied by BPC. The

procured materials and equipment were delivered to BPC's Phuentsholing central store by the supply contractors, from where BPC transported the materials and equipment to BPC's local stores for handing-over them to the erection contractors. It is reported that there are sufficient numbers of qualified local contractors for rural electrification. The ADB/RE-3 project is to be implemented using the same procedures.

19.4.2 Institution Plan of On-grid Project Implementation

(1) Principle Direction

Although improvement and work efficiency of BPC's work is required, the current rural electrification implementation structure and functions DOE and BPC will be successful. The following DOE strategies for the power sector during 9th FYP are expected to be realized.

(a) Human Resources Development (HRD) through a skills development and training program for strengthening the sectorial institutional capacity

(b) Examination of the possibility of centralized maintenance section (Begana and its small transformer manufacturing unit are to be privatized)

(c) Study of the possibility of power distribution services for community electricians (e.g. City Corporation to look after all utility services in a town) and private sector participation in billing z and payment collection, depending upon the feasibility

(d) Entrepreneurial skills development and training of community electricians, wiremen and linesmen for self-employment in the electrified areas for internal wiring, repair and line construction and maintenance contracts.

(e) Skills development and training of private electricians, wiremen and linesmen under an ADB-TA scheme

(2) Promotion of Work Efficiency

Through the Study Team's discussion with DOE/BPC personnel, several issues were identified in relation to implementation of the increasing rural electrification work volume. The Study Team suggests the following for efficiently working under the rural electrification master plan project so that the project can be implemented by the present work force of BPC, thereby reducing growing personnel costs.

- Contracts

  Turn-key ICB contracts may be considered as an alternative to the present separate contracts for material procurement and installation contracts. The major merits of turn-key contracts are:

  a) Reduction of work volumes for PSD and BPC-RED for administering bid and contract procedures,

  b) Saving BPC's costs for transportating materials and equipment from the Phuentsholing central store to local stores,

c) Reduction of unnecessary procurement of equipment and materials to recover damages and losses caused during storage and transportation by BPC, and

d) Easier project management of BPC (management of only one fully responsible contractor).

e) Savings due to the use of BPC's workforce to construct facilities instead of using local contractors. (At rpesent, BPC is compelled to undertake feeder construction where no offers are received for particular line sections, or where there is not enough time for completion because the re-tendering procedures would take too long.)

f) Bidding documents for the present separated contracts are easily combined for the turn-key contract. Evaluation of bid offers will be carried out by both PSD and BPC-RED.

Apprehensions about ICB leading to decreased participation and promotion of local contractors will be covered by giving preference[1] to bidders who employ local contractors or meet the terms of the national labor law.

- Accuracy of Survey

Frequent survey errors have been found in past projects. Accuracy of field survey affects estimates for necessary quantities of materials to complete the feeders. This in turn affects work progress and leads to economic losses.

The Study Team provided training in the use of GIS to BPC's staff. Using GIS will be effective for route survey to limit errors to minimum. BPC's work for the re-survey will be reduced by utilization of GIS data for monitoring the survey, and simultaneously work progress will be accelerated.

- Procedures of Environmental Clearance

Currently, from the BPC's experience, arrangement for obtaining clearance for work in environmentally sensitive areas is a huge burden, for the arrangement of respective survey being held by various organization unit (such as NEC, Ministry of Forest, and Dzongkhag Administrations). Also, they need a large amount of resource for the survey of tree cut for connstruction sites of distribution lines. Environmental inspections should be done jointly by the various bodies concerned with doing and assessing environmental examination. This will remove the need for doing repeated site inspections. In the future, it is expected that GIS data for land utilization and forest mapping will be constructed. GIS can also be uesd efficiently to find the required details of rights-of-way for the proposed feeder routes.

[1] Such local preference can not be applied to JBIC project.

- Supervision of Contractors' Works

  Construction of MV distribution networks is supervised by BPC-RED/DCS staff. More development of rural electrification may require more BPC-RED staff, even if the above measures for efficient work are taken. Participation in the work of construction surpervision of staff from ESD (approximately 160 staff at present) should be examined. Participation in the construction surpervision work will contribute to effective operation and maintenace of new MV distribution networks that will be constructed by ESD. Also, participation of ESD will reduce BPC-RED/DCS outstation allowance payments and the need to employ of additional.

(3) Examination of Employment of Additional Staff by BPC

Achieving one hundred percent (100 %) electrification in Bhutan by the year 2020 is the national goal. BPC's work for construction, operation and maintenance will naturally increase in proportion to expansion of power networks. Even though various efficient works will be executed on all fields of BPC's business and also participation of private sector to operation and maintenance work of networks will be realized, reinforcement of work force of BPC will be required to cope with the increasing construction works operation and maintenance work. BPC will not be able to increase the tariff to balance any financial shortage. Adequate assistance from the government will be needed for BPC to satisfactorily perform its duties in the country's power sector.

19.4.3 Institutional Planning for Off-grid Project Implementation

(1) Present Condition and Issues of Off-grid Electrification

The main source of off-grid power is mini/micro hydro and solar power. DOE-RED (Renewable Energy Division) in DOE is the implementation body for projects of off-grid PV systems. As for mini/micro hydropower, DOE is in charge of planning and BPC takes over operation and maintenance at present.

Economic evaluation in the master plan formulated that the number of off-grid electrification households in 2020 will be 5,129 in 449 villages (3,918 households were forecast for 2007). The off-grid villages are generally located in remote areas. Those households are mainly electrified by solar home system (SHS) by a household base. Preparation of the off-grid institution and organization needs to consider the following issues:

- Villages are located in the areas that are far from trafficable roads. According to the Village Base Line Survey (Chapter 7) and on/off-grid evaluation (Chapter 14), the time needed to get an access to a trafficable road is: 5.6 hours for off-grid villages while it is 7.1 hours for on-grid villages.
- The average number of households per village is small and households are scattered. According to the on/off-grid evaluation, the average is 11 households per village for

off-grid villages, while it is 31 households per village for on-grid villages.

Thus, the following points need to be considered when establishing the off-grid institution:

- High cost for installation, tariff collection, and operation and maintenance of the equipment, and a large requirement for man power and time;
- Little access to the market and low income level of villagers;
- Poor communication between villages and the difficulty in forming of community based organizations; and
- Differences in the culture between Dzongkhags and between mountain and valley areas. Therefore, it is difficult to prepare a single comprehensive regulation and institution which reflects local characteristics.

Considering the above, for some villages of which households are very scattered, difficulties might be seen in introducing the concept of community based organization (CBO) for solar SHS installation. It is essential to formulate the institution and regulation that considers the landscape, climate and social framework that exists in Bhutan.

As for mini/micro hydro, community participation projects are currently undergoing in Sengor and Chendebji and community is involved in construction and O&M activities. CBO concept would be effective for such mini/micro hydro schemes and SHS with comparatively dense community.

(2) Subsidizing the Burden Off-grid Electrification

RGoB has already indicated that it is unavoidable to apply a subsidy and different tariff system for off-grid electrification, not only to on-grid households. A draft of the document "Subsidies to Entities Carrying out Non-Economic Viable Electricity Supply" is currently being prepared. It is understood that a governmental subsidy is needed for the off-grid electrification where on-grid connection is not feasible.

Off-grid electrification in Bhutan presents the following economic problems:

- The investment cost of a PV system per household is approximately US$500, corresponding to about 80% of the average annual income of non-electrified households in Bhutan.
- The cost of energy for a small scale of PV system is around US$0.8/kWh[2], over a life time of twenty (20) years and a requirement for battery replacement every four (4) years. The cost for this far exceeds the on-grid electricity tariff. Therefore, it is not realistic to recover the cost from comsumers..

The above problems are also common to other countries. It would be essential to provide a subsidy, considering the income level of off-grid households and fairness in comparison to on-grid households, to which the subsidy has already been provided in practical terms.

[2] Annualized economic cost = 3,133 Nu. (→ Chapter 13.8), 3,133 Nu./year / 12 / 45 $/Nu. / 7.3 kWh = US$0.79

However, if the subsidy ratio is set to 100% (i.e. zero user burden), the users will lack a sense of ownership. In that case, the sustainability becomes less. For instance, a user had sold the equipment on the market, or a user had neglected maintenance of the system looking at experiences in other countires. Accordingly, it is preferred for sustainability that users share a certain burden of the initial capital to confer a sense of ownership and encourage them to carry out the operation and maintenance by themselves.

It is necessary to decide the ratio of the subsidy and thereby determine the size of the consumer's share of the burden. This will need to be done via a feasibility study In the study, the consumer's willingness to pay and ability to pay needs to be determined. In addition, the village remoteness, time of introduction, costs of installation, operation and maintenance, and the overall off-grid electrification budget need to be studied in the feasibility study. For example, if the household's share of the burden is set at 10%, with a target of 2,000 households being provided with off-grid electrification in 10th FYP, the government expense for the installation cost will be approximately US$900,000[3] and the operation and maintenance cost would be about US$86,000/year[4]. This operation and maintenance cost will need to be covered by the government every year.

(3) Policy on Institutional Organization of Off-grid Electrification

The following policies are proposed to prepare the institutional organization for the implementation, operation, and maintenance of off-grid electrification with solar home systems:

- To introduce a subsidy. At the same time, to enhance the user's sense of ownership. It requires the users to share some of the cost burden for installation, operation and maintenance.
- To increase efficiency, equipment procurement is proposed to be done by bulk purchase by the government, and the equipment is rented to users. The user's share of the cost burden is collected as part of the installation expense.
- Installation, operation and maintenance are to be carried out by the private sector. Efficiency will be increased by the establishing a private/public partnership.

(4) Stakeholders and Their Roles in the Proposed Off-grid Electrification System

The stakeholders in the off-grid electrification program will include the Renewable Energy Division (DOE-RED), private sector (RESCO, a rural electrification service company), users, the Rural Electrification Centers, development and finance organizations, local government, and so forth. The roles for each stakeholder are summarized in **Table-19.4.2** below.

[3] 2,000 households x US$500/household x 0.9 = US$900,000
[4] Annual cost of a charge controller: 258 Nu., annual cost for a battery: 1,176 Nu. Annual operation and maintenance cost (labor + transportation cost) 500 Nu., TOTAL: 1,934 Nu. 1,934 Nu. x 2,000 / 45 $/Nu. = US$85,955

Table-19.4.2 Stakeholders and Their Roles for Off-grid Electrification

Renewable Energy Division (DOE-RED)	■ Preparation of off-grid electrification plans and subsidy program, with a decision of the subsidy ratio. ■ Preparation of technical specifications for off-grid electrification systems and quality assurance. ■ Bulk purchase of solar equipment; Registration and management of the equipment. ■ Coordination of donors and implementation of projects. ■ Introduction of biomass and new schemes such as CDM and their implementation. ■ Preparation of a village organization manual and regulations for community-based mini/micro hydro ■ Preparation of terms of reference (TOR) and contracts for installation, operation and maintenance of solar equipment by private sector contactors (RESCO). ■ Preparation of monitoring plans, collection of monitoring reports and feed back to electrification plans ■ Preparation of institutions for the promotion of private sector, registration, issuing of licenses, information management of private sector, and preparation of penalty systems. ■ Operation of a subsidy program and payment to RESCO, according to the contract. ■ Management of capacity-building for villagers and the private sectors ■ Setting up and operation of an Off-grid Electrification Fund (OFF-REF).
Ministry of Finance (MOF)	■ Allocation of the national budget. ■ Coordination with donors, donor relations for grant aid. ■ Supervising the Off-grid Electrification Fund.
Development Finance Organization	■ Preparation and implementation of soft loans (micro finance) for burden share of villagers. ■ Support of local private sector. ■ Support of village organization and group for community based mini/micro hydropower generators.
RESCO (Private Sector)	■ Installation, operation and maintenance of solar equipment. ■ Guidance to village users for operation and maintenance of solar equipment. ■ Off-grid system information propagation and advertisement at the village level.
Rural Electrification Center (REC)	■ Provision of off-grid electrification and subsidy system information to villagers and the private sector. ■ Preparation of off-grid electrification plans and collection of results at Dzongkhag and Gewog levels, and report to DOE-RED. ■ Capacity building of villagers for mini/small hydropower generators ■ Implementation of monitoring and reporting to DOE-RED. ■ Sharing information with local government (Dzongkhags and Gewogs) and reporting to RED. ■ Coordination of off-grid electrification and development plans for local government, and reporting to DOE-RED.
Villagers	■ Introduction of equipment, operation and maintenance.

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■ Renewable Energy Division

Since license may be waived for electricity generation below 500 kW, the Rural Electrification Division (DOE-RED) will be the executive body and decision maker for off-grid electrification in Bhutan. DOE-RED already promotes and has experiences with solar project and mini/micro hydropower planning, both in association with donors and independently. In particular, DOE-RED will have roles of planning, propagation, preparation and management of the off-grid subsidy program, decision of technical specifications, quality assurance, bulk purchase of solar equipment, contracting of installation, operation and maintenance to RESCO, preparation of monitoring plans, management of capacity building for community organizations for mini/micro hydro, acceptance of donors, and introduction of new field such as CDM and biomass. The proposed organization structure and the roles are shown in **Figure-19.4.3** below:

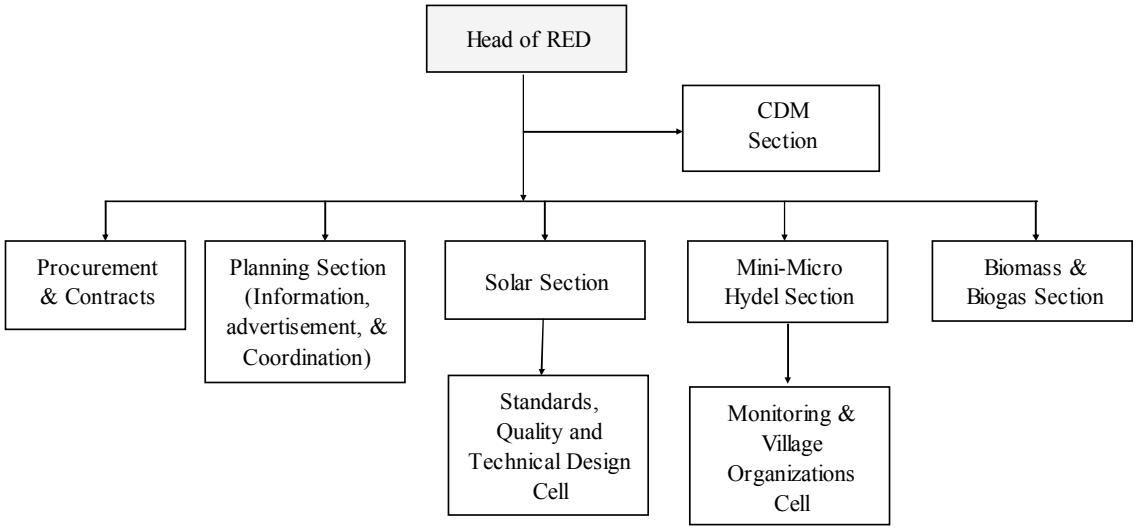

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Figure-19.4.3 Proposed Institution of Renewable Energy Division

■ Private Sectors (RESCO)

The Rural Electrification Service Company (RESCO) in the private sector will take on the roles of installation,and operation and maintenance work for off-grid electrification, i.e. the main role of off-grid solar implementation. The specific roles for RESCO in the off-grid electrification are as follows:

a) For electricity generation below 500 kW, DOE-RED will issue licenses to RESCO.

b) DOE-RED will select RESCO by local competitive bid.

c) Based on a contract for installation,and operation and maintenance, RESCO will install the equipment, carry out the replacement and recovery of batteries, supply consumables, and do promotion for systems.

d) RESCO will be required to report user information and the registration of users.

e) DOE-RED will include conditions in the contract about the replacement of equipment, such as batteries, at appropriate times, which will secure the sustainability of the solar systems.

