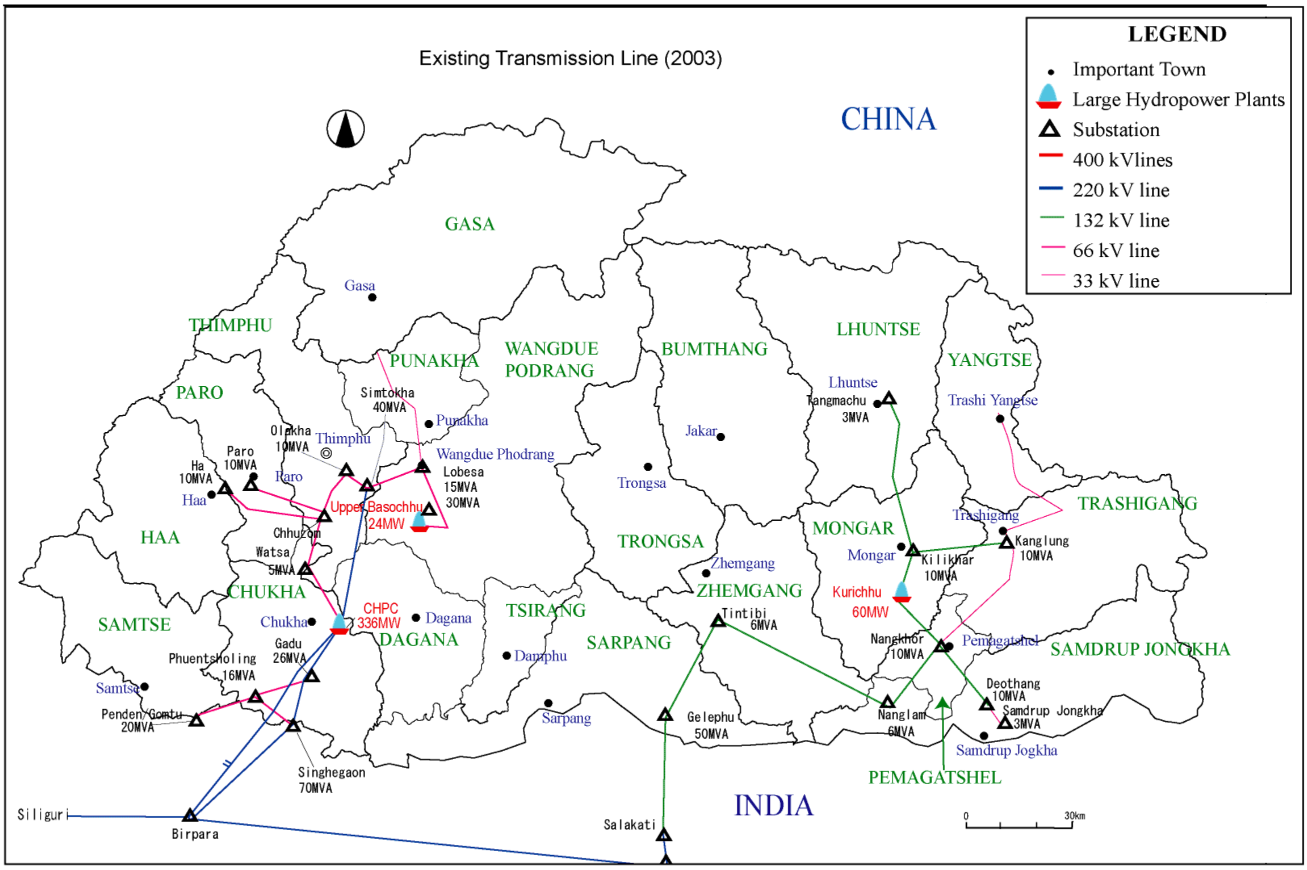
CHAPTER 4 EXISTING POWER FACILITIES

4.1 On-Grid Facilities

4.1.1 General

As seen in **Figure-4.1.1**, the power system of Bhutan as of June 2004 is individually operated as a 132 kV transmission system in the eastern-central region and a 220 kV transmission system in the western region. Interconnection of the two systems has not been done yet. Wheeling power flow between both systems is however possible through an interconnecting line through Bhutan and the northeast part of India.



Source : DOE (2003)

Figure-4.1.1 Power Facilities in 2003

4.1.2 Generating Facilities

Approximately 97% of the generating capacity in Bhutan is hydropower as summarized in **Table-4.1.1**. All hydropower stations are of run-of-river type, and at present all major hydropower stations are operated without serious issues. Both Tala power station, under construction targeted to be completed in 2006 with a total installed capacity of 1,020 MW, and Basochhu-II power station, completed in 2004 with an installed capacity of 40 MW, are also designed as run-of-river type stations.

Generating capacity in the period of low water-flow should be examined in the future to meet increasing power and energy demands, since the highest demand of the country appears in such small discharge season. In any case, surplus energy generated in the country is exported to India.

Table-4.1.1 Existing Generating Facilities (As of June 2004)

Generating Type	Name of Plant (Owner)	District (Region)	Installation (MW)	Commissioned Year	Production (02-3) (GWh/annum)
Hydro	Chukha (CHPC)	Chukha (Western)	336	1986~88	1,815.36
	Kurichhu (KHPC)	Mongar (Eastern)	60	2001~02	255.77
	Basochhu-I (BHPC)	Wangdue (Western)	24	2002	109.28
Micro-hydro	-	Whole Country	6	-	19.14
	Total of Hydro Type		426		2,199.55
Diesel	BPC	Whole Country	9	1966~2001	0.30
	Others	Whole Country	7	1981~2000	0.14
	Total of Diesel Type		16		0.44
	Grand Total		442		2,199.99

Source : Power Data 2002-03 (DOE)

4.1.3 Transmission Line Facilities

At present, the highest transmission voltage operated in Bhutan is 220 kV. The 220 kV lines are operated between the Chukha hydro power station and Simtokha substation near Thimphu in the western system as well as the export-use line from the Chukha hydro power to the Birpara substation in India.

The voltages of transmission lines operated in the western system are 220 kV and 66 kV, while that in the central and eastern system is 132 kV. **Table-4.1.2** summarizes the present transmission line facilities in the country. Total length of 220 kV transmission lines is 308 km for 6 sections in the western region. That of 132 kV is 354.2 km operated for nine (9) sections in the eastern region. The 66 kV lines are running over 246.1 km for 14 sections in the western region. Besides, a new 400 kV transmission line is under construction for energy export to India from the Tala hydropower station to be commissioned in 2005.

Bhutan transmission lines particularly apply facilities of high insulation level since high altitude makes the insulation strength of facilities lower. The conductors used for all transmission lines are standard ACSR (Aluminum Conductor Steel Reinforced). It is peculiar that conductors adopt unique size according to voltages. In British standard, Zebra conductor (400 mm^2) is used for 220 kV lines, Panther (200 mm^2) for 132 kV lines, and Dog (100 mm^2) for 66 kV lines. In order to increase transmission capacity and also to economize construction cost, it is deemed that various size conductors should be examined for selecting the most appropriate size for each transmission line. Another feature of transmission lines in Bhutan is that lines ought to be routed in steep and mountainous land resulting in more angle towers and less tangential towers, which increases construction cost.

In order to protect power conductors from lightning strikes, overhead ground-wire(s) are installed above conductors over the whole length of lines. Most of the existing overhead ground-wires installed for 66 kV lines in the western system have been replaced with "Optical Fiber Composite Overhead Ground Wire (OPGW)" for utilization of optical fiber, which is capable of transmission of huge quantities of information.

Table-4.1.2 Existing Transmission Line Facilities (As of 2004)

Voltage	Operating Section	Length (km)	Conductor
220	Chukha ~ Birpara-1 (interconnection with India)	71.0	Zebra
220	Chukha ~ Birpara-1I (Interconnection with India)	71.0	Zebra
220	Chukha ~ Singhegaon	36.0	Zebra
220	Sinhegaon ~ Birpara (Interconnection with India)	40.6	Zebra
220	Chukha ~ Simtokha	54.9	Zebra
220	Basochhu ~ Simtokha	34.5	Zebra
132	Kurichhu ~ Mongar (Kilikhar)	10.0	Panther
132	Mongar (Kilikhar) ~ Trashigang (Kalanlung)	30.0	Panther
132	Mongar (Kilikhar) ~ Tangmachhu	43.0	Panther
132	Kurichhu ~ Pemagmatsel (Nangkhor)	34.0	Panther
132	Pemagatshel (Nangkhor) ~ Nanglam	34.0	Panther
132	Pemagatshel (Nangkhor) ~ Deothang	24.0	Panther
132	Nanglam ~ Tingtibi	83.2	Panther
132	Tingtibi ~ Gelephu	46.0	Panther
132	Gelephu ~Salakati (interconnection with India)	50.0	Panther
66	Chukha ~ Gedu	20.1	Dog
66	Chukha ~ Watsa ~ Confluence (Chuzom)	37.0	Dog
66	Phuentsholing ~ Gomtu	27.0	Dog
66	Phuentsholing ~ Singhegaon	8.4	Dog
66	Singhegaon ~ Pasakha (BFAL)	2.0	Dog
66	Singhegaon ~ Pasakha (BCCL)	2.0	Dog
66	Phuentsholing ~ Gedu	17.7	Dog
66	Confluence (Chuzom) ~ Haa	31.0	Dog
66	Confluence (Chuzom) ~ Jemina	18.0	Dog
66	Jemina ~ Olakha	12.0	Dog
66	Confluence (Chuzom) ~ Paro	24.0	Dog
66	Simtokha ~ Wangdi (Lobesa)	26.0	Dog
66	Lobesa ~ Basochhu-1	20.9	Dog
66	Simtokha ~ Olakha	1.7	Dog

Source : DOE
Note: BFAL=Bhutan Ferro Alloy Ltd. BCCL=Bhutan Calcium Carbide Ltd.
Zebra, Panther, Dog = Conductor codes of British Standards

4.1.4 Substation Facilities

Technical elements of high voltage (HV) substations related to the above transmission lines are shown in **Table-4.1.3**. There are 9 substations with a total installed capacity of 210 MVA in the eastern-central system as of July 2004, and 15 substations with a total installed capacity of 812.5 MVA in the western system. All existing HV substations except those annexed to power stations have conventional layout and outdoor type. Operation of transmission lines and substations is controlled through PLC communications by the Kilikhar 132 kV substation in the eastern system, Simtokha 220 kV substation for the northern half part, and Singhegaon 220 kV substation for the southern half part of the western power system.

A national load dispatching center (NLDC) utilizing an OPGW communications system is planned by DOE for operation and management of the power system in the near future.