RESCO will transport the solar equipment to off-grid households and install the equipment that has been bulk purchased by DOE-RED. At that time, RESCO will collect the payment (cost burden) from the user as the installation cost, and RESCO will receive a certificate of installation from the users. When the cost burden paid by the user is not enough to meet the actual installation cost, RESCO will invoice DOE-RED for the difference in cost, as specified on the certificate of installation. This corresponds to a subsidy. DOE-RED and RESCO will determine the amount of this subsidy value at the time of bidding.

To promote participation of the private sector, a system needs to be established to give RESCO preferential treatment on tax and loans. If RESCO breaks the contract, or

operation and maintenance work is inadequate, the regulation should be formulated to impose a penalty on RESCO, such as a fine and disqualification of their license.

- Rural Electrification Center

It is proposed to establish Rural Electrification Centers (RECs) for operation and maintenance, monitoring, and capacity building under DOE and BPC. (A detailed description of RECs is provided later in Chapter 20, Section 20.3). RECs will be located in Thimphu, Wangduephodrang, and Bumthang. RECs will also exchange information with local government, such as Dzonghags, Gewogs and Dzongkhag branches of BDFC, provide coordination between rural development programs of other sectors, and report to DOE-RED.

As for monitoring, RECs will carry out periodical monitoring according to the monitoring plan prepared by DOE-RED, summarize the results, and send a regular report to DOE-RED.

- Development and Finance Organization

Bhutan Development Finance Cooperation (BDFC) is the only rural development finance organization in Bhutan. It mainly covers the development financing of the agricultural and industrial sectors in rural areas. With the support of ADB, BDFC was funded through the participation of RGoB, Bank of Bhutan, RICB(Royal Insurance Cooperation of Bhutan), and RMA (Royal Monetary Authority) in 1988. It has three regional offices in charge of the western, central, and eastern areas respectively, and branch offices in every Dzongkhag.

BDFC started up the Group Guarantee Lending and Saving Scheme (GGLS) as a micro finance scheme in 2002. The main sector for BDFC loans is agriculture, but there is no special limitation on sectors. For example, it is possible to apply the micro finance for private allocation when households in a group jointly purchase solar power generation equipment.

BDFC has already introduced mobile banking and it has a system to reach villagers directly, which is considered to be a strong point relevant to rural electrification too. Mobile banking is a system that service officers directly visit remote villages and carry out the loan settlement and collection of repayments. It is already performed in 120 Gewogs. With micro financing, BDFC is expected to participate in the information spread to villagers, monitoring, and support of operation and maintenance for off-grid electrification, in addition to money collection. .

- Villages and Village Electrification Committees

As for solar systems, each household will have the responsibility of management, operation and maintenance of the system in the off-grid electrification. At the time of installation, they will recieve training (capacity building) from RESCO so that they can manage the equipment properly and replace a battery and other equipment by informing RESCO at the appropriate time. Therefore, village organization is not taken into account for off-grid solar systems.

On the other hand, for electrification systems with an installed capacity more than 10 kW that supply electricity to over 10 households, e.g. by mini/micro-hydro mini-grid systems, it is proposed to form a Village Electrification Committee (VEC). The VEC will take

responsibility for construction work by villagers' participation, and for operation and maintenance of the system under the guidance of engineers from BPC or DOE. The merits of setting up VECs are as follows:

- Required skills for operation and maintenance of facilities and electrical equipment can be transferred to villagers in the process of their participation in the construction.
- It is possible to reduce construction cost.
- It enhances the villager's sense of ownership and participation in the project.

The roles for VECs are proposed as follows:

- Securing VEC membership, doing accounting, tariff collection, payment of salary to VEC members, management of repayments for micro finance or loans.
- Basic design of mini-grid systems, securing of land required for power facilities, preparation of construction materials such as gravel, sand, and bricks, and management of villager participation in the construction work.
- Carrying out the power system operation and maintenance, and demand side management.

The conditions will be different for each village, depending on the region and generation plant scale. The detailed organization need to be discussed individually for each project.

(5) Frameworks for the Implementation of Off-grid Electrification

The framework of funding, procurement of equipment, and implementation of off-grid electrification are proposed in **Figure-19.4.4** and **Figure-19.4.5** below.

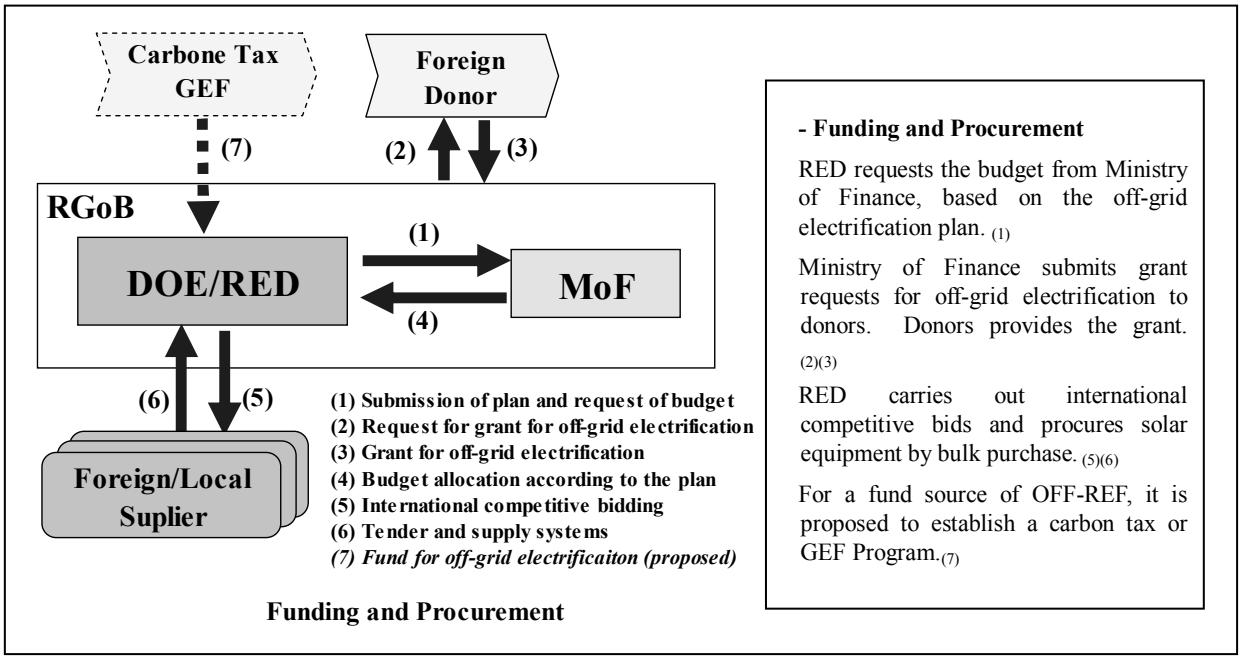

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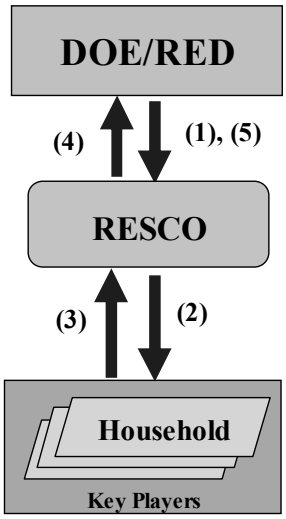
Figure-19.4.4 Framework of Funding and Equipment Procurement for Off-grid Electrification



(1) Local competitive bidding, contructing installation service
(2) Transportation and instalation
(3) Partial payment of for a service and issue a receipt
(4) Reporting of installation and request of remaining payment according to the receipt of (3)
(5) Confirmation of installation and payment for the service

Flow of Implementation

- **Implementation**

RED selects RESCO by a local competitive bid. (1)

RESCO transports and installs the equipment in village households under the contract with RED (2)

After installation, the user issues installation certificate and pays a part of installation fee to RESCO. (3)

RESCO proves the result of installation to RED and requests the payment of the subsidy component.(4)

RED will pay the subsidy part to RESCO based on the certificate (5)

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Figure-19.4.5 Framework of Implementation for Off-grid Electrification

Meanwhile, DPE-RED prepared "Report on Solar Scheme" in August 2005 and following items are planned:

- Villages prepare Solar Fund for operation and maintenance of SHS and village technicians carry out operation and maintenance;
- Solar systems are fully subsidized for the initial capital investment. Consumers pay an up-front fee of Nu. 5,000 that would be retained as a Solar Fund in the village for the maintenance and purchase of spare parts; and
- 50 Nu. per month is paid to village technicians for running and operation and maintenance of solar systems.

The report suggests that DOE-RED directly carry out solar system installation, and participation of private sector in installation and operation and maintenance is not considered.

Further examination would be needed in a feasibility study to see which is more feasible, participation of private sector in installation, operation, and maintenance of solar system in a business base or direct management by DOE-RED.

19.5 Implementation Schedule

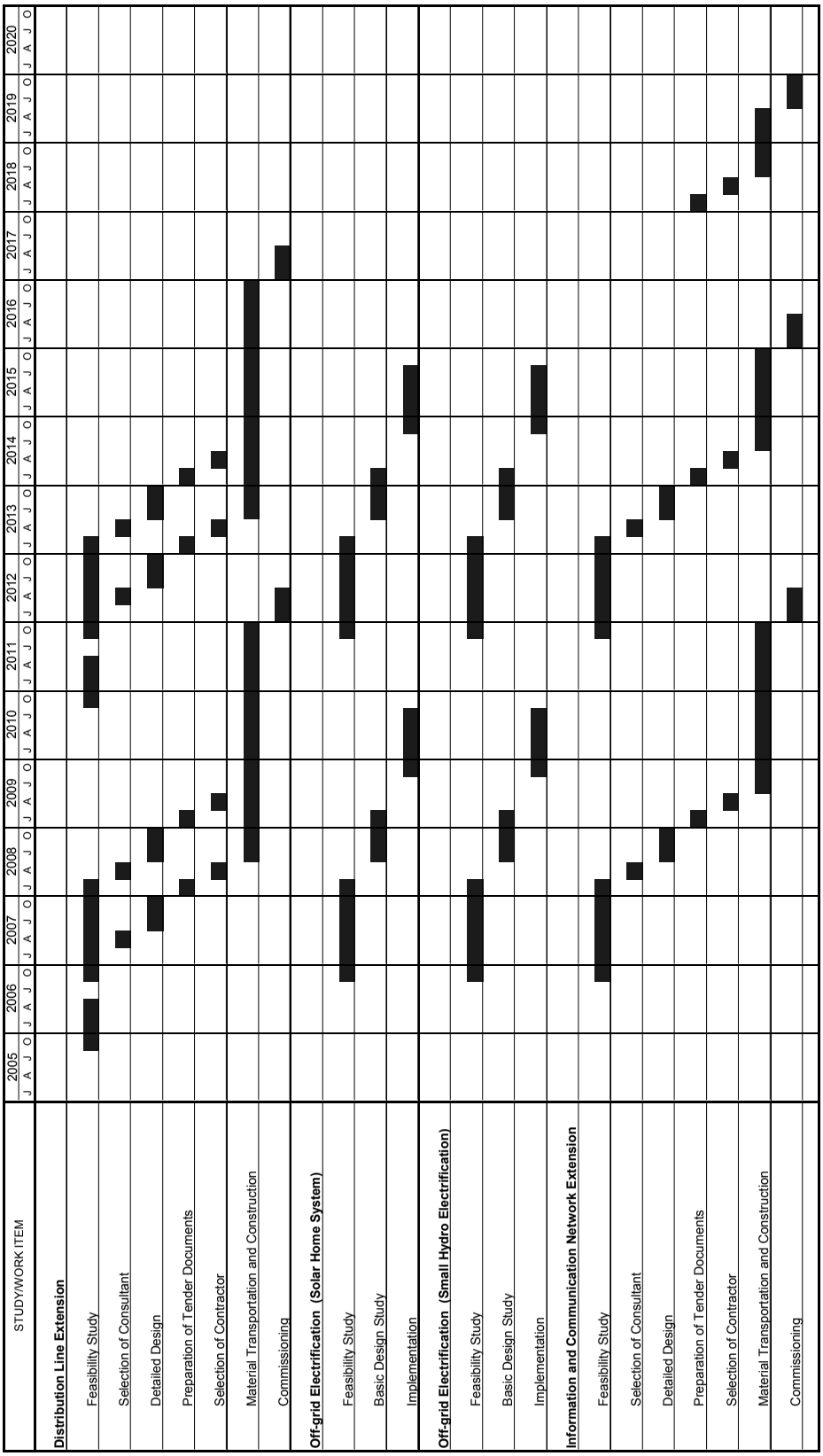
Table-19.5.1 in the next page shows the implementation schedule. The distribution line extension project is scheduled to be implemented in 10th and 11th FYPs. In both phases, the Study Team expects that the project will be implemented by loans from JBIC and ADB. The schedule is, therefore, prepared for both the JBIC package and the ADB package. It is assumed that the JBIC package will be initiated earlier than ADB package, considering the

present progress of the loan arrangement by JBIC; JBIC is going to dispatch their study team (SAPROF team) to Bhutan in November 2005 according to information obtained from JBIC in July 2005.

Regarding the off-grid electrification by solar home systems and small hydro electrification, the schedule is prepared on the assumption that the projects will be implemented under Japan's general grant scheme. These projects will be completed by the end of 11th FYP.

The information and communications network extension project is scheduled to be implemented in the three phases: 10th, 11th and 12th FYPs. Considering discussions held with the officials concerned with the master plan study, and the present progress of funding arrangements (actually none), the maximum length of time is shown, as this is the implementation period which extends until the end of the target year 2020. The implementation schedule will need to be reviewed in detail during the feasibility study.

Table-19.5.1 Implementation Schedule



Prepared by JICA Study Team

19.6 Implementation Plan for 10th Five Year Plan

The master plan will be completes at the end of October, 2005. The implementation period of the master plan is from the middle of July 2007 to the middle of 2020; the first phase of the implementation of the master plan – 10th FYP – starts at the same time and ends in the middle of July, 2012.

This Section describes the practical implementation scenario, specifically until the commencement of the project, in order to secure accomplishment of 10th FYP target of the master plan.

19.6.1 Scenario for Implementation

The on-grid electrification project is the major component of the master plan. **Figure 19.6.1** below shows a sample scenario for on-grid electrification in 10th FYP. This scenario is prepared as sample because as of August 2005, there is no commitment of execution of the studies shown in the figure from JICA, JBIC or ADB. However, the Study Team believes that the scenario is practical and might be realized.

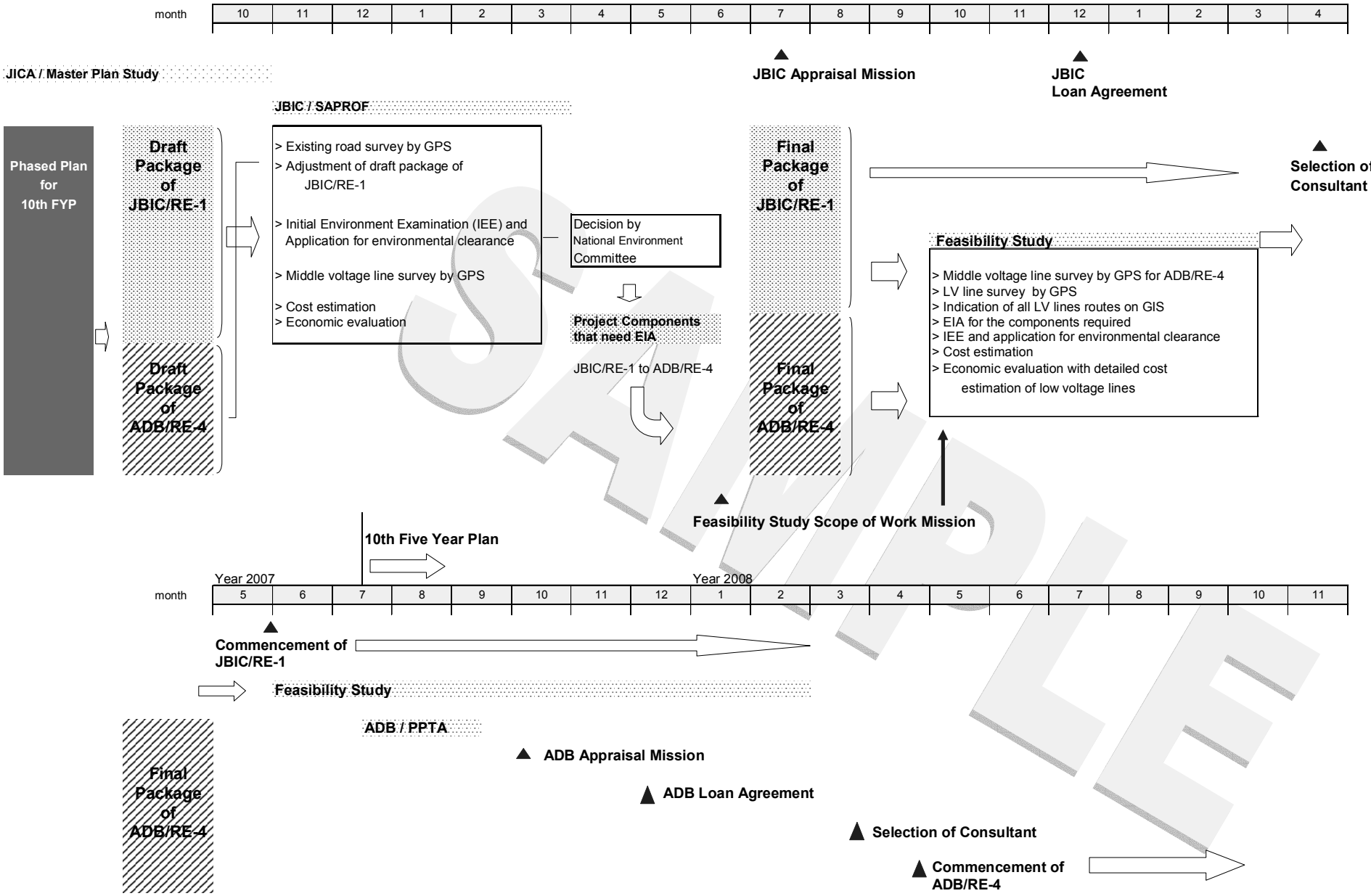
In the master plan study, the on-grid phased plan was divided into two packages, one for a JBIC loan (JBIC/RE-1) and the other for an ADB loan (ADB/RE-4). The demarcation between these two packages is shown in the next Section. It is understood that JBIC intends to conduct a SAPROF study for JBIC/RE-1. The Study Team recommends that the following work be carried out in the SAPROF study:

- Existing road survey by GPS.
- Adjustment of the draft package for JBIC/RE-1.
- Initial Environment Examination (IEE) and application for environmental clearance.
- Medium voltage line survey by GPS.
- Cost estimation.
- Economic evaluation.

JBIC is targeting to sign the loan agreement within the year 2006. The critical factor for keeping to the planned time schedule is the EIA. If an EIA is required for the project, JBIC usually can not sign the loan agreement before the EIA is completed. Hence, if some project components in the JBIC package (JBIC/RE-1), i.e. power line feeders, are judged to need an EIA, these particular feeders should be transferred to the ADB package. This is because ADB will start their procedures for project later than JBIC. Therefore, time will be available for the EIA work to be completed, without disrupting the overall schedule of the master plan.

In addition, the Study Team recommends that the feasibility study be conducted for all the packages prepared in the master plan, as shown earlier in in **Table-19.1.1** above. Regarding the on-grid electrification, the major work required for the feasibility study is the low voltage line survey and the EIA (if required). As for the off-grid small hydropower electrification, the candidate projects selected through the map study in the master plan will be scrutinized,

and some of these projects will be chosen for implementation. Further study is required for the solar electrification and biomass energy supply projects, with the purpose of formulating a tangible implementation plan. The feasibility study for the information and communications network extension will include studies for improvement of distance education, telemedicine and TV broadcasting.



Note: The scenario is prepared as sample by Study Team, there is no any commitment for the studies stated above to be conducted.
Prepared by JICA study Team

Figure-19.6.1 Sample Scenario for On-grid Electrification in 10th Five Year Plan

19.6.2 Demarcation between JBIC and ADB

Demarcation of the on-grid electrification project between JBIC and ADB was proposed on a Dzongkhag basis. First, Dzongkhags in which on-grid electrification will be implemented by a JBIC loan were selected, and the remaining Dzongkhags were allocated for implementation by an ADB loan package.

The Study Team selected the Dzongkhags for the JBIC loan based on the following criteria:

- Exclude the Dzongkhags which had been classified by the Japanese Ministry of Foreign Affairs as areas for security concern;
- Minimize the feeder section lengths crossing environmentally protected areas, including environmental corridors; and
- Make the target number of electrified households over 10,000 on a 2007 basis.

The Japanese government is very sensitive about security problems. As of August 2005, the Japanese Ministry of Foreign Affairs classified six Dzongkhags as areas for security concern: Dagana, Tsirang, Sarpang, Zhemgang, Pemagatshel and Samdrup Jongkhar. The sub-projects of the JBIC package, specifically feeder construction, in these areas might result in delaying commencement of the total project. Regarding Dagana, as the classified area is limited to a small part of the southern region, the planned feeders will not be affected. Therefore, five Dzongkhags, excluding Dagana, were removed when making the JBIC package.

In 10th FYP, there are six Dzongkhags which include feeders that will cross environmentally protected areas and corridors. These Dzongkhags are Wangduephodrang, Trongsa, Trashigang, Bumthang, Punakha and Lhuntse, listed in the order of the longest length of feeder section crossing the environmental areas. To minimize such section lengths, Wangduephodrang, Trongsa and Trashigang were excluded from the JBIC package and transferred to the ADB package. To maintain the target number of households to be electrified, Bumthang, Punakha and Lhuntse were included in the JBIC package. In Gasa and Thimphu, there are no feeders to be constructed in 10th FYP.

As the result of the above, **Table-19.6.1** shows Dzongkhags for JBIC loan package (JBIC/RE-1) with their target household numbers and estimated investment cost.

Table-19.6.1 Dzongkhags for JBIC Loan Package of On-grid Electrification

No.	Dzongkhag	Household Number*	Investment (x 1000: US$)
1	Bumthang	475	1,444
2	Chukha	1,422	2,721
3	Dagana	1,335	4,250
4	Haa	182	519
5	Lhuntse	821	2,134
6	Mongar	1,057	2,657
7	Paro	57	125
8	Punakha	167	485
9	Samtse	3,658	6,080
10	TrashiYangtse	874	2,017
	TOTAL	**10,048**	**22,431**

*: The number of households is forecasted number in the year 2007.

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JBIC/RE-1 covers 10 Dzongkhags, its target household numbers to be electrified is 10,048, and the investment cost is estimated at US$22,431 million. RGoB has requested JBIC to give the loan amounting US$26 for this project of 10th FYP and the remaining portion of 9th FYP of which the target household number is 3,000. From the view point of the balance between the package cost and the requesting loan amount, the project package is considered appropriate.

Similarly, **Table-19.6.2** indicates the Dzongkhags for ADB loan package (ADB/RE-4) with target household numbers and the estimated investment cost.

Table-19.6.2 Dzongkhags for ADB Loan Package of On-grid Electrification

No.	Dzongkhag	Household Number*	Investment (x 1000: US$)
1	Pemagatshel	470	1,074
2	Samdrup Jongkhar	2,203	4,725
3	Sarpang	1,385	2,876
4	Trashigang	1,606	3,594
5	Trongsa	706	2,220
6	Tsirang	2,423	5,226
7	Wangduephodrang	937	2,880
8	Zhemgang	1,336	4,189
	TOTAL	**11,066**	**26,783**

*: The number of households is forecasted number in the year 2007.

Prepared by JICA Study Team

ADB/RE-4 covers 8 Dzongkhags, its target household numbers to be electrified is 11,066, and the investment cost is estimated at US$26,783 million.

The selection above is a proposal at the master plan stage and will be finalized in the feasibility study.

CHAPTER 20 OPERATION AND MAINTENANCE PLAN

20.1 On-grid Institutional Plans for Operation and Maintenance

20.1.1 Institutional Arrangements for On-grid Power Distribution

In order to attain the goal of achieving 100% rural electrification by the year 2020, improvement of the management efficiency of rural power distribution in Bhutan is necessary. To achieve it, separation of assets and management is proposed. This will create a transparent accounting system and increase the efficiency of construction and operation of rural power distribution. The proposal includes establishment of a new holding company, tentatively called "Bhutan Rural Power Supply Holding Company" that will own and manage the assets related to rural power distribution. BPC will continue to offer its expertise in construction, operation and maintenance by providing management services to the holding company. At the village level, where possible, it is proposed that village power distribution companies will be set up and run by villagers, who will operate and maintain the low voltage (LV) lines and also the household interior wiring.

20.1.2 Need for Institutional Reform

It is widely recognized in Bhutan that rural power supply is closely related to poverty reduction. The majority of the poor are concentrated in rural areas. However, rural power supply is not financially feasible. Currently, BPC owns and manages all facilities related to rural power distribution, in addition to the entire transmission line system of Bhutan. BPC cross-subsidizes rural electricity consumers by the profits made from wheeling charges on the sales of power to India. In the fiscal year 2003-04, BPC recorded a loss of 68 million Nu. However, it is not known how much of the loss is attributable to the operation and maintenance of rural power distribution, since power tariffs in general are under-priced and less than the cost of delivery across the board. In the Study Teams estimate of rural power distribution operations alone, BPC would recover roughly 35 million Nu. per year and spend about 60 million Nu. on operation and maintenance, thereby incurring a deficit of 25 million Nu. per year. The cost for rural power distribution operation does not include the cost of power generation or transmission, let alone the opportunity cost of power sales to India. If the cost for generation and transmission is added, the deficit would increase to 50 million Nu. per year[1]. Given the level of rural electrification and future expansion, which adds around 2,400 km of MV lines, the operation and maintenance cost alone will increase by around 100 million Nu. per year, without considering asset depreciation. In any case, BPC would face an increased burden to shoulder the future expansion.

There is a general consensus that the government will need to subsidize rural electrification and distribution. There is a concern that excess subsidization will provide little incentive to

[1] The costs are estimated on the numbers of rural consumers and total consumers, length of LV lines and estimated marginal cost of operation and maintenance of BPC.

improve efficiency, while an inadequate subsidy could lead to poor maintenance and poor quality of service, and at worst, reduce or withdrawal of the investment. Therefore, accurate accounting information is necessary to determine the level of subsidy or tariff levels.

Another problem associated with operational costs of rural power distribution in the future is the expanse of coverage in remote areas. Already in ESD, the cost of meter reading and bill collection exceeds the collected revenue. This type of situation will become more prominent in the future when rural electrification is expanded.