Table-4.1.3 Existing Substation Facilities (above 66 kV) (As of 2004)

Voltage (kV)	System (District)	Name of Station	Voltage Ratio (kV)	No. & Capacity of Transformers (No. × MVA)	Total Capacity (MVA)
220	Western (Chukha)	Chukha P.S	11/220	12 × 35	420
		Chukha	220/66	2 × 20	60
			66/11	3 × 3	9
220		Singhegaon	220/66	2 × 35	70
			66/11	1 × 5 + 1 × 3	8
220	Western (Thimphu)	Simtokha	220/66	6 × 6.67	40
			66/11	2 × 10	20
66	Western (Chukha)	Pasakha (BCCL)	66/11	2 × 20	40
		Pasakha (BFAL)	66/22	1 × 28.5	28.5
			66/11	1 × 20	20
66		Watsa	66/33	1 × 5	5
66		Phuentsholig	66/11	2 × 3	6
66		Gedu	66/33	2 × 8	16
			66/11	2 × 5	10
66	Wesern (Thimphu)	Olakha	66/33/11	2 × 2.5/2.5	10
66	Western (Samtse)	Gomtu	66/11	1 × 5	5
66		Penden (PCAL)	66/6.6	2 × 5	10
66	Western (Paro)	Paro	66/33/11	2 × 2.5/2.5	10
66	Western (Haa)	Ha	66/11	2 × 5	10
66	Western (Wangduephodrang)	Lobeysa	66/11	2 × 5	10
			66/33	1 × 5	5
132	Central (Sarpang)	Gelephug	132/66	2 × 25	50
			66/11	2 × 10	20
132	Central (Zhemgang)	Tingtibi	132/33	2 × 3	6
132	Eastern (Samdrup Jongkhar)	Deothang	132/33	2 × 5	10
132		Nanglam	132/33	2 × 3	6
132	Eastern (Pemagatshel)	Nangkhor	132/33	2 × 5	10
132	Eastern (Mongar)	Kilikhar	132/33	2 × 5	10
132		Kurichhu	11/132	4 × 20	80
			132/11	1 × 5	5
132	Eastern (Trashigang)	Kanglung	132/33	2 × 5	10
132	Eastern (Lhuntse)	Tangmachu	132/33	1 × 3	3
				TOTAL	1,022.5

Source : Power Data 2003-03 of DOE

4.2 Distribution Facilities

The line length of the 6.6-33 kV medium voltage (MV) lines and the 400 V low voltage lines in each Dzongkhag are described in **Table-4.2.1**. The total length of medium voltage lines is approximately 1,500 km, with about 16% of them located in Thimphu and about 18% located in Trashigang. In Thimphu, many 11 kV lines are installed under the ground. The length of the underground lines is about 26 km.

The total length of low voltage (LV) lines is also approximately 1,500 km, and about 23% of lines in Thimphu are underground lines.

As for the distribution substations, about 82% of the 794 substations are 11/0.4 kV substations.

Table-4.2.1 Existing Distribution Facilities in each Dzongkhag (1/2)

		Name of Dzongkhag										Subtotal
		Bumthang	Chukha	Dagana	Gasa	Haa	Lhuntse	Mongar	Paro	Pemagatshel	Punakha	
High Voltage Distribution Line Length (km)	33 kV	0.000	0.000	0.000	0.000	0.000	15.000	12.500	29.760	24.000	21.900	103.160
	11 kV Overhead	56.653	99.312	0.000	0.000	38.850	32.000	47.160	77.820	4.000	30.740	386.535
	11 kV Under ground	0.000	0.000	0.000	0.000	0.000	0.000	0.176	0.000	0.000	0.000	0.176
	11 kV Total	56.653	99.312	0.000	0.000	38.850	32.000	47.336	77.820	4.000	30.740	386.711
	6.6 kV	5.123	0.000	36.780	0.000	0.000	0.000	3.400	0.000	0.000	0.000	45.303
	Total	61.776	99.312	36.780	0.000	38.850	47.000	63.236	107.580	28.000	52.640	535.174
Low Voltage Distribution Line Length (km)	400 V Overhead	40.279	119.111	13.000	0.000	64.949	29.500	50.920	167.290	6.000	46.720	537.769
	400 V Under ground	0.000	0.521	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.780	2.301
	Total	40.279	119.632	13.000	0.000	64.949	29.500	50.920	167.290	6.000	48.500	540.070
Distribution Substation (Number)	33/11 kV	0	0	0	0	0	0	0	1	0	0	1
	33/0.4 kV	0	0	0	0	0	0	0	0	3	11	14
	11/0.4 kV	19	78	0	0	28	19	21	84	0	24	273
	6.6/0.4 kV	6	0	17	0	0	0	2	0	0	0	25
	Total	25	78	17	0	28	19	23	85	3	35	313

Source: POWER DATA 2001-02 (Twentieth Edition), Department of Power/Ministry of Trade & Industry

Table-4.2.1 Existing Distribution Facilities in each Dzongkhag (2/2)

		Name of Dzongkhag										Sub total	Total
		Samdrup Jongkhar	Samtse	Sarpang	Thimphu	Tsirang	Trongsa	Trashigang	Wangdue-phodrang	Trashi-yangtse	Zhemgang		
Medium Voltage Distribution Line Length (km)	33 kV	13.500	31.300	0.000	72.770	0.000	0.000	39.800	30.570	39.790	0.000	227.73	330.890
	11 kV Over head	45.600	75.520	110.689	133.100	2.000	24.000	228.011	57.159	0.000	0.000	676.079	1062.614
	11 kV Under ground	0.000	0.225	0.000	25.618	0.000	0.000	0.000	0.000	0.000	0.000	25.843	26.019
	11 kV Total	45.600	75.745	110.689	158.718	2.000	24.000	228.011	57.159	0.000	0.000	701.922	1088.633
	6.6 kV	0.000	0.000	3.264	6.368	6.600	2.772	0.000	6.118	0.000	20.487	45.609	90.912
	Total	59.100	107.045	113.953	237.856	8.600	26.772	267.811	93.847	39.790	20.487	975.261	1510.435
Low Voltage Distribution Line Length (km)	400 V Over head	50.450	116.345	101.630	187.801	14.44	14.482	300.053	91.217	25.660	16.455	918.533	1456.302
	400 V Under ground	0.000	0.000	0.080	55.477	0.000	0.000	0.000	0.000	0.000	0.000	55.557	57.858
	Total	50.450	116.345	101.710	243.278	14.44	14.482	300.053	91.217	25.660	16.455	974.090	1514.160
Distribution Substation (Number)	33/11 kV	0	0	0	0	0	0	0	0	0	0	0	1
	33/0.4 kV	0	0	0	22	0	0	10	19	21	0	72	86
	11/0.4 kV	35	45	29	159	0	3	71	37	2	0	381	654
	6.6/0.4 kV	0	5	0	0	11	3	0	2	0	8	29	54
	Total	35	50	29	181	11	6	81	58	23	8	482	795

Source: POWER DATA 2001-02 (Twentieth Edition), Department of Power/Ministry of Trade & Industry

4.3 Off-grid Facilities

4.3.1 Off-grid Power Generation

Table-4.3.1 describes the number of electrified households by power source as of June, 2004.

Table-4.3.1 Number of Electrified Households by Power Type (As of June, 2004)

Type of Electricity		As of June 2004	
		Electrified Households	(%)
Grid		43,841	91.3%
Non Grid	MHP	1,721	3.6%
	Diesel	129	0.3%
	Solar	2,336	4.9%
	TOTAL	48,027	100%

Prepared by Study Team, with hearing from DOE in July, 2004

At the moment, the number of households electrified by off-grid systems consists of 2,336 households by solar and 1,721 by small hydropower with mini-grid. The combination of small hydro along with diesel is included in the numbers. In contrast, the number of households depending on diesel only is 129.

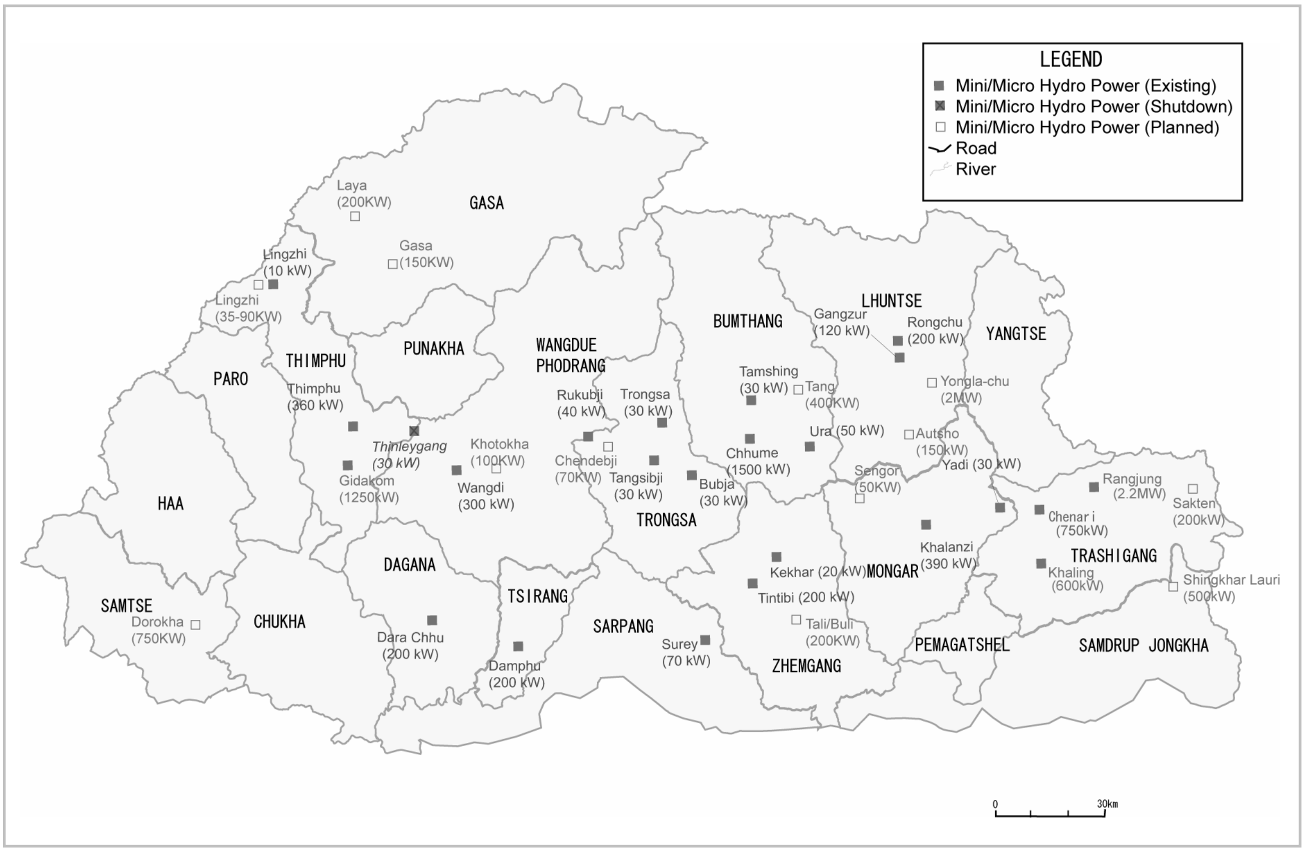
4.3.2 Micro Hydro Power

The breakdown of the number of households electrified by small hydropower is shown in **Table-4.3.2**. As of June, 2004, 15 small hydropower plants were in operation. 13 power plants out of 15 were built with Japanese Grant Assistance. Some of these power plants have already been connected the grid. **Figure-4.3.1** shows the location of the existing small hydropower plants.