20.1.3 Methodology for Separation of Accounts

Separation of accounts can be achieved in several ways. There are three possibilities:

- Option 1: Strict cost accounting to segregate rural power distribution;
- Option 2: Establishment of a dedicated division within BPC for rural power distribution; and,
- Option 3: Separation of entities.

As the option list is descended from 1 to 3, the level of separation increases. Strict cost accounting requires discipline within BPC to adhere to a certain set of rules for billing and payment procedures. A dedicated division could be held more easily accountable for specialized tasks. However, separation of staffing could lead to inefficiency due to overlapping functions between personnel. The third option of separation of entities will attain the highest transparency in accounting, but could lead to redundancy if a full-fledged organization dealing solely with rural power distribution. Hence, the Study Team's proposal is to realize the merits of both transparency and efficiency, as discussed below.

20.1.4 Decentralized Power Distribution System

One way to reduce the cost of meter reading and bill collection is to allocate this function to the village level. Here, "village level" means a cluster of villages in one locality that provides economic efficiency in operation. There is no doubt that the cost of administration will be reduced. However, the system should be structured in such a way that the local management is fully aware of the risks and consequences of poor accounting and lack of technical skill enhancement. One way of doing this is to transfer the entire responsibility to a village entity. However, if some disaster happens, it is questionable if a small village level entity could withstand the consequences.

Application of prepaid meter, as described later in Chapter 20.2, is one possible measure.

20.1.5 Proposed Institution

The proposed institution is to establish an independent entity for rural electrification and operation. The functions of this entity will just focus on financial transactions, to realize the separation of accounts. In other words it is a mixture of Option 1 and 3, since the proposed entity does not have in-field staff or operation and maintenance functions, but rather deals solely with financial transactions with the external agencies and organizations. The proposed entity is tentatively named the "Rural Power Distribution Holding Company."

In addition, at the field operation level, the establishment of "Village Power Distribution Company" (VPDC) is proposed. This will increase the efficiency in billing and meter reading, payment collection, and maintenance.

1) Rural Power Distribution Holding Company

The recommendation is to establish a small-size holding company that owns all the facilities related to rural power distribution, but only deals with financial aspects of the business. A holding company, staffed by capable financial experts, can manage the asset and instill management efficiency for the construction and operation of the rural power distribution network.

2) BPC

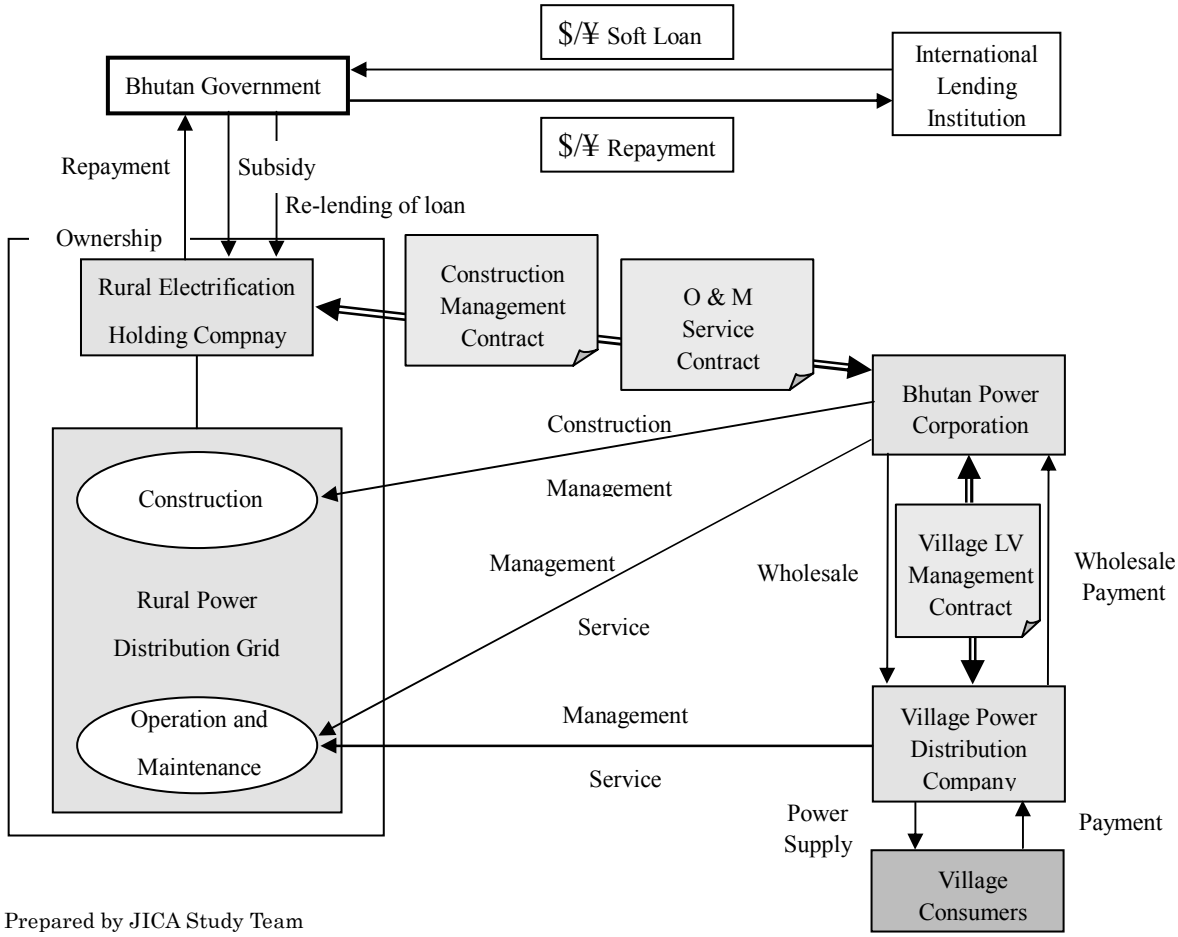
BPC will become a service provider in the suggested model. BPC will provide construction management services at the initial period of erecting poles and installing lines. BPC might have to bear the risks of procurement and contractor selection at this stage. After the construction of grid feeders, BPC will undertake operation and maintenance services of medium voltage (MV) lines and low voltage (LV) lines where the VPDC cannot provide the service.

3) Village Power Distribution Companies

Village Power Distribution Companies (VPDCs) will assume the responsibility of LV lines after the MV/LV transformers. The VPDCs' responsibility includes meter reading, billing, LV line maintenance and maintenance of internal wiring in houses. The technical capacity of the operators needs to be improved with the assistance of BPC and DOE, to cope with the increased responsibilities. To provide a cushion for some unexpected events and consequent need for spare parts to replace major components, an insurance system for repair and maintenance that is pooled and managed by BPC or the holding company is envisaged. One incident could result in a large expenditure being incurred for replacement parts. If this happens when the savings of a local entity are not adequate, the result would be total abandonment of the local grid system. However, a state-wise pooled fund could absorb such localized incident risks.

20.1.6 Financial Projections for Decentralized System

The financial implications of adopting a decentralized system have been estimated, as shown in **Table-20.1.1** and **Table-20.1.2** below. The number of households connected to the grid is expected to grow by threefold from the current consumer base to 74,585 by 2020. The deficit in rural power distribution is expected to increase from the current deficit of 50 million Nu. to 128 million Nu. The cost of maintenance and operation under BPC is estimated to be 226 million Nu. By transferring the local management responsibilities to villages, the reduction in costs is expected to be 53 million Nu. As shown previously in **Table 20.1.1** below, the budgets are balanced both for BPC and VPDC's.



Prepared by JICA Study Team

Figure-20.1.1 On-grid Institutional Setup

Table-20.1.1 Rural Power Distribution Financial Projection Assumptions

Item	Unit	Year 2004	Year 2020	Year 2020 After Reform
Number of Households	Number	24,833	74,585	74,585
Annual Energy Demand	GWh	42,911	128,883	128,883
Tariff	Nu./kWh	0.8	0.8	1.4
Wholesale Price	Nu./kWh			0.6
LV distance	km	3,106	8,081	8,081
LV investment	Million Nu.	373	970	970
Annual Replacement Cost	Million Nu.	11	29	29

Prepared by JICA Study Team

Table-20.1.2 Estimated Profit and Losses for BPC and Village Power Distribution Companies

Unit: million Nu.

BPC	Year 2004	Year 2020	Year 2020 After Reform
Revenue	34	103	77
Annual LV Maintenance Cost	59	154	0
Generation and Transmission Cost	26	77	77
Profit/Loss	-50	-128	0

Unit: million Nu.

VPDC	Year 2020
Revenue	180
Wages	72
Payment to BPC	77
Material Cost	29
Profit	2

Prepared by JICA Study Team

20.2 Options for On-grid Operation and Maintenance

In case of on-grid rural electrification, BPC manages the operation and maintenance of distribution facilities and tariff collection, though a part of that work may be transferred to VPDCs. As villages and households are scattered over Bhutan, it is very important that these jobs are implemented efficiently from the viewpoint of an effective operation.

1) Operation and Maintenance of Facilities

The operation and maintenance of facilities refers to tasks such as periodic patrols and inspections and, in the event of problems are identified, repair work. The maintenance and inspection will be implemented in accordance with BPC's guideline 'Maintenance Schedule for Distribution System' described earlier in Chapter 10 (Technical Standards for Power Facilities). Basically, the work is carried out by technicians from each Customer Service Division in BPC. It is essential that BPC secures an adequate number of technicians to meet the increased demand as facilities are expanded through rural electrification projects. In addition, BPC needs to provide sufficient training in the area of patrols and inspections. It is important to consider delegating the responsibility for operation and maintenance work to individual villages such as VPDC from the viewpoint of cost reduction if the villages are located far from BPC's Customer Service Division.

2) Tariff Collection

With regard to tariff collection, there are key tasks to be performed, such as meter reading and money collection. In terms of rural electrification, in which villages and households are dispersed, reducing the cost of tariff collection becomes a very important consideration.

At present, BPC dispatches meter readers every month to check the meters of customers and to distribute their bills. The customer must pay in cash at their respective service office. Countermeasures for reducing BPC's meter reading costs and travel costs for tariff payment by customers must be developed in rural electrification.

In order to reduce the tariff collection cost for BPC and payment costs for customers, the following five (5) countermeasures should be considered in addition/combination with VPDC concept:

(1) The adoption of prepaid meters

Meter reading and money collection can be avoided by installing prepaid meters. Though there would be a travel cost involved in purchasing a prepaid recharge card, instead of the customer traveling to their respective Electricity Service Division, they may be able to save time if prepaid recharge cards are available for purchase at several types of shops. A kWh tariff system, in which the tariff is calculated in proportion to the consumption of power only, should be introduced for the prepaid system. The most critical aspect is the high initial cost of meters designed for the pripaid system.

(2) The adoption of the fixed monthly charge system

The adoption of a fixed monthly charge system would abolish need for meter reading. On the other hand, the system is likely to lead to some energy wastage because of a lack of an incentive for saving energy. This system would be suitable, only for loads such as streetlights, where energy consumption is almost constant.

(3) Expansion of the meter reading period

The meter reading cost can be reduced by extending the interval of the period to quarterly or half-yearly. In this system, the money collection in the month when meter reading is not undertaken will be carried out by performing bill estimation. Though this system is effective when the bill is drawn automatically from a customer's bank account or when a customer pays the bill at a bank, generally, it is not so effective when money collection is carried out at the same time as the meter reading. In addition, when the avility to pay of the user is low, it would be needed to consider about group payment.

(4) Simultaneous implementation of meter reading and money collection

By implementing the meter reading and money collection tasks at the same time, the travel costs can be reduced. However, the conditions of this system requires the condition that the customer is at home and has the cash to pay the bill at the time of meter reading.

(5) Implementation by the community

This countermeasure involves the BPC delegates the tasks of meter reading and money

collection to the community, for an effective and sharp drop in the tariff collection cost. Still, in this system, BPC must periodically perform a check measurement of all meters itself.

It is important to combine the above countermeasures into a feasible system that will suit each village.

20.3 Off-grid Institutional Plans for Operation and Maintenance

20.3.1 Outline of Off-grid Solar Home System Operation and Maintenance

It would be difficult to form a community organization for operation and maintenance of the off-grid electrified households that are based on solar home systems in Bhutan. The endemic topographic conditions and culture in Bhutan would be a barrier for this, as described earlier in Chapter 19, Section 19.4. Consequently, it is realistic to outlet private sectors to carry out the operation and maintenance work. Meanwhile, each household would manage the system with the sense of ownership.

(1) Battery

As for SHS (Solar Home System), the most important thing is the replacement and recovery of expired batteries. The average lifetime of a battery is about four (4) years. When expired batteries are discarded in the environment, there is a possibility of causing soil contamination because of the lead and sulfuric acid contained in the batteries. Additionally, the battery lifetime can be shortened by inappropriate usage, such as over discharge. At the time of installation, it is necessary for the private sector, i.e. a rural electrification service company (RESCO), to provide guidance and capacity building to users for appropriate operation of the system.

It is essential to confirm the above two points, i.e. appropriate replacement and recovery of batteries and provision of guidance to users, to maintain the sustainability of off-grid electrification. The contract between RED (Renewable Energy Division) and the RESCO for installing solar equipment should include these two points as duties of the RESCO.

(2) Monitoring

Monitoring is necessary in order to increase sustainability and make the overall off-grid planning more realistic. However, the implementation of monitoring would be a large burden to the government in Bhutan, in which off-grid households are widely dispersed in remote areas. Accordingly, it is proposed that Rural Electrification Centers (RE Center), be formed in three Dzongkhags to take on the role for monitoring, as described in later Section 20.4, and that RED be the main body responsible for administration of operation, maintenance and monitoring.

The RE Centers will regularly dispatch monitoring teams to rural households that use

solar home systems. The users would be selected at random under a monitoring plan formulated by RED. In addition to a regular report, RE Centers will inform RED when accidental problems are found. RED will issue an order to the RESCO contractor to solve the problem. As the RESCO will have the contract for ensuring that the solar home systems are keep in appropreate condition, RED may impose a penalty on the contractor, such as a fine or a disqualification, if inspections by the RE Centers and RED reveal that some systems are not being maintained correctly.

It is necessary to establish specific regulations for administering the operation, maintenance and monitoring of off-grid solar home systems.

20.3.2 Cost and subsidy for Operation and Maintenance of Off-grid Electrification

Subsidies will be needed for not only for installation cost but also operation and maintenance expenses.

- Needs of subsidy

The average annual economic cost per a household will be 3,100 Nu. (see Chapter 13.9) when considering the expenses of renewal of PV panel, replacement of batteries and charge controllers, and labor cost. This seems to be much more than the ability to pay of each household. Furthermore, the energy cost for operation and maintenance will be US$0.49/kWh[2] even without considering the renewal cost of PV panel. It is not realistic to collect this amount by a tariff. Consequently, it would be essential to apply the subsidy to both initial capital and also operation and maintenance.

With 2,000 households of the target off-grid electrification in 10th FYP, the cost of operation and maintenance is roughly estimated to be US$86,000[3] annually[4].

Table-20.2.1 is an estimation of the operation and maintenance cost per a household.

Table-20.3.1 Estimation of Operation and Maintenance Cost per a Household

Item	Unit cost Nu.	nos	Cost Nu.
PV panel	7,866	1	7,866
Battery	4,000	1	4,000
Charge controller	1,438	1	1,438
O&M	500	L.S.	500
Battery replacement cost (every 4 years)			4,500
Battery + Chage controller replacement cost (every 8 years)			5,938
PV panel replacement (every 25 years)			13,804

Prepared by JICA Study Team

When applying subsidy, it is necessary to determine the ratio of subsidy. Users have to have a share burden as well as capital subsidy. Assuming if a share burden of a user is set to be 20%, user will pay 900 Nu. every four years for battery replacement, and will pay

[2] Charge controller: 258 Nu. Annual cost of battery: 1,176 Nu. Annual cost of operation and maintenance (labor＋transportation) 500 Nu. Total: 1,934 Nu. When monthly power generation of PV is 7.3 kWh, 1,934Nu./12 month/45 $US/Nu./7.3 kWh = US$0.49

[3] Total annual expense: 1,934Nu. x 2,000 households/45 $US/Nu. = US$85,956.

[4] When the equipment is to be installed in all the households in one village at one time, regular replacement will also be implemented in all households in a village at the same time. This will reduce the transportation and labor cost.

2,760 Nu. every 25 years for PV panel replacement. The remaining 80% is correspondent to be a subsidy. It is recommended to determine this percentage in the feasibility study as well as the determination of subsidy rate of capital investment.

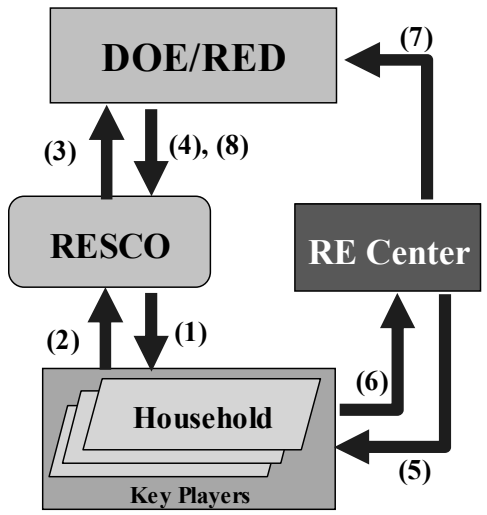
- Operation of subsidy

As for the way of payment of subsidy, the following method is proposed: the RESCO carries out operation and maintenance according to requests from users and RED. When the RESCO completes operation and maintenance, it receives payment which corresponds to a share of the user. The user issues an operation and maintenance completion certificate. The RESCO requests payment to RED for deficiency amount in operation and maintenance with the certificate. RED pays for the amount to the RESCO, which will become a subsidy.

The expense for operation and maintenance has to be covered every year, as long as off-grid electrification by a solar home system is continued. Even if the absolute amount per a year is small, finally the government burden becomes large considering the expense occurs every year. Thus, it is recommended to secure the funding by the establishment of OFF-REF, as presented in earlier in Chapter 19, Section 19.4 above.

20.3.3 Framework of Off-Grid SHS Operation and Maintenance System

The institutional framework for the off-grid SHS operation and maintenance system is shown in **Figure-20.3.1** below.



Flow of O&M and Monitoring

(1) Regular maintenance & repair needed by an accident
(2) Request for repair in case of accident, partial payment for maintenance and repair, issue of O&M certificate
(3) Reporting of O&M and request of remaining payment according to the certificate of (2)
(4) Payment according to the report
(5) Monitoring
(6) Reporting about performance of equipment and RESCO
(7) Reporting about result and problem
(8) Request of O&M

O&M and Monitoring

The RESCO carries out regular maintenance for users and replacement of equipment damaged by accident. According to operation and maintenance completion, users pay their share of the cost to the RESCO and the user issues an Operation and Maintenance Completion Certificate.(1), (2)

The RESCO requests payment from RED for the difference between the certificate amount and the actual cost. RED pays the RESCO according to this request.(3), (4)

The RE Center regularly monitors households selected at random, according to the RED monitoring plan, and reports to RED. RED orders the RESCO to do remedial work when problems are found in their contracted work.(5)~(8)

Prepared by JICA Study Team

Figure-20.3.1 Framework of O&M and Monitoring of Off-grid Electrification

Further examination would be needed to see if private sectors can economically work out to participate in operation and maintenance works. The plan of "Report on Solar Scheme" prepared by DOE-RED is described in Section 19.4 for operation and maintenance of villages and payment from villagers for it.

20.4 Framework for Human Resources Development in the Rural Electrification Master Plan

This section describes the framework proposed for human resources development associated with rural electrification. This framework is suggested as a part of the rural electrification master plan prepared under the master plan. It is needs to conduct further study to examine feasibility considering cost for human resources and other expenses.

The framework is made up of the following two components:

- Establishment of Rural Electrification Center (REC) as a training and maintenance facility
- Training for managers and for operation and maintenance Staff.

The framework of each of the above components is explained in detail in the subsequent sections.

20.4.1 Framework for Establishment of Training and Maintenance Centers

The framework for establishing Rural Electrification Centers by DOE and BPC is summarized in **Table-20.4.1** below.

Table-20.4.1 Framework for RECenters

Components	Contents of Component
Parent Organizations	The Center belongs to and is shared by the following two organizations: - **Department of Energy (DOE**), Ministry of Trade and Industry (MOTI), and - **Bhutan Power Corporation (BPC)**.
Key Functions	The Center functions as a: - **Regional training center** of DOE/BPC to provide practical training for (a) operation and maintenance of rural electrification and (b) meter reading, tariff collection and distribution line observation including foe VPDC, and (c) operation and maintenance of community based mini/micro hydro - **Regional maintenance center** of DOE/BPC to supervise and monitor operation and maintenance of rural electrification.
Target Trainees and Training Subjects	The Center targets the following staff: - **BPC Branch staff** for training in (a) distribution operation and maintenance, (b) electricity measuring and testing, (c) electrrol-mechanics, (d) community based mini/micro hydropower system operation and maintenance. - **Consigned local staff** for training in (a) meter reading, (b) tariff collection and (c) distribution line observation, including for VPDC.
Staff of the Center	The training staff of the Center assigned by DOE/BPC are: - **Training and Maintenance Manager** (1 staff for each center) serving as the head of the Center, - **Training and Maintenance Officers** (5 staff for each center) in charge of (a) preparation of training plans, (b) conducting training and (c) supervision and monitoring of operation and maintenance work of BPC branch offices, (d) monitoring off-grid solar home systems, - **Administrative Officer** (1 staff for each center), and - **Accounting Officer** (1 staff for each center).
Location and Territory (Dzongkhag) of the Center	The name, location and territory (Dzongkhags) of the Centers are: - **Central Training and Maintenance Center** located in Thimphu serves as the national headquarters, as well as one of the regional training and maintenance centers, and covers 5 Dzongkhags (Thimphu, Paro, Haa, Chukha and Samtse), - **Wangduephodrang Regional Training and Maintenance Center** covering 8 Dzongkhags (Wangduephodrang, Punakha, Gasa, Dagana, Tsirang, Trongsa Sarpang and Zhemgang), and - **Mongar Regional Training and Maintenance Center** covering 7 Dzongkhags (Mongar, Bumthang, Lhuntse, Yangtse, Trashigang, Pemagatshel and Samdrup Jongkhar).
Requirements of the Center	The Center shall include accommodation facilities for trainees and be located in or around the BPC branch offices where the Center is established.

Prepared by JICA Study Team

20.4.2 Framework for Training of Managers and for Operation and Maintenance Staff

(1) Training for Management Staff

The training framework for developing and upgrading the capacity of management staff of DOE and BPC Central Office is summarized in **Table-20.4.2** below.

Table-20.4.2 Framework for Training of Management Staff

Components	Contents of Component
Key Objectives	To develop and upgrade professional competencies of senior and junior staff of DOE and BPC Central Office in topics related to **(a) planning, (b) operation and maintenance, and (c) project implementation of rural electrification.**
Types of Training Methods	Training methods provided for training of management staff are: - **Long-term training**, which provides postgraduate studies abroad at the master degree level, - **Medium-term training**, which provides postgraduate studies abroad at the diploma level, and - **Short-term training**, which includes short courses and seminars provided in the country, the region and elsewhere abroad.
Target Trainees and Training Methods	The target trainees and training methods are: - **Executive and Assistant Engineers/Managers** of DOE and BPC Central Office, who are eligible for (a) long-term training and (b) short-term training, and - **Junior Engineers/Managers** of DOE and BPC Central Office, who are eligible for (a) medium-term training and (b) short-term training.
Requirements of Management Staff Training	Prior to implementing the training, the following procedures shall be carried out by DOE and BPC in order to identify specific training needs, plan for the identified training, and prepare for its implementation: - Assessment of training needs, - Preparation of training plans, and - Identification of training institutes.

Prepared by JICA Study Team

(2) Training for Operation and Maintenance Staff

The training framework for providing basic skills and knowledge to operation and maintenance staff of BPC branch offices and consigned local staff is summarized in **Table-20.4.3** below. It should be noted that the target trainees and training subjects for operation and maintenance staff from BPC branch office and consigned local staff have already been explained in **Table-20.4.1** above

Table-20.4.3 Framework for Training of Operation and Maintenance Staff

Components	Contents of Component
Key Objective	To provide basic skills and knowledge necessary for operation and maintenance of rural electrification for BPC Branch staff and consigned local staff, as well as community based mini/micro hydropower systems.
Types of Training Methods	Training methods provided for operation and maintenance staff are: - **Course work**, which provides postgraduate graduate studies abroad at the masters degree level, - **On-the-job-training (OJT)**, which provides postgraduate studies abroad at the diploma level, and - **Follow-up training**, which includes short courses and seminars provided in the country, the region and elsewhere abroad.
Target Trainees and Training Methods	The target trainees and training methods that will be provided are: - **BPC Branch Staff**, who are provided with (a) course work, (b) on-the-job training and follow-up training, and - **Consigned Local Staff**, who are provided with only course work including VPDC according to necessity.

Prepared by JICA Study Team

20.4.3 Implementation Schedule of Human Resources Development for the Rural Electrification Master Plan

(1) Implementation Schedule

The training framework explained in the previous sections integrated into the master plan implementation schedule, as shown in **Table-20.4.4** below.

Table-20.4.4 Implementation Schedule of Human Resources Development for Rural Electrification

Work Items		Implementor	Phase I Construction				
			1st Year	2nd Year	3rd Year	4th Year	5th Year
A Establishment of RE Centers							
A-1 Preparation of Training Materials							
1 Training Curriculum		Consultant					
2 Training Modules		Consultant					
3 Training Textbooks		Consultant					
A-2 Construction of Training and Maintenance Centers							
1 Central Training and Maintenance Center (Thimphu)		Contractor					
2 Wangduephodrang Regional Training and Maintenance Center		Contractor					
3 Mongar Regional Training and Maintenance Center		Contractor					
B Training for Management and Operation & Maintenance Staff							
A-1 Training for Management Staff							
1 Executive and Assistant Engineers/Managers of DOE and BPC							
- Assessment of Training Need		RGOB					
- Preparation of Training Plan		RGOB					
- Identification of Institutes		RGOB					
- Long-Term Training (Postgraduate Master Courses)		RGOB					
- Short-Term Training (Short-Term Training Programs)		RGOB					
2 Junior Engineers/Managers of DOE and BPC							
- Assessment of Training Need		RGOB					
- Preparation of Training Plan		RGOB					
- Identification of Training Institutes		RGOB					
- Medium-Term Training (Postgraduate Diploma Courses)		RGOB					
- Short-Term Training (Short-Term Training Programs)		RGOB					
B-2 Training for Operation & Maintenance Staff							
1 Training Center Staff:							
- Training for Training and Maintenance Managers and Officers		Consultant					
- Follow-Up Training and Evaluation for Trained Staff		Consultant					
2 BPC Branch Staff:							
- Training for Grid Operation and Maintenance		Training Center					
- OJT for Trained Staff in Construction by Contractor		Training Center					
- Follow-Up Training and Evaluation for Trained Staff		Training Center					
3 Consigned Local Staff:							
- Training for Meter Reading and Tariff Collection		Training Center					
- Training for Grid Distribution Line Observation		Training Center					
C Assignment Schedule of Consultants	**M/M**						
Training Expert (Distribution Operation and Maintenance)	13.0	Foreign Expert					
Training Expert (Electric Measuring and Testing)	13.0	Foreign Expert					
Training Expert (Electrics-Mechanics)	13.0	Foreign Expert					
Training Expert (Mini Hydro Power Operation and Maintenance)	13.0	Foreign Expert					
Training Expert (PV Power Operation and Maintenance)	24.0	Foreign Expert					

Prepared by JICA Study Team

(2) Assumptions Made for Implementation Schedule

The implementation schedule shown in **Table-20.4.4** above has been prepared with the following assumptions:

a) All components of the human resources development component of the rural electrification master plan are to be funded by a project loan through an international development financial institution,

b) With a project loan provided by an international development financial institution, engineering consulting services are to be provided to supervise implementation of the project, and

c) The engineering consulting services will include a soft component to provide consulting services for:

(i) preparation of training materials for training and maintenance centers;

(ii) training for management staff;

(iii) training for maintenance managers and officers; and

(iv) training for operation and maintenance staff..