Table-4.3.2 Existing Small/Micro Hydropower Plants

No.	Plant Name	Location (Dzong-khag)	Financing /Installed Country	Total Installed Capacity (kW)	Head (m)	Commi-ssion Date	Remarks (Present Condition)	Electrified Household (as of 2004) (HH)	Generated Energy (2001-02) (GWh/yr)	Const-ruction Cost (US$)	Unit Const. Cost (US$/kW)
1	Gangzur (Lhuentse)	Lhuntse	India	120	56	Mar. 2000 (old 1986)	Working (Upgrad.in 2000)	249	299.7	166,667	1,389
2	Rongchu	Lhuntse	RGOB	200	40	17 Dec. 2001	Working		700.8	760,000	3,800
3	Thinleygang	Thimphu	Japan	(30)	40	Mar. 1987	Shutdown	-	0.0	*303,158*	*10,105*
4	Rukubji	Wangdi	Japan	40	40	Feb. 1987	Working	62	20.3	*404,211*	*10,105*
5	Tangsibji	Trongsa	Japan	30	40	Mar. 1987	Working	126	42.6	*303,158*	*10,105*
6	Trongsa	Trongsa	Japan	50	40	Mar. 1987	Working	Grid connected	187.5	*505,263*	*10,105*
7	Bubja	Trongsa	Japan	30	50	Mar. 1987	Working	114	106.8	*303,158*	*10,105*
8	Tamshing	Bumthang	Japan	30	50	Feb. 1987	Working	38	63.3	*303,158*	*10,105*
9	Ura	Bumthang	Japan	50	20	Mar. 1987	Working	148	127.5	*505,263*	*10,105*
10	Yadi	Mongar	Japan	30	50	Apr.1987	Working	Grid connected	46.8	*303,158*	*10,105*
11	Kekhar	Zhemgang	Japan	20	30	Mar. 1987	Working	37	587.6 *1)	*202,105*	*10,105*
12	Surey	Gelephu	Japan	70	50	Apr.1987	Working	53	345.4	*707,368*	*10,105*
13	Tintibi	Zhemgang	Japan	200	58	Apr. 1992	Working	248	1,021.9	4,018,462	20,092
14	Chanchey /Damphu	Tsirang	Japan	200	58	June 1991	Working	293	135.0	3,791,538	18,958
15	Darachu	Dagana	Japan	200	22	Apr. 1992	Working	377	527.2	4,276,154	21,381
16	Lingshi	Thimphu	EU	10	?	1999		-	-		
	TOTAL / AVERAGE			**320**				**1,745**	**662**		

Source: DOE (Power Data 2002, and other information from DOE)
Note *1) : Cumulative generation till 16.8.1994.



Prepared by JICA Study Team based on the materials by DOE

Figure-4.3.1 Existing Transmission Lines and Location of the Small Hydropower Plants

4.3.3 PV Power Generation Systems

Though 239 kWp of PV power generation system have been installed within the country, most of these systems were installed under development programs of foreign donor agencies and there are only a few PV projects that have been financed by RGoB. Moreover, there are local distributors developing the commercial market for PV power generation systems within the country.

At present there is no example of the electrification of non-electrified village with PV, wind, biomass or other system utilizing renewable energies. But there are several examples of installations of SHS systems in public facilities, monasteries, temples, schools, health clinics, and individual households that were implemented by DOE-RED under assistance programs of foreign donor.

Beside these installations, there are installations in Bhutan that were carried out by Bhutan Telecom with the assistance of the Japanese Government or with their own budget. It is known that there are several systems that have been installed by private companies and individuals that import and sell PV equipment in Bhutan from a neighboring country.

The experiences as reported by DOE of small PV power generation systems as of December, 2003 are summarized in **Table-4.3.3**, and the detailed installations in each Dzongkhag and the relevant donor are shown in **Appendix A-III-1**. The installations of PV power generation systems by Bhutan Telecom in each Dzongkhag are shown in **Appendix A-IV-1**.

Table-4.3.3 The Actual Establishment of PV Power Generation Systems up to December, 2003

Installation	Donor Agency (Total)	Installation through DOE within the total installation (Total)
Total Number of Modules	4,521	3,102
Total Number of Systems (Sets)	2,336	1,551
Total Watts-peak (Wp)	239,105	170,610

Source : Renewable Energy Division (DOE-RED)

On the other hand, the questionnaire study in the Gewog level found that there are 574 installations in five Dzongkhag for lighting. The number of systems installed in each Dzongkhag is summarized in **Table-4.3.4**. The total number of households in the villages using SHS system is shown in **Appendix A-III-2**.

Table-4.3.4 SHS System Installed at each Dzongkhag

Name of the Dzongkhag	Households
Haa	157
Samdrup Jongkhar	111
Bumthang	64
Thimphu	92
Wangduephodrang	150
TOTAL	**574**

Prepared by JICA Study Team

4.3.4 Other Power Generating Systems

(1) Diesel Generator

Diesel Generators are installed in some areas where the power supply is already available by the grid. There are three (3) types of diesel generator operation:

- As a backup of the grid supply
- Parallel operation with mini-grid of small hydro
- Independent operation of diesel mini-grid

The Diesel Generators that are installed as backups are seldom operated, because they are utilized only when the regular power supply from hydropower generation is disturbed or some part of the grid malfunctions. The diesel generators are operated either with grid synchronization or independently from the grid system for partial supply to a specific area.

Where diesel power supply is done in parallel with a small hydro, the power is supplied mainly at the time of morning and evening peak hours and in the winter seasons. Even if the synchronous diesel generator is installed, the power distribution area is separated.

Table-4.3.5 summarizes the places where diesel generators are operated together or partially together with mini/micro hydro power supply.

Table-4.3.5 Diesel Generators Operated with Mini/Micro Hydro Power

Location	Unit (no.)	Capacity (MW)	Total Capacity (MW)	Installation (Year)
Trongsa	1 1	0.056 0.25	0.306	1976 1999-00
Zhemgang	1 1	0.08 0.25	0.33	1983 1999-00
Dagana	1 1	0.04 0.025	0.29	1983 1990-00
Bumthang	1 2	0.056 0.25	0.556	1988 1999-00
Tsirang	1	0.266	0.266	2001-02

Source : BPC/DOE-RED

In Bhutan, Kalikhola and Panbang are the two places where diesel generators operate as off grid systems and power distribution is done in the same way as the grid. As for Panbang, Dzongkhag pays for the capital cost. Subsidy for fuel from the government is now stopped and it is planned to connect to the grid in 10th FYP with priority. At both places the electricity tariff is the same as in Thimphu. All diesel generators are operated and maintained by BPC. **Table-4.3.6** summarizes the capacity of diesel generator and electricity tariff.

Table-4.3.6 Capacity of Diesel Generator and Electricity Tariff

Location (Dzongkhag)	Unit (nos.)	Capacity (kW)	Total Capacity (MW)	Total Household (nos.)	Electricity Tariff (Nu. / kWh)	Installation (Year)
Panbang (Zhemgang)	1	50	50	50	1-80 kWh =0.6 Nu. 81-200 kWh= 0.9Nu. 201 kWh above = 1.0 Nu.	1998-99
Kalikhola (Sarpang)	1 1	52 100	152	86		1999-00 1998-99

Source : BPC/DOE-RED

(3) Other Power Generating Systems

Neither wind power generating facilities nor biomass energy facilities have been recognized for implementation yet in Bhutan though the experimental plants have been introduced.

CHAPTER 5 DEVELOPMENT PROGRAM FOR THE POWER SECTOR

5.1 9th Five Year Plan

The country's hydroelectric potential is estimated to be over 30,000 MW. However, by the end of 8th Five Year Plan (FYP), only 1.42 percent of that potential has been harnessed. Therefore, the goals of the hydropower sector set out for 9th FYP are:

- Strengthening the economic self-reliance of the nation by enhancing the electricity generation capacity;
- Providing adequate, safe, and both quantitatively and qualitatively reliable electricity through sustainable and environmentally friendly development of hydroelectric resources; and
- Achievement of 100 percent rural electrification by 2020.

Table-5.1.1 9th Five Year Plan Outlay

(million Nu.)

	Recurrent	Capital	Total
Centre	1,718	4,500	6,218
Dzongkhag	139	3	142
Total	1,857	4,503	6,360

Source: 9th Five Year Plan

The total outlay for the energy sector is 6,360 million Nu., of which, 6,218 million Nu. is for the central programs and 142 million Nu. for the Dzongkhags.

In order to progressively fulfill 9th FYP goals, several strategies will be pursued, encompassing the following prominent ones:

- Preparation of conditions of private sector participation
- Rural electrification
- Strengthening the institutional capacity
- Automation of generation, transmission, and distribution of electricity
- Determination of a tariff system
- Preparation of a energy and water resources management plan
- Construction of a transmission grid

5.2 Review of the Power System Master Plan (PSMP)

5.2.1 General

Norconsult International had studied a development program for getting by the year 2022 for the Bhutan power sector under the NORAD fund from 2001 to 2004. The final report was submitted to DOE in April 2004. The following main themes were studied, but studies for the distribution network were outside of the scope of work.

- Large scale hydro-power projects for the ensuing term (examination of candidate sites, evaluation of those sites and ranking of candidate projects for development)
- Planning of high voltage (HV) transmission systems relating to the candidate hydro power projects
- Examination and recommendations to supply power to off-grid areas

Following are the résumés of the main subjects for the development programs discussed in the final report of PSMP.

5.2.2 Electricity Demand Forecast in PSMP

Dzongkhag and category-wise forecasts of peak power and energy requirements were studied up to the year 2022 in PSMP. Methodology of the forecast for each consumer's category employed by Norconsult is extracted in Section 12.2 of this report.

PSMP studied two (2) cases of the forecast; base-case forecast and forecast for the planning of the transmission system. The latter forecast covers new loads proposed by new industrial estates and load-increases proposed by the existing major industries in addition to loads projected in the base-case forecast. The base-case forecast does not include most of those additional industrial loads for the reasons of uncertainty of developing scale and implementation timing of those industries. While, the forecast for planning of transmission systems was prepared for examining capacities of the planned transmission lines in case that those additional industrial demands the power system.

In the base-case forecast, annual energy consumption by each consumer's category (domestic, industrial, commercial, and public consumers) in each district is projected. Adding energy losses worked out at the assumed loss rates to the projected energy consumption, annual energy requirements in each Dzongkhag are estimated. Dzongkhag annual peak power is estimated with an assumed load factor. Then, the peak power thus estimated is allocated to the existing and newly planned HV/MV substations.

The forecast for transmission line planning does not show energy requirements, but indicates peak powers only, which are estimated in addition to proposed industrial load to peak demand of the base-case forecast.

Following table is the results of the country-wise forecasts of PSMP.

Table-5.2.1 Results of PSMP's Demand Forecasts

	Category	2005	2010	2015	2020	2022	Annual growth rate
Base-Case Forecast							
Energy Consumption (GWh)	Domestic	88	141	202	272	305	7.60%
	Industrial	487	584	779	988	1,062	4.69%
	Commercial	30	46	67	95	109	7.88%
	Public	29	43	63	91	106	7.92%
	Total	615	813	1,110	1,447	1,582	5.72%
Loss (GWh)		75	134	179	193	211	6.27%
Energy Requirement (GWh)		690	947	1,289	1,640	1,793	5.78%
Peak Load (MW)		129	191	252	323	352	6.08%
Forecast for Transmission Line Planning							
Peak Load (MW)		136	328	413	476	536	8.40%

Source : PSMP, Final Report (April 2004)

PSMP states that the electrification rate of the domestic household category by on-grid in 2022 is 55%. PSMP also explains that this electrification rate seems to set lower than the Government's target, since actual number of consumer may not necessarily be equivalent to the number of existing energy meters. It is noted that more than one consumer is connected to the same meter in some cases, and DOE/BPC classifies such case in one bulk consumer.

Tala (1,020 MW) hydropower plant is scheduled to be commissioned by 2006. Basochhu-II (40 MW) hydropower plant has been completed in 2004. Although the output and energy production of power plants in Bhutan have been greatly increased, all plants are run-of-river type, and therefore production in dry season will be much lowered. PSPM points out that: "If no new generating source would be developed after Tala plant, the peak power supply capacity will fall short of the total peak power requirements projected in PSMP for the whole country."

On the other hand, Eastern power system is mainly supplied by the Kurichhu hydro-power station (actual output of 48 MW). PSMP's forecast indicates that the peak demand in this system will be beyond the maximum output of the Kurichhu power station before 2010, and the PSMP report suggests energy import from the Indian power grid will be necessary to cover the shortfall.

5.2.3 Candidate Sites for Future Hydropower Generation

The final report of PSMP details the review results of the previous PSMP on the candidate generation sites studied by the same consultant in 1993. The main purpose of development of new large scale hydro power stations in Bhutan is energy export to India and also energy supply to domestic needs.

A total 20 sites were at first selected from 78 candidate sites for development through 9-step screening. Those 20 candidate sites were further reduced to 11 sites through the examinations on preliminary design, cost estimates, and IEE. The remaining 11 sites were technically studied on hydrological parameters such as annual discharge, firm discharge, flood discharge, etc. and geological studies for tunnels, underground power stations, etc. as well as the environmental situation around the project. Applying the initial estimates for firm peak power/energy and seasonal energy production, PSMP conducts preliminary design of routes of construction access roads, scales of intake dams, tunnels, penstocks, powerhouses, tailrace, and other facilities for each candidate site. Transmission line facilities were preliminary designed and by examining maps of 1:571,430 scale, transmission line route were also preliminary selected. Based on those designs, construction cost for each candidate was estimated. Development priority among those 11 candidate sites is ranked through the said MCA (Multi Criteria Analysis) the technical by relevant personnel, for economic, social and environmental aspects. The analysis was made based on the economic evaluation results of the estimated energy production and the present value of the total cost of each candidate site, including construction cost and O&M costs.

According to the result, the 11 candidate sites were ranked for development priority. Finally, seven (7) candidate sites including five (5) candidate sites and two (2) sites required for additional investigation were determined as priority sites to be developed by the year 2022. It is noted that the top priority site selected is Punatsangchhu-I power station for which JICA assisted with the Feasibility Study in 2000. **Table-5.2.2** indicates the outline of the ranked candidates.

Table-5.2.2 Development Priority of Large Scale Hydro-Power Stations

Priority	Project	District	Type	Installed Capacity	Max. Output	Firm Power	Firm Peak Power	Mean Production	Firm Peak Energy	Construct. Schedule	Investment	EUCE (*2)
			(*1)	(MW)	(MW)	(MW)	(MW)	(GWh/year)	(GWh/year)		(10^6 US$)	(USc/kWh)
1	Punatsangchhu-I	Wangdue	ROR	1,002	973	168	920	4,770	1,343	2007-11	861.3	2.86
2	Mangdechhu	Trongsa	ROR	670	651	92	535	2,909	782	2009-13	587.7	3.23
3	Punatsangchhu-II	Wangdue	ROR	992	949	165	888	4,667	1,297	2011-15	875.1	2.97
4	Chamkharchhu-I	Bumthang	ROR	671	651	113	645	3,207	942	2014-19	546.8	2.97
5	Chamkharchhu-II	Bumthang	ROR	568	551	95	546	2,714	797	2018-22	407.0	2.48
6	Kholongchhu	Yangtse	ROR	486	478	61	361	2,207	527	2020-23	382.9	2.64
7	Amorchhu	Samtse	ROR	499	487	82	473	2,210	690	5 years	500.9	3.62
Total		-	4,888	4,888	4,746	776	4,368	22,684	6,378	-	4,161.70	-

Source : Final Report of PSMP
(*1) : ROR = Run-of-River
(*2) : Economic Unit Cost of Energy at Delivery Point

5.2.4 Development of Transmission System

Transmission Systems related to the candidate projects

PSMP studied development programs including outline of facilities and commissioning year the interconnecting HV transmission lines for exporting energy from the above mentioned highly ranked candidate power stations to the Indian grid and for domestic supply as well as the related HV substations for the supply of industrial power to be completed by the year 2022. 400 kV transmission systems are considered for energy exporting to India. As mentioned later in Section 10.1, standard system security criteria are applied for designing the domestic supply systems. However, the report does not discuss a load dispatching center that comprehensively manages the domestic power system in the country.

JICA master plan for rural electrification is to be formulated based on those domestic existing and planned substations.

Table-5.2.3 outlines PSMP's plans for the new transmission facilities to be constructed. The Bhutan power system for the year 2020 planned in PSMP is shown on **Figure-5.2.1**.

Table-5.2.3 New Transmission Facilities to be Completed by 2022

	Voltage (kV)	Cct	Length (km)	Development Program				Conductor (ACSR)
				2003 -2007	2008 -2012	2013 -2017	2018 -2022	
Lines for New Power Stations								
Punatsangchhu-1 ~ II	400	2	23		O			2 x Martin (690 mm^2)
Punatsangchhu-1 ~ India	400	2	101		O			4 x Martin (690 mm^2)
Mangdechhu ~ Tingtibi	400	2	37			O		2 x Moose (525 mm^2)
Tingtibi ~ India	400	2	82			O		4 x Moose (525 mm^2)
Chamkharchhu-I ~ II ~ Tingtibi	400	2	30				O	3 x Moose (525 mm^2)
Domestic Supply Lines								
Gelephu ~ Chowabari	132	1	(60)	O				Panther (200 mm^2)
Basochhu-II ~ Panatsangchhu-I	220	1	(15)		O			Zebra (400 mm^2)
Malbase ~ Singhegaon	220	1	(10)	O				Zebra (400 mm^2)
Sarpang ~ Chowabari	132	1	(50)		O			Panther (200 mm^2)
Sarpang ~ Damphu ~ Dagapela	66 (or 132)	1	(40)		O			Dog or Panther
Singhegaon ~ Pasakha	66	2	(20)	O				Dog (100 mm^2)
Simtokha-I ~ Olakha	66	2	(14)		O			Dog (100 mm^2)
Olakha ~ Chuzom	66	1	(18)			O		Dog (100 mm^2)
Chukha ~ Gedu	66	1	(20)		O			Dog (100 mm^2)
Singhegaon ~ Gomtu	66	1	(50)				O	Dog (100 mm^2)
Lines for Construction								
Basochhu-II ~ Punatsangchhu-I	33	1	(10)	O				n.a
Tingtibi ~ Mangdechhu	66	1	(97)		O			Dog (100 mm^2)
Punatsangchhu-1 ~ II	33	1	(10)		O			n.a
Tingtibi ~ Chamckharchhu-I ~II	33	1	(30)			O		n.a
Substations for Domestic Supply								
Tingtibi	420	-	-				O	-
Punatsangchhu	420/220	-	-		O			-
Sarpang	420/132/66	-	--		O			-
Basochhu	66/33	-	-	O				-
Tingtibi	132/66	-	-		O			-
Mangdechhu	66/33	-	-		O			-
Chamkharchhu	132/33	-	-				O	-

Source : Final Report of PSMP, April 2004
(Cct) : Number of circuits of transmission line

Eastern-Western Interconnection of Both Power Systems

(a) Present System

The present power system of Bhutan consists of two individually operated systems; the eastern system supplied energy by Kurichhu power station and the western system supplied by Chukha and Basochhu power stations. Both systems are not interconnected. Since each system is connected through Indian north-eastern grid, both systems are virtually interconnected through the Indian grid. Therefore, PSMP's viewpoint is that further interconnection of both systems within Bhutan's territory would not be needed.