20.5 Possibility for Applying Demand Side Management and Its Position in the Master Plan

(1) General

Demand Side Management (DSM) is the general concept of improving the total efficiency of the energy supply system by introducing energy-saving appliances and/or leveling the load fluctuation etc., on the demand side (i.e. consumers). It is possible to apply this concept to the master plan for rural electrification in Bhutan.

Leading measures of DSM that are used in various countries are shown in **Table-20.5.2** below.

The recommended way for practical DSM to be applied particularly to rural electrification in Bhutan is as follows:

- Introducing LED lamp
- Hydrogen production and use on the demand side

Table-20.5.1 General Demand Side Management Measures

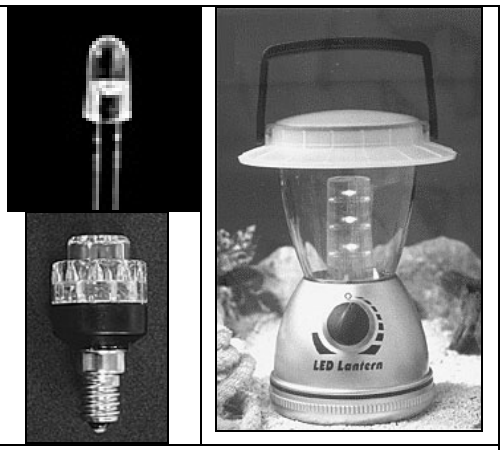
- Distribution, subsidy/assistance, publicity activities/campaigns for introduction of energy-saving products.
- Labeling of "eco-friendly marks", etc. on the energy-saving products.
- Load management by introduction of time-zone tariff systems.
- Introduction/promotion of heat storage system or co-generation systems.
- Acceleration of effective energy utilizations, such as micro-grids.
- Reward system for people who achieve energy-saving (as "avoidable cost").
- Encouragement of energy-saving buildings, lead through Building Standards Acts or building construction permit.
- Remote control of air-conditioner, etc.
- Introduction of discount electricity tariff for customers that contract to switch off (e.g. via remote control) home air conditioners during certain periods. This can also apply to commercial heavy users/large customers.
- Consultation/advisory services or inspections to encourage use of a heat shield/insulation countermeasures for residential houses or business buildings.
- In the northern hemisphere, planting deciduous trees on the south side of buildings for coolness in summer and warmth in winter. ("green air-conditioner" in Sacrament City, USA). (Planting on the north side is done in the southern hemisphere.)
- Encouragement and cooperative request for installation of a solar water heaters or PV (solar battery) systems.
- Introduction of a real-time energy consumption monitoring and display systems.
- Introduction of remote control systems for the electrical appliances via ICT (information and communications technology) network system.
- Promotion of ECSO (Energy Service Company) businesses.
- Provision of information about "environmental accounting" (environmental preservation cost including energy saving, cost and benefit evaluations for efficient enterprise management).
- Introduction of the "Summer Time" / "Daylight Saving Time" (DST).
- Limitation of the electricity supply on an hourly or region-wise basis.

Prepared by JICA Study Team. (based on information of METI, Japan, etc.)

(2) LED Lamp

Light Emitting Diode (LED) lamps, as shown in **Figure 20.5.1**, are used to increase the efficiency of lighting. As energy-saving lamp, many of advanced lamps are being developed. The most popular energy saving lamp is a compact fluorescent lamp (CFL). However, the voltage fluctuations in rural areas harmfully affect fluorescent lamps and shorten their life.

LED lamps are robust, and are not greatly affected by voltage fluctuations. In addition, LED lamps have a higher energy-saving rating than compact fluorescent lamps.



Source: TheLEDLight.Com

Figure 20.5.1 LED Lamp

It is appropriate to introduce LED lamps in Bhutan around 2010, considering the present price; it is still slightly expensive, but is expected to decrease in the near future. The above recommendations are introduction of advance technology.

(3) Hydrogen Production and Use

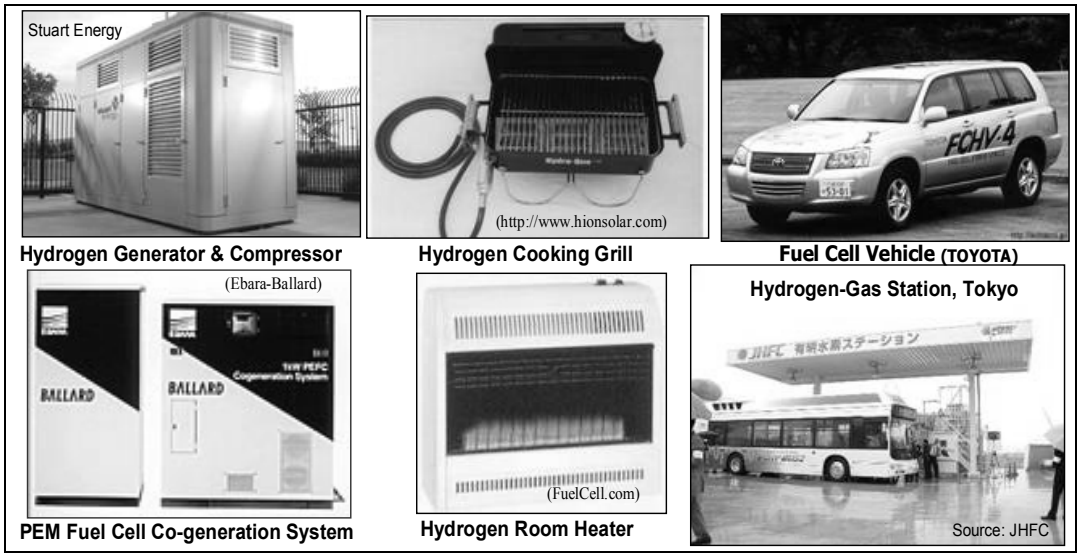
A demand feature of rural areas in Bhutan is that the peak demand is remarkably high compared to other development countries. This is because the people use electricity for cooking, even in rural areas. In order to depress the peak demand in the mornings and evenings, and level the demand fluctuation, it is necessary to decrease the electricity consumption being used for cooking (i.e. rice cooker, etc.).

As a countermeasure for the future, it is recommended to use electricity to produce hydrogen in off-peak times, conserve the hydrogen, and burn it directly for cooking when required.

Using the off-peak surplus electrical energy to decompose water into hydrogen and oxygen is conducted by the water electrolysis method. The energy can be stored in the form of hydrogen gas. At peak times, the chemical energy of hydrogen can be used to generate electricity via a fuel cell. In addition, the hydrogen can be used for cooking by direct combustion in a hydrogen-gas cooker/grill. The hydrogen can also be burnt for home heating in winter, hot-water supply, or utilized for transportation via fuel cell vehicles, etc., as shown in **Figure 20.5..2** below. Use of hydrogen technology will also assist to reduce Green House Gases (GHG) such as CO_2 and to preserve forests.

This measure is possible to apply to off-grid consumers as well. The hydrogen is produced by efficiently utilizing electricity from solar and small hydropower generators in off-peak times.

The technology for producing and storing hydrogen is practically proven. Since the price of the facilities is still slightly expensive, it is expected to introduce the technology to Bhutan in around 2010.



Source: As indicated in each frame.

Figure 20.5.2 Fuel Cell and Hydrogen Technology

If the peak electricity demand can be depressed, the capacity of the distribution facilities can be reduced, which leads to cost reduction in the initial investment.

In order to evaluate the practicability of hydrogen utilization in off-grid areas, the following desk study was conducted for Rukubji village in the Wangduephodrang Dzongkhag. This village has 64 households, and it was selected for the model of hydrogen utilization because it has an existing micro-hydropower (MHP) system. The existing micro-hydropower generator in Rukubji village has an installed capacity of 40 kW.

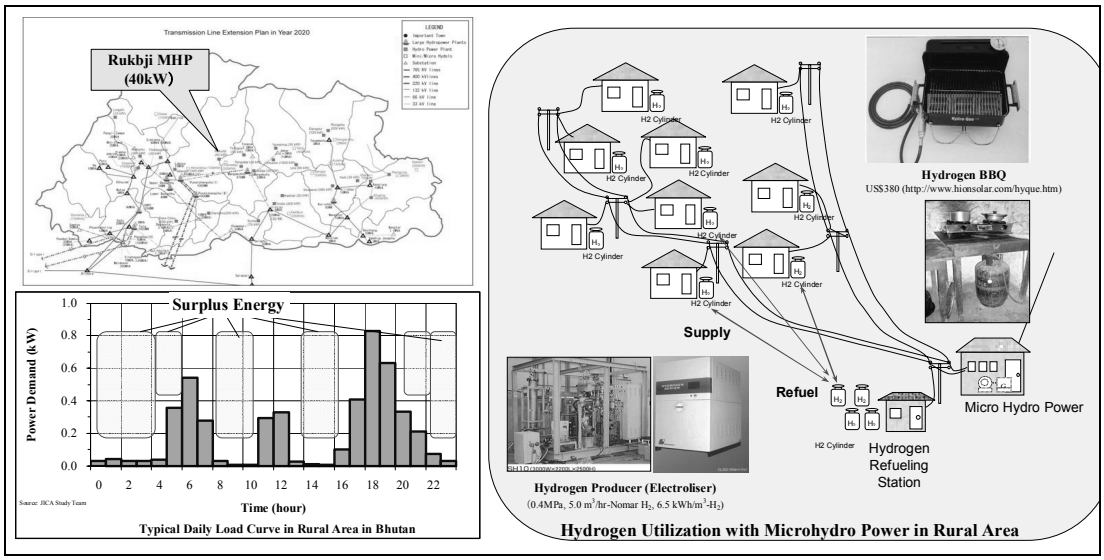
The desk study model consists of:

(i) Production of hydrogen by using surplus energy at off-peak times of the day when power supply exceeds demand,

(ii) Store the hydrogen in high-pressure gas cylinders,

(iii) Distribution of the hydrogen gas cylinders to each house, and

(iv) Utilization of the hydrogen gas for cooking by using a direct hydrogen griller, as shown in **Figure 20.5..3** below.



Prepared by JICA Study Team

Figure-20.5.3 Proposed Hydrogen Utilization Plan at Rukubji MHP

In addition to the existing micro-hydropower plant, necessary equipment includes:

- A hydrogen generator (PEM[5] type Electrolyzer);
- A gas compressor;
- A bulk gas storage tank;
- A hydrogen gas dispenser (gas refueling injector);
- Hydrogen gas cylinders (350 bar pressure, 39 liters ,1.5 x cylinders per household); and
- A hydrogen gas cooking stove/griller (1 per household).

The result of the cost estimation for the proposed hydrogen system is shown in **Table 20.5.2** below. The total cost of a hydrogen gas supply system for a village of 65 households was

[5] PEM : Proton Exchange Membrane or Polymer Electrolyte Membrane

estimated at approximately US$1.0 million. The internal equipment expense, cost of a hydrogen gas producer and a compressor represents 53% of the total expense. The cost of high-pressure hydrogen gas cylinders comprises 27.5% of the whole.

Table 20.5.2 Results of Cost Estimation for Proposed Hydrogen Plan in Rukubji

Name of Target Village	Rukubuji (Wangduephodrang)	
Number of Target Household	**65**	**HH**
Source of Power	Microhydropower	Rukubuji
Installed Capacity of Micro Hydro Power	40	kW

Estimated of Required System and the Cost

Maximum Pressure of Hydrogen Gas Cylinder (20kg LPG cylinder size)	350.00	bar
	35.00	MPa
Capacity of Hydrogen Gas per Cylinder	10.561	Nm^3 H_2/cylinder
Capacity of Hydrogen Gas per Cylinder	0.940	kg H_2/cylinder
Calorie of Hydrogen Gas	3,050	kcal/m^3
Calorie of Hydrogen Gas per Cylinder	32,210	kcal/cylinder
Average Calorie Consumption per Hour by Gas Range	2,500	kcal/hr/unit
Available Hour per Hydrogen Gas Cylinder	12.88	hours/cylinder
Average Utilization time (minutes) per Day per Household	37.5	min/day/HH
Average Utilization time (hours) per Day per Household	0.63	hours/day/HH
Available Days per Cylinder	**20.61**	**days/cylinder**
Average No. of Refueling Cylinder per Day at H2 Producer	3.2	day/cylinder
Required Production of Hydrogen Gas	33.3	Nm^3 /day
Assumed Hydrogen Production Hours per Day	13.0	hr/day
Required Capacity of Hydrogen Gas Production per Hour	2.6	Nm^3/hr
	↓	
Required System of Capacity	5	Nm^3/hr
Required No. of System of Hydrogen Generator	**1**	**set(s)**
Power Consumption	32.5	kWh
Unit Power Consumption	6.5	kWh/Nm^3
Dispensing Pressure	4.0	bar

No. of Hydrogen Gas Range (Hydrogen BBQ)		**65**	**sets**
No. of Hydrogen Gas Cylinder	1.5 x	**98**	**nos.**
Unit Cost of Hydrogen Gas Grill (include shipment cost)		1,000	US$/set
Unit Cost of Hydrogen Gas Cylinder (including regulator, etc.)		2,672	US$/set

COST

Electrolyser (Hydrogen Generator) Output Pressure =	0.40 Mpa	273,000	US$
H_2 Compressor (including Bulk Storage Tank, etc.)		236,000	US$
Manifold (Refueling) Facility and Storage Facility, etc.		18,000	US$
Civil and Building/ Structures (assumed)	5.0% of above	26,350	US$
Cost of Hydrogen Gas Range (Hydrogen Gas Range/Grill)		65,000	US$
Cost of Hydrogen Gas Cylinder (350 bar, 97.5sets)		260,520	US$
MHP Generation System & Installarion (existing)	0 US$/kW	0	US$
Transportation and Installation cost	2.5% of above	22,000	US$
SUB-TOTAL		**901,000**	**US$**
Design, Construction Supervion, Training, etc., (L.S.)	2.5% of above	23,000	US$
Miscellaneous Cost	2.5% of above	23,000	US$
TOTAL COST		**947,000**	**US$**

Prepared by JICA Study Team

Due to the low calorific value of hydrogen compared with Liquefied Petroleum Gas (LPG), when compared to present costs, the proposed hydrogen system is not highly favorable from an economic point of view. On the other hand, use of a clean heat energy source derived

from utilization of surplus renewable energy, is expected to produce beneficial effects for the environment. This will occur through preservation of forests that results from reduced harvesting of firewood and the reduction of green house gas (GHG) production resulting from use of a non-polluting fuel. Accompanied with a future cost reductions, a hydrogen gas supply system should be considered as a practicable possibility for an off-grid village.

In this desk study, the supply of hydrogen gas to households was considered by using a cylinder with 350 bar (35 MPa) pressure. This type of cylinder has a capacity of 39 liters of hydrogen, and the net gas weight is 0.92 kg (= 10.56 Nm^3 H_2). Nevertheless, one cylinder can supply only around 20 hours of cooking time when used with a single stove/griller. If the hydrogen gas was used for more cooking stoves, or for other purposes such as room heating and/or hot water supply, the gas cylinder will last a shorter time. In this case, collection and transportation of the cylinder to the re-filling station should be done more frequently. Hydrogen supply by a pipeline network is considered a suitable alternative in cases where the supply area is small.

An additional point to consider is that hydrogen can be dangerous if mishandled, so there is a possibility of a serious accident occurring, though the combustibility is rather low compared to conventional fuel gas such as natural gas. Further technical research and development of safety device is required so that rural households can easily and safely utilize hydrogen.

(4) Position of the Demand Side Management in the Master Plan

Both of the above two (2) proposals are new technologies. Therefore, these technologies are treated as proposals in this master plan. A full economic analysis of these systems was not conducted, except for LED lamps for use where there is off-grid electrification.

CHAPTER 21 CONCLUSION AND RECOMMENDATION

21.1 Conclusion

The conclusion of the master plan study is shown below.

1. All the target villages of the master plan study, which are to be electrified in and after 10th FYP, i.e. from July 2007, were visited and surveyed by the local consultant recruited by Study Team. As the result of this site reconnaissance, it was confirmed that there were 1,716 non-electrified villages and 29,942 non-electrified households in those villages.
2. The location coordinates (longitude and latitude) of all the non-electrified villages were recorded by GPS. These coordinate data were transferred to a GIS data and saved. In addition, GPS was used to record the location of the existing middle voltage lines and the planned middle voltage lines to be constructed in 9th FYP. These coordinates were also transferred to the GIS. By utilizing these data, the major work of formulating the master plan was efficiently conducted via use of GIS software.
3. The demand forecast up to 2020 of all the non-electrified villages was carried out. The Study Team forecast that the number of non-electrified households would increase to 43,702 in 2020. Through this increase of household numbers and the associated increase in electricity consumption of each household, the total demand of all the non-electrified villages in 2020 was estimated to be 58.6 MW for peak demand and 9,623 MWh/month for energy consumption.
4. The Study Team forecast the future demand of the area that is already electrified. The national demand of both non-electrified villages and the existing electrified area in 2020 were forecast at 442.7 MW for peak demand and 182 GWh/month for energy consumption. With regard to the power source side, there seems to be no problem because the total generating capacity of Bhutan will increase to around 1,450 MW after the Tala hydropower station (1,020 MW capacity) starts its operation in 2006.
5. The electrification method for non-electrified villages was decided one by one through doing economically rational analysis to compare on-grid electrification by distribution extension and off-grid electrification by a solar home system (SHS).
6. As the result of the above on/off-grid analysis, it was determined that in 2020, 73.8% of non-electrified villages, which comes to 88.4% of non-electrified households, would be electrified by on-grid, and the remaining villages and the households would have off-grid electrification. The total length of the required distribution lines was estimated to be 2,321 km and the construction cost of these lines was estimated to be US$71.35 million. The cost of solar home systems for off-grid electrification was estimated to be US$2.54 million.
7. In the master plan, 100% of electrification is planned to be accomplished by the end of 2017, which is the last year of the 11th FYP. The master plan was also summarized on

a Dzongkhag-wise basis so that the Dzongkhag people could easily refer to their own Dzongkhag electrification plan.

8. The on-grid electrification plan for the 10th FYP envisages that 858 villages and the corresponding 21,519 households (year 2007 basis) will be electrified. The investment cost for the 10th FYP work of on-grid is estimated to be US$49.2 million. By the end of the 11th FYP, 410 villages and the corresponding 7,819 households (year 2007 basis) are planned to be electrified. The investment cost for the 11th FYP work is estimated to be US$22.1 million.

9. The study team examined the possibility of utilizing micro hydro power (MHP) for off-grid village electrification. An economic evaluation and comparison with on-grid electrification was conducted for 39 MHP schemes at the desktop study level. The results of the analysis showed that 5 of the proposed MHP schemes (Lingshi and Jangothang in Thimphu Dzongkhag, Laya in Gasa Dzongkhag, Sengor in Mongar Dzongkhag, and Khelphu in Trashigang Dzongkhag) were evaluated as being economically more feasible than on-grid electrification. Among these 5 schemes, the Sengor MHP project is to be started in 2005 with UNDP/GEF funding support. For other 4 schemes, and some additional sites where grid extension is technically difficult or the power supply from the Indian grid is not preferred (such as Shingkhar-Lauri in Samdrup Jongkhar Dzongkhag), further detailed surveys and feasibility studies are recommended.

10. In the master plan formulation stage, the Study Team paid a lot of attention to environmental conservation, and stated necessary countermeasures and recommendations for ensuring environmental protection. Therefore, the Study Team believes that the environmental burden incurred by the implementation of electrification projects will be mitigated.

11. For the efficient rural development, the expansion of the information and communications network is planned along with the rural electrification plan. The information and communications network plan is scheduled to be implemented in three phases over five year plans 10 to 12. The EIRR of each phase of the plan was estimated to be 1.8%, 6.2% and 24.0%, respectively for the 10th, 11th, and 12th FYP. Based on this result, the Study Team considers that implementation of the project is rational.

12. Regarding the operation and maintenance of rural electrification, the Study Team proposed a financially transparent and efficient institutional setup. This will be achieved by introducing the idea of a holding company and decentralized operation systems for on-grid electrification. For off-grid electrification, the Study Team proposed cost sharing with the consumers to enhance the consumers' sense of ownership. In addition, private sector participation is suggested to undertake the operation and maintenance work in order to secure sustainability of the project.

13. Close collaboration with the Bhutanese counterparts was carried out when formulating the master plan in order to achieve effective technology transfer. By setting clear

targets for the technology transfer; such as all the presentations in the workshops being carried out by the Bhutanese counterparts, efficient and high level technology transfer was achieved.

21.2 Recommendation

The recommendations of the master plan study are listed below.

1. The Study Team proposes that the on-grid electrification and distribution line extension project package for the 10th FYP be implemented by loans from JBIC and ADB, respectively. JBIC had already started their SAPROF study in October 2005. In this study, it is conceivable that the site survey of the middle voltage lines and the application of the environmental clearance will be conducted. After the SAPROF study is completed, the route decision for the low voltage lines, quantity and cost estimation, and if necessary, execution of an EIA, will remain as major works. The Study Team recommends, as one option, that all these works be conducted under technical assistance from donor agencies including JICA.

2. The master plan needs to be reviewed, if possible every year, and at least once in each of the five year plans. To allow the Bhutanese counterparts to conduct this review by itself, the Study Team made a lot of effort to carry out the required technology transfer during the master plan study. Many conditions that were used to formulate the master plan will vary as time goes on. It is recommended that the master plan be reviewed with the latest data, especially paying attention to the forecast demand and price decrease of the equipment required for solar home systems.

3. Regarding the above forecast demand, the Study Team recommends confirming whether the forecast demand was appropriate or not by making sample measurements of electricity consumption of households for various 24 hour periods.

4. As one of the alternatives for demand side management, the application of new technology, such as Hydrogen and Fuel Cell technology are worth considering in the future. Using surplus energy generated in off-peak times for electrolysis to decompose water into hydrogen and oxygen could be done. The energy could be stored as liquid hydrogen. During peak times, the chemical energy contained in the hydrogen can be converted to electrical energy by using a Fuel Cell. The hydrogen is also able to be used directly for cooking, heating, and hot-water supply by direct combustion of hydrogen-gas in a cooker/grill or burner. The hydrogen could also be used for transportation, in the form of a Fuel Cell vehicle, etc. Hydrogen technology is expected to become a measure for reducing CO2 emissions and, by reducing timber usage for cooking and heating, also for forest preservation.

5. The Study Team recommends formulating a data base for basic environmental information. At present, consolidation of the existing data about natural and social environment is not sufficient. Although a lot of studies have been conducted regarding flora and fauna, the data cannot be used easily because it is not systematically consolidated.

6. The proposed information and communication network expansion plan is included in the project to reduce the rural development costs and also make the rural development more efficient by coordinating different sectors. As the next step, it is recommended that further studies be conducted as part of the feasibility study.

THE INTEGRATED MASTER PLAN STUDY
FOR DZONGKHAG-WISE ELECTRIFICATION
IN BHUTAN

FINAL REPORT

ANNEXES

ANNEX

Annex-1: Scope of Work (June 27, 2003)
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ANNEX-1

SCOPE OF WORK

AGREED UPON BETWEEN

JAPAN INTERNATIONAL COOPERATION AGENCY AND

MINISTRY OF TRADE AND INDUSTRY

JUNE 27, 2003

SCOPE OF WORK
FOR
THE INTEGRATED MASTER PLAN STUDY
FOR DZONGKHAG-WISE ELECTRIFICATION
IN
THE KINGDOM OF BHUTAN

AGREED UPON BETWEEN

JAPAN INTERNATIONAL COOPERATION AGENCY

AND

MINISTRY OF TRADE AND INDUSTRY

Thimphu, June 27, 2003

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Dasho Karma Dorjee
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Mr. Sonam Tshering
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&
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In Witness:

Mr. Yasuyuki Mori
Resident Representative
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In Witness:

Mr. Pema Tshewang
Officiating Director General
Department of Aid and Debt Management
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1. INTRODUCTION

In response to the request of the Royal Government of Bhutan (hereinafter referred to as "RGOB"), the Government of Japan decided to conduct the Integrated Master Plan study for Dzongkhag (District) wise electrification in Bhutan (hereinafter referred to as "the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programme of the Government of Japan, will undertake the Study in close cooperation with the Department of Energy (hereinafter referred to as DOE), Ministry of Trade and Industry, the counterpart agency and other concerned authorities of RGOB.

The present document sets forth the scope of work with regard to the Study.

2. OBJECTIVE OF THE STUDY

The RGOB aims to achieve "Electricity for All" by the year 2020. The target requires formulating a comprehensive rural electrification plan.

The main objective of the Study is, (1) to produce a sustainable techno-economic rural electrification plan and corresponding financial plan and (2) to strengthen planning and implementation capacity to accomplish the goal of electrification program up to the year 2020. The techno-economic plan shall be formulated as an optimal Dzongkhag (District)-wise rural electrification plan (hereinafter referred to as "RE Master Plan"), in which on-grid and off-grid electrification plans are combined. Also, capacity building programs shall be included to transfer necessary ideas and technologies in the course of the Study to the counterpart personnel of related organizations.

3. THE STUDY AREA

The Study shall cover all of the twenty Dzongkhags of Bhutan

4.SCOPE OF THE STUDY

The Study shall be carried out in the following three stages and appropriate capacity building programs shall be incorporated:

First Stage - Preliminary Survey

Second Stage - Analysis and Planning

Third Stage - Master Plan and Strategy Formulation

Details of undertakings at each stage are itemized as follows:

1) Preliminary Survey Stage

(1) Data collection and review of background data

Collection and review of the data and information relevant to:

- Long-term national plan for social development and social welfare
- Socio-economic data of remote villages (i.e. census data)
- Related national network development plan (i.e. road, telecommunication)

(2) Data collection and review on the power sector and rural electrification

Collection and review of the data and information relevant to:

- Policy and regulatory framework for rural electrification
- Power generation, transmission and distribution
- National budget plan for the power sector and financial plan of Bhutan Power Corporation
- Off-grid electrification projects in the past and their current status
- Cost data regarding on-grid and off-grid rural electrification
- Relevant study reports.

(3) Data collection and review on technical issues

Collection and review of the data and information relevant to:

- Existing electric power supply facilities and operation and maintenance of the facilities
- Design standards, construction and operating costs of transmission and distribution network
- Power supply technologies suitable for remote less populated areas
- GIS technologies suitable for power system planning and management

(4) Evaluation of medium voltage distribution network planning methodologies

Review and discussion on relevant computer programs and GIS maps for medium voltage distribution network planning shall be carried out to select the most appropriate medium voltage distribution network planning methodology to be applied in the Study. In the course of discussions, planning simulations shall be conducted on several model villages considering distance from existing power line, demand density and topography. Also, difficult-to-access

areas in Bhutan shall be studied to assess potential boundaries of on-grid and off-grid areas.

(5) Village data survey and database creation

In order to create a database of village-wise information necessary for formulating the RE Master Plan, a local subcontractor shall be selected and the following tasks shall be carried out:

- Data collection on unelectrified village from relevant organizations
- On-site unelectrified village survey with Global Positioning System and collection of village data (excluding those villages where key data can be obtained from other sources)
- Data compilation and data input to GIS map

(6) Study on off-grid energy sources

As an energy source for off-grid electrification, availability, cost, benefits and shortcomings of mini/micro-hydro, photovoltaic, wind power, and other technologies and resources shall be studied. Existing survey data of mini/micro-hydro sites shall be reviewed and preliminary site surveys shall be conducted.

(7) Preliminary site survey and power demand estimation

A series of preliminary site surveys at electrified and un-electrified villages shall be conduced in order to identify the needs for electricity and to estimate electricity demand.

Demand forecast analysis of un-electrified villages shall be conducted for the period up to year 2020, considering various consumer categories of residential, commercial, industry, government and other electric power use. Dzongkhag-wise Demand Map, showing the distribution of village load centers together with geographical conditions, is needed in the subsequent medium voltage distribution plan, and shall be constructed on GIS database.