(b) Interconnection Plan

Partial domestic interconnection systems in Bhutan will be inevitably formed through developing various power projects. In the project of Punatsangchhu-I power station (scheduled to be commissioned from 2012) in the western system, a 400 kV transmission line will be constructed to India via Sarpang substation (400/132/33 kV). A new 220 kV line will connect the Punatsangchhu-I power station with Simtokha substation, main station in Thimphu, via Basochhu-II power station. While, the Sarpang substation is to be connected with the eastern power system by 132 kV (heat capacity of 80 MW) line before 2012. Thus, when the development of the Punatsangchhu-I power station and transmission line expansion is realized, the interconnection of the eastern and western systems is established. 400 kV transmission line for export electricity will be constructed according to new powerhouse development, but there is no specific plan to reinforce the domestic interconnection lines at present.

(c) Issue of Power Supply Shortage in Eastern System

Peak demand of the eastern system under high growth scenario in the year 2007 will grow to 78 MW including 20 MW of a new industrial estate at Deothang in Samdrup-Jongkha Dzongkhag. As discussed in the forthcoming Section 12.7, the peak demand will exceed the actual output (48 MW) of Kurichhu power station. The supply shortage will continue until the year 2012 when a 132 kV interconnection line will be established. During the period, surplus power of the western system will be wheeled to the eastern system through Indian grid. Under the medium growth scenario, 5 to 6 MW shortage in the eastern system is apprehended. After 2014 when completion of Mangdechhu power station is scheduled, no issue of power shortage in the eastern system is foreseen.

(d) Reinforcement of System Interconnection

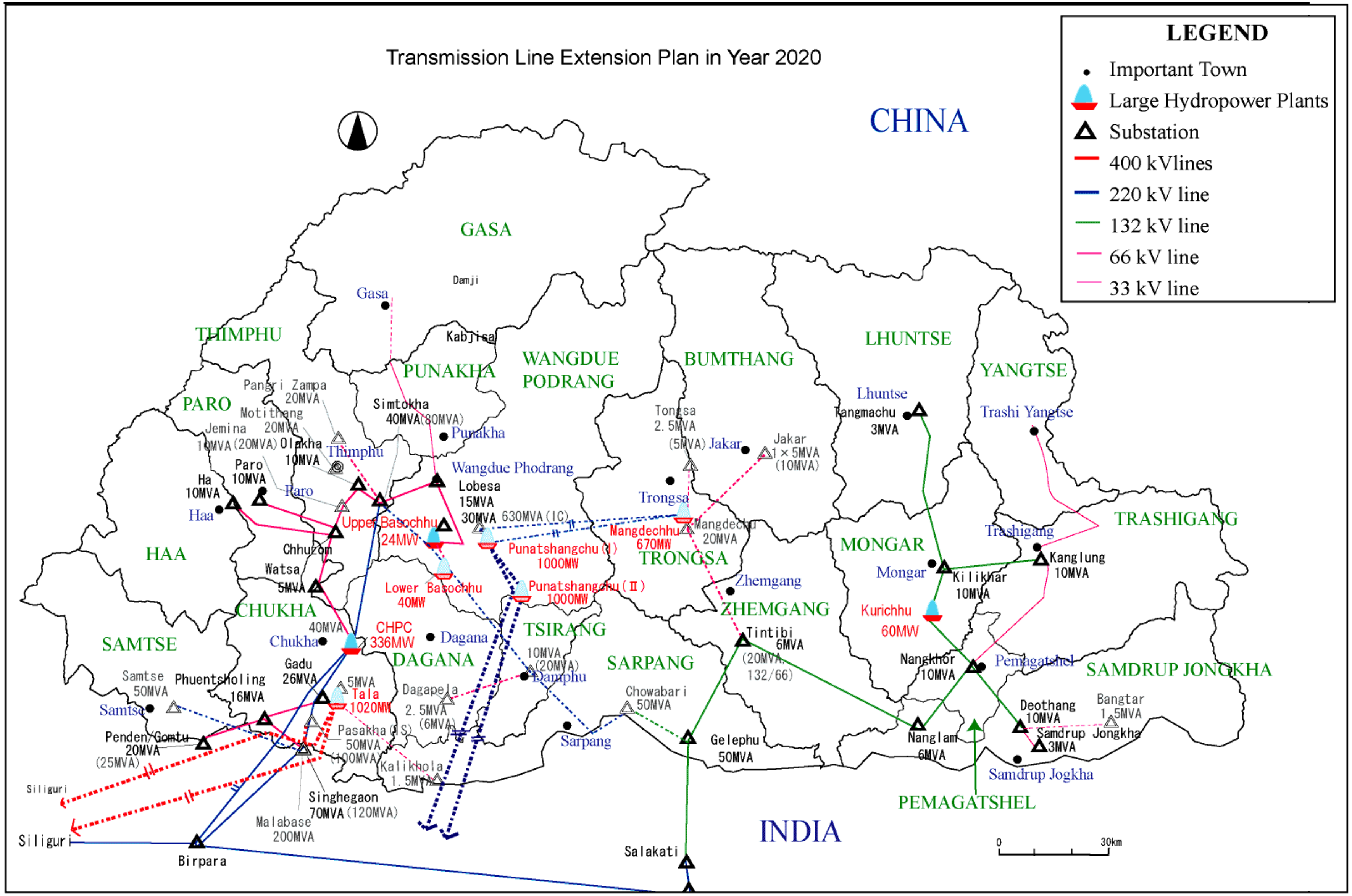
Although there is no other specific plan of the system interconnection than that via Sarpang, DOE examines following alternatives for formation of the domestic loop interconnection.

(i) 132 kV Simokha-Trongsa-Jakar-Kilikhar and Trongsa-Mangdechhu

(ii) 220 kV Simtokha-Trongsa-132 kV Jakhar-Kilikhar and 132 kV Trongsa -Mangdechhu

(iii) 400 kV Punatsangchhu-I-Mangdechhu -132 kV Jakhar-Kilikhar

The above alternative (iii) runs in Black Mountain National Park over its whole route length of 70 km, and no access roads are expected along the route, therefore it deems very difficult to be materialized. Alternatives (i) and (ii) are more realistic due to routing along the east-west highway running in the central part of the country and passing through major towns. Considering the transmission capacity, 220 kC backbone interconnection is recommended. By this alternative (i) or (ii), domestic loop interconnection will be established. Which transmission system to be applied would be a matter of national policy of self-power supply; interconnection through the Indian grid or interconnection through the domestic loop.



Report of PSMP, April 2004

Figure-5.2.1 Power System Map in 2022

5.2.5 Comprehensive Development Program by 2022

(1) Power Facilities

Table-5.2.4 summarizes the development program recommended in PSMP for the hydropower station, transmission line, and substation facilities. Tala (1,020 MW) power station is under construction in the western power system. New 400 kV transmission lines on two routes from Tala power station to India are also under construction.

Table-5.2.4 Long-term Development Plan for the Power System by 2022

Power Station or Domestic-use Line/Substation	Construction Period	Investment (10^6 US$)	Max. Output (MW)
Punatsangchhu – I power station	2007-2011	861.3 (*)	973
Mangdechhu power station	2009-2013	587.7 (*)	651
Punatsangchhu – II power station	2011-2015	875.1 (*)	949
Chamkharchhu – I power station	2014-2019	546.8 (*)	651
Chamkharchhu – II power station	2018-2022	407.0 (*)	551
220 kV, 132 kV, 66 kV Lines	By 2007	12.0	-
132 kV & 66 kV Substations(5 sites)	By 2007	10.0	-
220 kV, 132 kV, 66 kV Lines	2008-2012	10.8	-
132 kV & 66 kV Substations (3 sites)	2008-2012	9.0	-
66 kV Lines	2013-2017	1.0	-
66 kV Substation	2018-2022	1.5	-
Reinforcement of Existing Lines and Substations for increasing demand	2007-2022	15.0 (**)	-
Total Investment		3,337.2	

Source : PSMP (*) : including costs for lines for export-use. (**) : Estimate of JICA Study Team (additional transformers/switchgear, etc.)

(2) National Load Dispatching Center (NLDC)

The eastern and western transmission systems are managed and operated individually at present and the country-wise power system management is not carried out.

More reliable power supply is required in accelerating industrialization of the country and expanding power networks to rural areas. The present separated power system will be interconnected in the near future, and the comprehensive system operation will be more complicated. Therefore, supervising and controlling efficient operation and maintenance of the interconnected national level system's essential, and NLDC is required for it. Functions of the NLDC is expected to contribute improvement of system reliability, shortening of power interruption time, reduction of system energy loss, efficient operation and maintenance duties, and so on.

DOE ordered Power Grid Corporation India to conduct the feasibility study about the establishment of NLDC and received the report in July 2003. The plan recommendation in the report is the maximum utilization of the existing control and communications equipments provided in the system.

Followings are the representative functions of the NLDC.

- Real-time data acquisition, data processing, and calculation of power system and facilities

- Analysis of operation sequence of power system and instructions on operation of power facilities
- Preparation and instruction of the most economical output planning of each power station
- Preparation of generation program taking into account the demand forecasts of the next day and next week, and also interchange transaction evaluation
- Controlling by the monitor of demand/supply balance from power flow and frequency of transmission lines
- Preparation of economical solution of system faults

In the eastern system, PLC communications facilities are installed to connect Kurichhu power station, all substations, and Nangkhor Master Center. The existing communications facilities in the eastern system are fully utilized, accordingly. The report recommends that the Master Center and NLDC connected through a leased communications lines or VSAT. In the western power system, OPGW is suggested to be utilized. The OPGW will connect all power stations and substations to NLDC.

The cost for establishment of NLDC and whole network is estimated at about 167 million Nu. on the price level of the year 2003 including costs for facilities, land, installation, and consulting fee. The report states that the investment will be recovered in 4.5 years taking into account various benefits from the recommended system.

For efficient and economic operation of the comprehensive power system, the NLDC and network are expected to be operated before the year 2012, when the domestic trunk power lines and eastern-western interconnection grid in the south trough Sarpang substation with 400/132 kV lines will be materialized. Therefore, detailed design of the facilities and arrangement of the project fund and budget are required at the earliest time, as well as capacity building of the personnel.

5.2.6 Procurement of Funds

According to the estimate of PSMP, total investment required for the 5 hydropower stations to be developed by 2022 is US$3,300 million at the present values of the year 2003, as shown in **Table-5.2.4**. Total investment for all facilities, including new transmission lines for domestic supply, substations, and necessary reinforcement for the lead increase of HV systems amounts to US$3,400 million.

PSMP points out the difficulties in securing the financial sources for those development plans. Although Indian investment is confirmed for the Punatsangchhu-I project, domestic financial resources are limited. PSMP emphasizes that public funds available for large infrastructure projects in developing countries were far short of the requirements, and development and ownership of new power stations are passed on to private investors more and more frequently. However, the commercial priorities of private developers tend to favor other forms of generation than hydro, i.e., thermal generation with shorter construction periods, earlier return of invested capital, and lower perceived risks. PSMP says that the need of India to import hydropower in the future is obvious, but the financial capacity in

India is limited. In addition, environment issues for large hydro is foreseen. PSMP explains that privately financed projects elsewhere are typically in the range below 300 MW, however the planned projects are from around two to three times the indicated upper limit range, and that to overcome the problem of size, a public-private ownership seems to be necessary together with the firm cooperation with international lending agencies such as the World Bank or Asian Development Bank. Furthermore, potential sources of financing should be reserved for the largest projects, leaving the more moderately sized projects for international financing with private participation.

5.2.7 Power Supply to Off-grid Areas

PSMP only suggests options for power supply to off-grid areas. No recommendation is stated for specific alternatives for the areas where it is difficult to expand the grid due to the accessibility and economic problems. PSMP suggests that a study should be conducted to compare the feasibility of grid extension and small systems powered by diesel or mini hydro generation for power supply to off-grid areas. For the more remote areas, PSMP states that the more problematic solutions should be examined in terms of construction costs, the availability of the necessary operating skills, carrying out repair and maintenance tasks, and the provision of fuel for diesel generator for mini hydro and diesel option.

As for biomass or biogas generation PSMP states that it is not effective in Bhutan because of low availability of fuel materials. Options of wind power or thr combination of wind-diesel generation is not recommended because: no wind is data available; it is less reliable; and more costly than diesel or small hydro at the present condition of technological development.

For application of SHS option using PV, PSMP concludes that: the people’s needs will not be met due to an unstable energy supply because of variation in the natural environment; low generation during winter season; and difficulties of maintenance of batteries and chargers. On the other hand, PSMP suggests that the dealers should be responsible for repair and maintenance of PV equipment.

5.3 Review of the Distribution Line Expansion Plan (ADB/RE-1, RE-2 and RE-3)

5.3.1 The Overview of the Distribution Line Expansion Plan (ADB/RE-1, RE-2 and RE-3)

In Bhutan, three rural electrification projects financed by ADB have been implemented:

1) ADB/RE-1, planned in 7th FYP (1992 to 1997), was completed in June 2000 and about 3,000 households were electrified.

2) ADB/RE-2, planned in 8th FYP (1997 to 2002), was completed in December 2003. Although at first about 6,000 households in 150 villages were planned to be electrified in the project, about 7,000 households were already been confirmed as electrified by January 2004, and now more than 10,000 households in total will eventually be electrified.

3) ADB/RE-3 is currently in the implementation stage (from 2002 to 2007) and about 8,357 households are expected to be electrified.

The consultants the projects are WORLEY (New Zealand) for ADB/RE-1, TATA Consulting Engineering (India) for ADB/RE-2, and SMEC (Australia) for ADB/RE-3.

The planned extensions of medium voltage lines (33 kV and 11 kV) in each RE project are described in **Table-5.3.1**.

5.3.2 ADB/RE-1and RE-2

In ADB/RE-1, the electrification plan was drawn up for about 3,000 households in 7 Dzongkhag: Chukha; Paro; Punakha; Trashigang; Yangtse; Thimphu; and Wangduephodrang; from the requested 5,690 households in 12 separate Dzongkhags.

The target Dzongkhags were chosen based on factors such as economic and financial viability and socio-economic benefit, and thereby, five (5) Dzongkhags, Bumthang, Mongar, Samtse, Sarpang and Trongsa, were excluded from the project.

The project includes the construction of the Basochhu 220 kV transmission line (Basochhu-Simtokha substation). The cost for distribution project was estimated to be US$7.5 million.

In ADB/RE-2, the project for about 6,000 households in 150 villages of 15 Dzongkhags, the targets for electrification were chosen considering: 1) technical conditions such as the generation capacity, load current and voltage drop and line capacity; 2) future grid expansions with Kurichhu and Basochhu hydro projects; and 3) the fund limitations.

The total cost was about US$12.1 million, consisting of about US$10 million expected from a foreign loan. The electrification cost per household was about US$2,000.

5.3.3 ADB/RE-3

ADB/RE-3 is the project for about 8,357 households in eight (8) Dzongkhags. The number of target households was reduced from 15,000 households in 20 Dzongkhags because of the high cost, US$21 million. The selection of the targets was performed using the following procedure.

Firstly, the number of households was reduced to about 11,500 in 12 Dzongkhags by the following steps:

- The Dzongkhags that have a prospective transmission plan were deleted.
- The remoted areas where electrification cost was high were deleted.
- The Dzongkhags that installation of facilities are required to be installed in the National Park were deleted.

Secondly, 8,357 households including about 1,600 to 3,500 poor households (20-43% of all target households) in eight (8) Dzongkhags were chosen considering the project cost and the economic index such as EIRR.

The total project cost is estimated at US$11.38 million and the electrification cost per household is about US$1,400.

9th Five Year Plan target is still 15,000 households and not reduced. But so far, the number of households of which funding is secured is 13,781 through various donors/schemes (8,357 households from ADB, 3,799 households from SDS (Netherlands), 1,096 households from Austrian Coordinate Bureau funding, and 529 households from RGoB). This also includes the number of households electrified under fund savings from ADB/RE-2 and SDS/RE-1. Although DOE has a will to realize to electrify remaining 1,219 households in 9th FYP the funding is not secured.

Table-5.3.1 Distribution Line Extension Planning in Rural Electrification Project (ADB/RE-1, ADB/RE-2, ADB/RE-3)

(Unit: km)

Dzongkhag	ADB/RE-1			ADB/RE-2			ADB/RE-3		
	33 kV	11 kV	Total	33 kV	11 kV	Total	33 kV	11 kV	Total
Thimphu	0	8	8	35.4	13.6	47.0	17.87	0.79	18.66
Chukha	24	0	24	26.8	6.1	31.9	71.14	25.07	96.21
Haa	0	0	0	0	0	0		12.36	12.36
Paro	0	13	13	24.1	16.4	40.5	47.75	13.06	60.81
Samtse	25	0	25	23.4	0	23.4		51.88	51.88
Tsirang	0	0	0	0	0	0	1.69	35.31	37.00
Dagana	0	0	0	0	11.7	11.7	15.46	14.4	29.86
Punakha	45	0	45	36.8	0	36.8	34.27	4.5	38.77
Gasa	0	0	0	0	0	0	29.86		29.86
Wangduephodrang	19	0	19	15.5	0	15.5	43.91	22.77	66.68
Bumthang	20	0	20	0	3.6	3.6	0	44.76	44.76
Sarpang	30	0	30	0	6.4	6.4	49.64	8.9	58.54
Zhemgang	0	0	0	0	0	0	38.13		38.13
Trongsa	19	0	19	0	0.1	0.1	49.31		49.31
Lhuntse	0	0	0	0	23.2	23.2	34.22	20.51	54.73
Mongar	2	0	25	34.0	26.0	60.0	63.16	18.34	81.50
Pemagatshel	0	0	0	33.4	11.1	44.5	31.14	11.28	42.42
Samdrup Jongkhar	0	0	0	0	0	0	46.1	30.71	76.81
Trashigang	29	0	0	2.5	23.9	26.4	22	71.76	93.76
Yangtse	45	0	0	13.4	0	13.4	51.7	5.06	56.76
Total	**252**	**21**	**273**	**245.3**	**142.1**	**387.4**	**647.35**	**391.46**	**1038.81**

出典：DOE

Table-5.3.2 The Number of Electrified Households

Dzongkhag	ADB/RE-1	ADB/RE-2
Thimphu	104	738
Chukha	597	464
Haa	0	0
Paro	160	294
Samtse	0	231
Tsirang	0	0
Dagana	0	94
Punakha	585	473
Gasa	0	0
Wangduephodrang	201	315
Bumthang	0	98
Sarpang	0	189
Zhemgang	0	0
Trongsa	0	14
Lhuntse	0	265
Mongar	0	828
Pemagatshel	0	828
Samdrup Jongkhar	0	
Trashigang	750	739
Yangtse	750	440
TOTAL	**3,147**	**6,010**

出典：DOE

Table-5.3.3 Overview of ADB/RE-3

Dzongkhag	Electrification Cost per Household (US$)	The Number of Households	EIRR (%)
Chukha	1,890	901	10.7
Lhuntse	1,691	631	12.0
Mongar	1,634	1,093	12.5
Pemagatshel	1,351	981	14.9
Punakha	1,423	521	14.2
Samtse	1,229	1,259	16.3
Sarpang	1,267	936	15.8
Trashigang	1,171	1,729	17.0

出典：DOE

5.4 Development Planning by Off-grid Power Supply

5.4.1 Micro Hydro Power

Many small hydropower plants have been in operation in Bhutan, including 13 small hydropower plants built with grant aid from the Government of Japan.

However, DOE/BPC expects, based on their experiences, that the demand for electricity will soon exceed supply despite the hydropower plants are constructed. Besides, it can also be an issue that it is more difficult to maintain civil engineering structures and turbine generators than to maintain distribution lines. Although the small hydropower plants are maintained by BPC staff at the moment, it will be difficult to continue this practice, according to DOE/BPC. It would be ideal that the local villages maintain the power plants by themselves, but since the facilities are designed for engineers' use, it is not promising that the villagers could operate them properly. The issues mentioned above have to be considered when planning off-grid small hydropower plants in the rural areas.

When it comes to the construction of small hydropower plants, roads for trucks to transport equipment such as turbine and generators are required. However, if the proposed site were not easily accessible, it could be an obstacle in terms of transportation, construction methods, cost, and maintenance.

Up until the present, surveys and planning for small hydropower, except surveys for projects where construction has been done, were carried out by the Central Water Commission of India (1980's), Swedish technical assistance (1999), UNDP/GEF (2000)[1], as well as by Bhutan's DOE.