Also, site surveys at the villages with off-grid systems shall be carried out to identify the benefits and shortcomings of off-grid electrification. After the site surveys, the unit electricity demand per household in remote areas to be used in medium voltage distribution network planning shall be set out. In setting the unit electricity demand per household, it is important to consider the following points:

- actual electricity consumption in the electrified villages
- village characteristics and electricity demand patterns
- objectives of rural electrification such as reduction of use of fuel wood, poverty alleviation, improvement of health and education and socio-economic development

(8) Environmental data collection

Policy, legislation and programs on environmental conservation and environmental impact assessment with respect to rural electrification shall be studied. Also, environmental data and information on the environmental sensitive areas, including National parks, Wildlife Sanctuary, Biological Corridors, Forest Management Unit, habitat of endangered species and cultural and/or religious heritage site, shall be collected. On premises that collected data and information will be complied as GIS topographical distribution on the important areas from environmental viewpoint will be clarified as much as possible at the data collection stage.

2) Analysis and Planning Stage

On-grid

(1) Evaluation of efficiency and economic viability of rural electrification

Based on the results of the first-stage study, basic approaches for rural electrification, both on-grid and off-grid, shall be thoroughly reviewed with the involvement of concerned RGOB officials by paying attention to the key issues such as financial resources, efficient public spending, level of electricity tariff and subsidy requirements, and coordination with other sectors.

Electric power consumption in rural households shall be reviewed and assessed with regard to types of equipment in-use and the amount of consumption through the results of the first-stage study, and the evaluation shall be made of adequacy in introducing "Energy Best Mix", " New Renewable Energy", and "Demand Side Management" in improving efficiency in household electricity consumption.

(2) Technical review of medium voltage distribution network system in remote mountainous areas

Technical review on medium voltage distribution network system shall be carried out to examine technology options (system configuration and equipment) in order to ease the difficulties of grid extension work in remote mountainous areas with a view to securing reliability and cost saving.

(3) Development of methodologies for medium voltage distribution network planning

Using the computer program selected in the first-stage study, appropriate methodologies for GIS based medium voltage distribution network planning shall be developed. After incorporating relevant data, the developed methodologies shall be actually tested by Japanese study team. Computer operation training for Bhutanese engineers shall be conducted to make them master

the computer skills for medium voltage distribution network planning.

(4) Joint work to develop Dzongkhag-wise medium voltage distribution network plan

After setting technical and financial criteria for medium voltage grid extension in remote areas, a medium voltage distribution network plan for each Dzongkhag shall be developed as collaborative work between Japanese study team and RGOB counterparts paying attention to mitigating environmental impacts. Adequate mitigation measures shall also be investigated in consultation with National Environment Commission and other relevant organizations, if necessary.

The grid extension plan under RE Master Plan shall cover the 33kV and 11kV distribution lines that will supply electricity to un-electrified villages. Low voltage distribution network within the villages shall not be a part of the Study. Dzongkhag-wise distribution network plan shall be, after GIS formatting, superimposed on the existing network diagrams. Based on the training imparted, Bhutan Power Corporation (BPC) shall provide the existing network diagrams to cover those Dzongkhags electrified by the previous RE-1, RE-2, and RE-3. Distribution system analysis shall be conducted to estimate the least-cost electricity distribution.

(5) Review and adjustment to power system master plan

The Updated Power System Master Plan of Bhutan shall be reviewed and checked for the locations and specifications of interconnections with the medium voltage distribution network. In particular, the transmission substations shall be adjusted so as to enable efficient and reliable electricity supply to Dzongkhag-wise medium voltage distribution network. Recommendations for alternative plan shall be made, if any.

Off-grid

(6) Field survey

Considering the difficult-to-access areas studied in the first stage, socio-economic field surveys shall be conducted in selected villages to obtain in-depth socio-economic data for developing off-grid electrification model plans. Also, field surveys to identify mini/micro hydro resources shall be continued.

(7) Joint work to develop Dzongkhag-wise off-grid model plan

After selecting appropriate technologies, recommendable village-based off-grid electrification model plan by renewable energy sources for each Dzongkhag shall be developed as collaborative work between Japanese study team and RGOB counterparts paying attention to

mitigating environmental impacts. Villages in off-grid zones of each Dzongkhag shall be classified into sub groups that correspond to suitable off-grid model plan. In developing the off-grid model plans, it is important to consider the following points:

- Implementing agency of off-grid rural electrification
- Village organization to achieve autonomous operation and management
- Cost recovery and financial sustainability including public assistance
- Affordability and suitable financing scheme for the users
- Technical sustainability including backstopping scheme
- Income generation by using electricity

At the same time, efforts shall be made to study the possibility of connecting the existing off-grid plants to the grid system to secure reliable power supply.

Common issues

(8) Operation and maintenance scheme

Analysis on appropriate operation and maintenance scheme of on-grid and off-grid electricity supply systems shall be conducted.

(9) Environmental assessment

Strategic Environmental Assessment (SEA) study shall be conducted in cooperation with relevant organizations/personnel in order to build a consensus on rural electrification and environment. The study shall be conducted based on the process prescribed in the Regulation on Strategic Environmental Assessment of RGOB. Environmental guidelines of international donors, such as the World Bank, Japan Bank for International Cooperation (JBIC), Asian Development Bank (ADB), etc., shall also be considered.

(10) Evaluation of socio-economic impacts

Issues relating to rural electrification such as change of lifestyle, poverty alleviation, improvement of education and health, gender issues, greenhouse gas emissions, de-forestation shall be analyzed.

3) Master Plan and Strategy Formulation Stage

(1) Joint review of Dzongkhag-wise rural electrification plan

A draft of integrated on-grid and off-grid electrification plan up to the year 2020 for each Dzongkhag shall be jointly reviewed between JICA study team and RGOB counterparts. The

Dzongkhag-wise rural electrification master plan (RE Master Plan) shall be developed after the review.

(2) Estimation of capital investment and recurrent costs

Necessary financial requirements covering the capital investment and recurrent costs shall be estimated up to the year 2020 based on the RE Master Plan. In-village low voltage line costs shall be included in the cost estimates, and shall be derived based on past rural electrification programs and as such will not cover detail survey and BOQ of low voltage connections within the villages.

(3) Strategic planning for the implementation of RE Master Plan

Measures necessary to implement the RE Master Plan and to achieve the goal of rural electrification shall be studied. Items to be studied will include:

- Financing strategies
- Cost allocation and electricity tariff scheme
- Institutional framework
- Human resource development
- Coordination with other social development activities
- Recommendation on environmental management and monitoring

(4) Conduct workshops on the RE Master Plan

Workshops to be attended by representatives from all Dzongkhags shall be held to take into account stakeholders' opinions.

(5) Finalize the RE Master Plan and preparation of summary report for distributing to possible donors/investors

4. STUDY SCHEDULE

The Study is planned to be conducted for a period of 24 months in accordance with the tentative time schedule attached in Appendix I.

5. REPORTS

JICA shall prepare and submit the following reports in English to RGOB at the due timing shown in the schedule.

1. Inception Report (Ic/R) twenty (20) copies

2. Progress Report (P/R)	twenty (20) copies
3. Interim Report (It/R)	twenty (20) copies
4. Draft Final Report and Summary (Df/R)	thirty (30) copies
5. Final Report and Summary (F/R)	thirty (30) copies

The RGOB shall provide JICA with comments in writing on the Draft Final Report within one month after receiving the report.

6. DIVISION OF TECHNICAL UNDERTAKING

The division of technical undertakings by JICA and the Department of Energy, Ministry of Trade and Industry is detailed in Appendix II attached herewith.

7. UNDERTAKING OF THE ROYAL GOVERNMENT OF BHUTAN

1. To facilitate smooth conduct of the Study, the RGOB shall take necessary measures:

(1) to permit the members of the Japanese study team to enter, leave and sojourn in Bhutan for the duration of their assignments therein, and exempt them from foreign registration requirements and consular fees;

(2) to exempt the members of the Japanese study team from taxes, duties and other charges on equipment, machinery and other materials brought into Bhutan and out for the implementation of the Study;

(3) to exempt the members of the Japanese study team from income tax and charges of any kind imposed on or in connection with any emoluments or allowances paid to the members of the Japanese study team for their services in connection with the implementation of the Study;

(4) to provide necessary facilities to the Japanese study team for remittance as well as utilization of the funds introduced into Bhutan from Japan in connection with the implementation of the Study;

(5) to facilitate prompt clearance through customs and inland transportation of equipment, materials and supplies required for the Study and of the personal effects of members of the Japanese study team.

2. The RGOB shall bear claims, if any arises, against the members of the Japanese study team resulting from, occurring in the course of, or otherwise connected with the discharge of their

duties in the implementation of the Study, except when such claims arise from gross negligence or willful misconduct on the part of the members of the Japanese study team.

3. The DOE shall act as a counterpart agency to the Japanese study team and also as coordinating body in relation to other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

4. The DOE shall, on behalf of RGOB, at its expense, provide the Japanese study team with the following in cooperation with other concerned organizations:

(1) security–related information on as well as measures to ensure the safety of the Japanese study team;

(2) information on as well as support in obtaining medical services;

(3) available data and information related to the Study;

(4) counterpart personnel;

(5) suitable office space with necessary equipment in Thimphu;

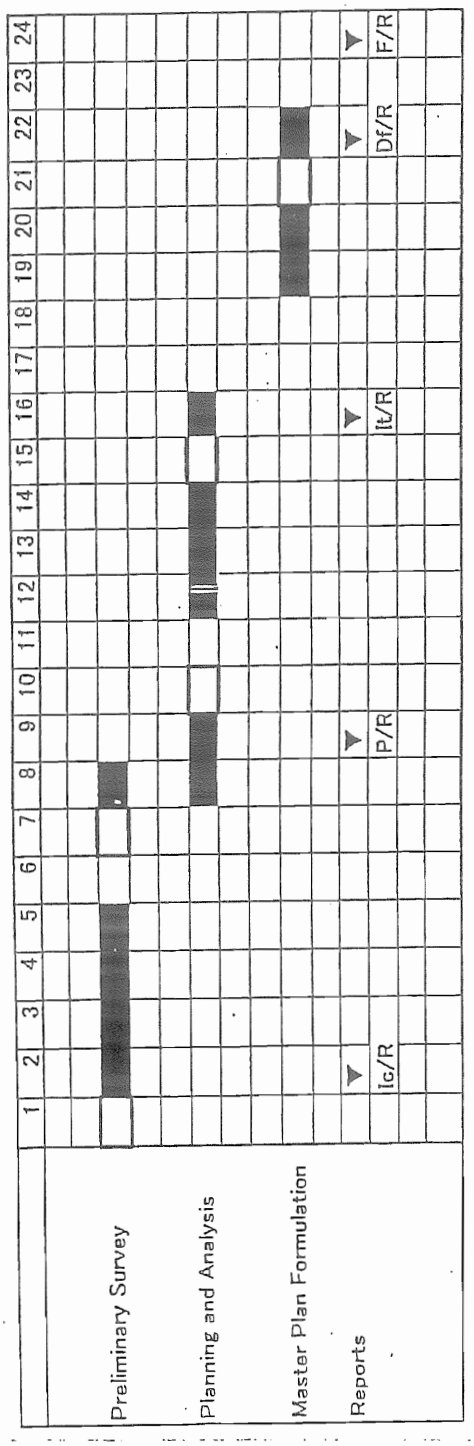
(6) credentials or identification card

8. OTHERS

JICA and DOE shall consult with each other in respect of any matter that may arise from or in connection with the Study.

Appendix I

Tentative time schedule



Undertakings by JICA and DOE/BPC

Work Items	Undertakings by JICA	Undertakings by DOE/BPC
1) Basic data collection	1) Data collection and analysis	1) Provision of necessary data, reports and information 2) Arrangements for data collection from relevant organizations
2) Geographical Information System	1) Review of GIS maps, computer systems and software 2) Instruction and training on GIS technologies	1) Provision of GIS maps (1:50,000) 2) Provision of GIS-based outputs of RE-3 3) Participation in training 4) GIS mapping of existing power system
3) Preliminary socio-economic site survey	1) Interview survey on socio-economic conditions, electricity demand, environmental issues, etc. 2) Data analysis	1) Arrangements for site visits 2) Provision of assistance (counterpart) to site survey
3) Mini/Micro-hydro site survey	1) Survey on mini/micro hydro sites for near-by villages 2) Data analysis	1) Arrangements for site visits 2) Provision of assistance (counterpart) to site survey

Work Items	Undertakings by JICA	Undertakings by DOE/BPC
4) Medium voltage distribution network planning methodology	1) Evaluation of candidate computer programs 2) Selection of most appropriate program 3) Training of counterpart officers 4) Preparation of operation manuals	1) Participation in review and evaluation 2) Provision of comments 3) Participation in training
5) Village data survey (by subcontract)	1) Preparation of TOR 2) Tendering and subcontracting 3) Supervising the work (survey and database creation)	1) Provision of comments and advice on workflow 2) Provision of assistance for tendering 3) Arranging with Dzongkhag and BPC offices for smooth undertaking
6) Analysis of issues on rural electrification	1) Data collection and conducting interviews/discussions 2) Conducting analyses	1) Provision of relevant information and data 2) Provision of comments
7) Technical review on remote power supply system	1) Data collection 2) Evaluation of available technologies	1) Provision of comments
8) Dzongkhag-wise medium voltage network plan	1) Demand estimation 2) Setting criteria for medium voltage network 3) Demonstration of planning process with sample Dzongkhags 4) Provision of instructions and coaching for Bhutanese officials 5) Review and evaluation of draft plans	1) Provision of comments and advice on workflow and criteria 2) Participation in workshops/training to master skills for medium voltage network planning 3) Load flow analysis and GIS mapping of draft network plans

Work Items	Undertakings by JICA	Undertakings by DOE/BPC
9)Socio-economic field survey for off-grid planning	1) Investigation on renewable energy potentials 2) Interview survey on socio-economic conditions, electricity demand, environmental issues, etc. 3) Data analysis	1) Arrangements for site visits 2) Provision of assistance (counterpart) to site survey
10) Off-grid model plan	1) Analysis on technical, economic, and institutional issues relating to off-grid electrification 2) Creation of model plans	1) Provision of relevant information and data 2) Provision of comments
11) RE Master Plan	1) Study and evaluation of MV network plan and off-grid plan 2) Integration into the RE Master Plan 3) Investment and recurrent cost estimation	1) Provision of relevant information and data 2) Provision of comments 3) Organizing workshops
12) Strategic planning	1) Making policy recommendations and strategic action plans	1) Involvement of concerned organizations 2) Holding meetings to discuss implementation