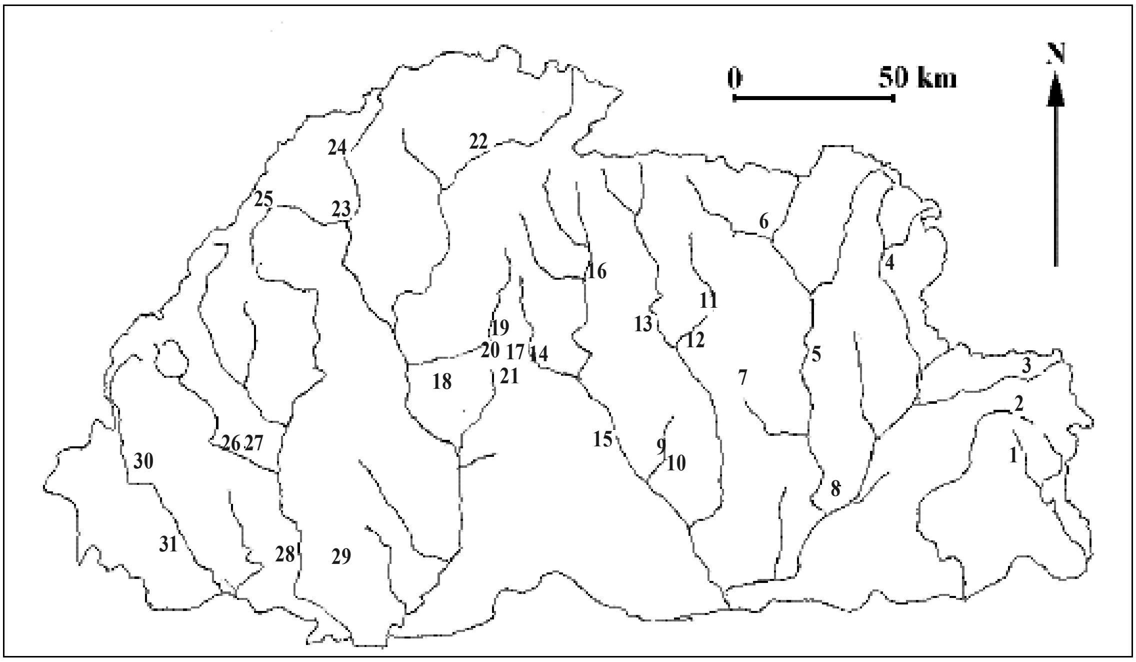
However, each of the proposed sites in those surveys is located in areas that are relatively accessible and/or already electrified by the grid, or that are planned to be connected to the grid in the near future.

There are only two small hydropower projects that have already been selected for implementation. One is a demonstration project in Sengor, Mongar Dzongkhag undertaken by UNDP/GEF and RGoB, and the other is a small-scale CDM project in Trongsa, which was started in 2004 by e7, an NGO organized by electricity companies from seven (7) developed countries.

(1) Survey by Swedish Technical Assistance (1999: Phase-1)

In this survey, Sustainable Mini/Micro Hydropower Development for Rural Electrification, the 31 potential sites were selected by DOP (as DOE was previously called), which are shown in **Figure-5.4.1** and **Table-5.4.1.** Those were screened by various criteria and reduced to eight (8) sites, and field studies were conducted on these eight (8) sites. The finally selected eight (8) potential sites are Sakten (Trashigang Dzongkhag, 150 kW), Autsho (Lhuntse, 150 kW), Sengor (Mongar, 50 kW), Tang (Bumthang, 200 kW), Tali/Buli (Zhemgang, 200 kW), Khotokha (Wangduephodrang, 100 kW), Dorokha (Samtse, 750 kW), and Gasa (100 kW).

[1] The surveys conducted by Sweden and UNDP/GEF were successive, and each of the two phases was carried out with each fund.



Source : Project INT/94/R13 – Swedish Fund for Consultancy Services 98 BHU 3150 Micro/Mini Hydropower Development Project, Final Report, SwedPower, 10 Jan. 2000.

Figure-5.4.1 Potential Sites for Small Hydropower Selected by DOP (as of 1999)

Table-5.4.1 Potential Sites for Small Hydropower Selected by DOP (as of 1999)

Dzongkhag	No.	MHP Proposed Site Name	P (kW) by Swdish Study 1999	P (kW) by UNDP/GEF Study 2000	Notes
Samdrup Jongkhar	1	Shingkhar / Lauri			
Trashigang	2	Merak			
	3	Sakten	150	200	
Yangtse	4	Upper Yangtse			
Lhuntse	5	Autsho	150		Grid will connect (9thFYP)
	6	Upper Lhuentse			
Mongar	7	Sengor	50	50	UNDP/GEF.Project (2004-)
	8	Kengkhar			
Zhemgang	9	Tali	200		
	10	Buli			
Bumthang	11	Tang	200	400	Grid will connect (9thFYP)
	12	Tangsebi			Grid will connect (9thFYP)
	13	Shuri Kertsho			
Trongsa	14	Chendibji			e7 CDM Project (2004-)
	15	Korphu			
	16	Upper Bji			
Wangduephodrang	17	Sephu			
	18	Khotokha	100		Grid will connect (9thFYP)
	19	Dangchu			
	20	Nobding			
	21	Phobjikha			PV
Gasa	22	Lunana			
	23	Gasa	100	150	Grid will connect
	24	Laya			
Thimphu	25	Lingshi			DOE Study (2003-2004)
Paro	26	Nagu			Grid will connect (9thFYP)
	27	Bitekha			Grid will connect (9thFYP)
Chukha	28	Dungna			Grid will connect (9thFYP)
	29	Getana			
Haa	30	Sombeykha			
Samtse	31	Dorokha	750		

Prepared by JICA Study Team (source book : Project INT/94/R13 – Swedish Fund for Consultancy Services 98 BHU 3150 Micro/Mini Hydropower Development Project, Final Report, SwedPower, 10 Jan. 2000.)

(2) Survey by UNDP/GEF PDF-B (2000: Phase-2)

A more detailed survey was carried out on the four (4) sites (Sakten, Sengor, Tang, and Gasa), which were chosen by DOP out of the eight (8) potential sites selected in Phase-1.

As for Gasa and Tang, however, it has almost been decided to be connected to the grid in a few years, and Sakten is also considered for electrification by grid extension, according to DOE.

The consultants are ETC Energy (Netherlands), ENTEC (Switzerland), and a Bhutanese consultant. **Table-5.4.2** represents an overview of the survey conducted by UNDP/GEF (2000).

Table-5.4.2 Plan for Small Hydropower Proposed in the UNDP/GEF Survey (2000)

Site	Sakten	Sengor	Tang	Gasa
Distance of site from road	25 km	on road	1.5 km	30 km
Type of scheme	run-of-river	run-of-river	run-of-river	storage
Type of intake	diversion weir	Tyrolean weir	diversion weir	storage intake
Location settling basin (= desilter)	20m after intake	15m after intake	10m after intake	20m after intake
Type of headrace	open canal	low pressure pipe	open canal	none
Headrace canal/pipe length	950 m	660 m	2400 m	-
Location of forebay	end of headrace	none	end of headrace	storage as forebay
Penstock	steel pipe	steel pipe	steel pipe	polyethylene/steel pipe
Penstock length	283 m	372 m	410 m	881 m
Penstock diameter	0.350 m	0.250 m	0.500 m	0.250 m
Location of powerhouse	at river bank	at river bank	at river bank	at river bank
Type of turbine(s)	Turbo impulse	Crossflow	Crossflow	Pelton
Gross Head	128 m	102 m	105 m	228 m
Net Head	117 m	85 m	102 m	204 m
Design Flow	230 l/s	90 l/s	670 l/s	95 l/s
Available Flow	240 l/s	120 l/s	680 l/s	54 l/s
Installed Capacity	200 kW	50 kW	2 x 200 kW	150 kW
Firm power available	200 kW	50 kW	400 kW	94 kW
Peak power demand forecast (Year 2010)	200 kW	45 kW	393 kW	149 kW
Assumed energy load factor	0.35	0.35	0.35	0.35
Estimated annual energy generation (Year 2010)	595 GWh	149 GWh	1,190 GWh	446 GWh
Length of distribution lines, 0,4 kV	3 km	1 km	10 km	5 km

Source: UNDP/GEF, "Bhutan Mini And Micro Hydropower Development Project", ETC Energy, ENTEC, November 2000

(3) Sengor Micro Hydropower Demonstration Project funded by UNDP/GEF

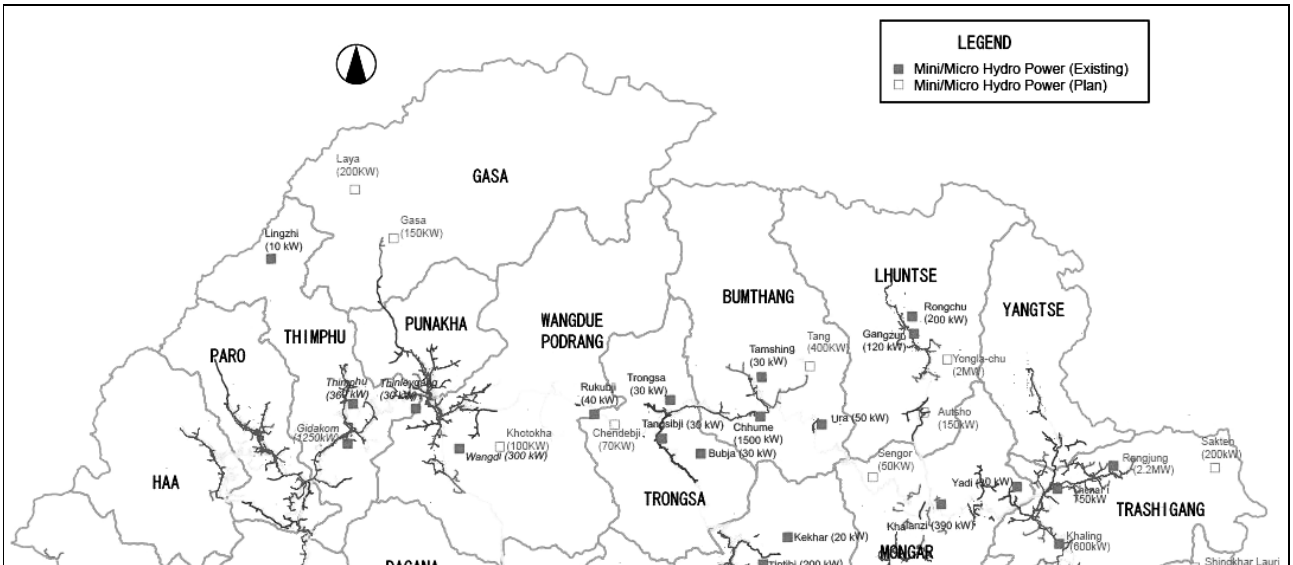
UNDP/GEF has decided to implement a demonstration project in Sengor (Mongar Dzongkhag) for human resource development, empowerment of the organization, and sustainable operation and maintenance. The Project is to be started in 2005. The fund accounts for US $ 520,000 from GEF and US $ 335,000 from UNDP. In addition, DOE is supposed to take the initiative in this program. The construction, operation and maintenance, and monitoring will be carried out by villagers participation. In addition, the nurturing of technicians are planned in order that the villagers can operate and maintain the power plants by the themselves. Since the survey by UNDP/GEF was finished, the number of households in Sengor has been increasing year by year; therefore, DOE has revised the power demand forecast and subsequently increased the design output from 50 kW to 100 kW.

But then, the river flow rate of the selected site in Sengor is reduced low during the dry season and output limit is estimated to be 50 kW. To get over this, DOE not only conducted a survey to find out alternative potential sites but also designed the capacity of the head tank larger so as to reserve the water in the off-peak hours and use it in the peak hours to increase the output to 100 kW.

(4) Other Small/Micro Hydropower Planning

In addition to the plans mentioned above, DOE has carried out a survey regarding a new plan for a small hydropower plant in Lingzhi, which is in the northern part of Thimphu. The preliminary survey by DOE shows that there are 4 alternative sites, which allow 35-90 kW of power generation and electrification for 76 households. But the surrounding area consists of 7,000 m high Himalayan Mountains, which makes access difficult.

Figure-**5.4.2** indicates the small hydropower sites surveyed and planned so far.



Prepared by JICA Study Team

Figure-5.4.2 The Small Hydropower Sites under Survey or in the Planning Stage

5.4.2 PV Power Generation

In 9th FYP, it is mentioned that the areas where power supply is impossible by grid extension or small hydro power and so on, PV energy will be utilized. The establishment of small PV power generation systems installed in a household (Solar Home System: SHS) and Solar Hot Water Systems (SHWS) is scheduled with this plan as a use of solar energy.

(1) Solar Home System (SHS)

In the case of SHS it is scheduled to install about half the number of systems shown in 9th FYP from July, 2004. The selection of installation sites is in the process. The procedure is as follows: RED informs the possible number of systems to provide to Dzongkhags; each village discusses the viability of the proposals amongst themselves and submits their decision to the Gewog; and after conformation by Gewog it is submitted to Dzongkhag. RED is planning to purchase the systems through a biding process and Dzongkhag and each individual user needs to bear the transportation and installation cost by themselves. The execution period, number of systems, and sources of funding are mentioned below and **Table-5.4.3** summarizes the system components and design parameters.

4) Execution Period : July 2004 to June 2005

5) Total Systems : 450

6) Source of Funding : RGoB

7) Total Budget : 13 million Nu.

Table-5.4.3 System Components and Deign Parameters

S. Nos.	Parameter	Value	Unit
1	Yearly average Horizontal Solar Irradiation (Country Average)	4.25	kWh/m^2・day
2	Daily operation hours	4	Hours
3	Derating factor of PV module (Dust, Temp. & so on)	10	%
4	Days of Autonomy	3	Days
5	Battery Efficiency	85	%
6	Depth of Discharge (DOD)	80	%
7	Ballast of Efficiency of Light	80	%
8	Coldest average temperature	-20	℃
9	Temperature Derating factor of Storage Battery	85	%
10	Provided length of Cable (Size: 2.5 Sq. mm, Copper)	50	meter
11	Charge Controller (12 V DC type)	10	Amp
For the Schools, Monasteries and other public Institutions			
12	CFL Lights (Number of lights 5)	11	Watt/light
13	PV module specification (55 Wp x 2 nos.)	110	Wp
14	Storage Battery (Capacity at C10 rate, Tubular, Deep Cycle)	110	Ah
For the Rural households			
15	CFL Lights (Number of lights 3)	11	Watt/light
16	PV module specification	70	Wp
17	Storage Battery (Capacity at C10 rate, Tubular, Deep Cycle)	70	Ah

Source by Renewable Energy Division (RED)/ DOE

As there is limitation in the budget, the above program have not been able to establish. Instead of above mentioned program new announcement was made in May 2005. The number of system estimated to be installed within the program, total budget and type of system is as mentioned below.

Table-5.4.4 The New Announcement of Solar Program in 2005

Item	No.s	Unit	Note
Nos. of PV systems	258	sets	
Nos. of Solar Lantern	42	sets	
Total Investment	around 5.98	million Nu.	
Each PV system			
PV module	60	Wp	
Type of Lamps	11	W	CFL
Lamp in each set	3	no.	
Capacity of Battery	70	Ah	deep cycle tubular
Days of Autonomy	3	days	
Daily hours of use	4.5	hours/day	
Each set of solar lantern			
PV module	10	Wp	12 V
Type of Lamp	7	Wp	CFL
Capacity of Battery	7	Ah	maintenance free
Daily hours of use	4.5 to 5	hours/day	estimated value

Source：Renewable Energy Division (RED)/ DOE

(2) Solar Hot Water Systems (SHWS)

As for Solar Hot Water Systems (SHWS), the size of the system, necessary budget, and execution plan is still in the process of examination.

Table-5.4.5 summarizes the outline of the renewable energy program in 9th FYP and **Table-5.4.6** shows the number of SHS and SHWS systems scheduled in 9th FYP.

Table-5.4.5 Outline of Renewable Energy Program

1. Sector	Electricity (Light)
2. Location	20 Dzongkhags
3. Executing Agency	Department of Energy (DOE)
4. Implementing Agencies	Dzongkhag Electricity Section of BPC and Alternate Energy Division (RED)
5. Estimated capital cost during 9th FYP	200 million Nu.
6. Duration	5 years
7. Implementing Date	From the date that the fund is released
8. Status	Fund mobilization

Source：Renewable Energy Division (RED)/ DOE

Table-5.4.6 The Number of SHS and SHWS Systems

S. Nos	Dzongkhag	Number of System	
		Photovoltaic (SHS)	Solar Hot Water Systems (SHWS)
1	Bumthang	22	10
2	Chukha	60	30
3	Dagana	45	20
4	Gasa	8	5
5	Haa	19	10
6	Lhuntse	42	20
7	Mongar	73	40
8	Paro	47	30
9	Pemagatshel	65	30
10	Punakha	35	20
11	Samdrup Jongkhar	67	20
12	Samtse	83	25
13	Sarpang	62	20
14	Thimphu	43	40
15	Trashigang	115	60
16	Yangtse	54	30
17	Trongsa	24	20
18	Tsirang	46	20
19	Wangduephodrang	55	30
20	Zhemgang	35	20
Total		1,000	500

Source: Renewable Energy Division (RED) / DOE
Note: (a) For PV system there may be two type of systems.
(1) 3 light system for small households with around 60 Wp Module and 60 to 70 Ah battery.
(2) 5 light system for rather large households with around 110 Wp Module and 110 Ah battery.
(b) The size of the SHWS is not yet decided.
(c) The founding source is not yet finalized.

5.4.3 Biomass Energy

The consumption of the fuel wood per capita in Bhutan is one of the largest in the world. 99.7% of non-electrified households use fire wood for cooking and 81.7% for heating[2]. In rural areas, the consumption of fire wood per capita is 3.95 kg per day[3], corresponding 1.27 tons per year. A data[4] shows that 86.4% of domestic energy consumption is covered by fire wood. The effective use of fire wood and charcoal is thus recommended since the reduction of fire wood consumption directly affects to the preservation of forest resources.

GEF(Global Environment Facility) by UNDP provided SGP(Small Grants Programme) and implemented Wood Energy Conservation Project from 1998 to 1992 in Trashigang and Tsirang Dzongkhags. Similar project is now being planned by Austrian-Bhutan Energy Sector Progam, and RED is preparing the proposal for it.

5.5 Activities of Donors in the Power Sector

There are several program projects by donors in the power sector in Bhutan. **Table-5.5.1** indicates the overview of each activity and budget.

[2] Fuelwood Consumption and Alternative Energy Sources in Bhutan, 2001, Norlha
[3] Village Baseline Survey（JICA Study Team, 2004）
[4] Wood Energy Sectral Analysis,1991, FAO

Table-5.5.1 Activities and Budget of Each Donor

Donor	Project Title	Type	Duration	Amount ($x10^6$US$)	Remarks
ADB	Power System Development	PPTA	1993-1994	0.245	WORLEY
	Rural Electrification Project (ADB/RE-1)	Loan	1995-1999	7.500	
	Second Rural Electrification	PPTA	1997-1998	0.600	TATA
	Institution & Financial Development DOP	PPTA	1997-1998	0.400	
	Sustainable Rural Electrification (ADB/RE-2)	Loan	1997-2002	-	
	Rural Electrification and Network Expansion (ADB/RE-3)	PPTA	2002-2003	-	SMEC
JICA	Establishment Project for Micro Hydropower Facilities (Phase-1)	Grant	1986-1987	-	
	Establishment Project for Micro Hydropower Facilities (Phase-2)	Grant	1991-1992	-	
	Feasibility study of Punasangchu HPP (870 MW)	F/S completed	1999-2001	-	
e7	Chendebji (70 kW)	F/S completed	2001-	-	CDM Project
UNDP/GEF	Rural Energy Development Project, Rangjung	Grant	1994-1996	0.037	
	Mini/Micro Hydro Development Feasibility Study Decentralozation of Rural Electrification (Sakteng :200 kW, Sengor :50 kW, Tang :400 kW)	Grant	1998-1999	0.364	
	Solar Energy Programme Review and Preparation of Sustainable Solar Energy Programmes and Project Proposals in Bhutan	Grant	2001-2002	0.055	
	Replacement of Naked Kerosene Lamp with Solar Lanterns to Reduce Carbon-dioxide Emission by Mendrelgang Farmers Association (MFA)	Small Grants Programme	2003-2004	0.003	
Government of India	Rural Electrification	Grant	1993-1999	1.108	
	Subtransmission and Distribution (Urban Areas)	Grant	1993-1999	0.625	
	Semtokha II	Grant	1993-1994	0.504	
	Mini/Hydel, Thimphu (Rehabilitation)	Grant	1994-1998	0.313	
	Geytsa Pondage Scheme (Rehabilitation)	Grant	1996-1997	0.018	
	Kurichhu Hydro Power Project	Loan	1994-2001	24.045	
	Kurichhu Hydro Power Project	Grant	1995-2001	38.304	
	Tala Hydro Power Project	Loan	1996-2004	132.788	
	Tala Hydro Power Project	Grant	1997-2004	199.151	
	Power Tramsmission Eastern Grid	Grant	1998-2002	18.859	
	Power STD Phase 2 (Thimphu & Paro)	Grant	1998-2002	9.318	
	Eight Mini-Hydels	Grant	1998-2002	4.859	
	Improvement and Upgradation of Transmission Grid	Grant	1998-2002	4.479	
	Rural Electrification Transmission Lines	Grant	1998-2002	1.031	
	Urban Electrification	Grant	1998-2002	6.374	
	Improvement and Upgradation of Electric Services	Grant	1998-2002	9.765	
Netherlands Government	Solar Lighting	Grant	1995-1999	0.472	
	Rural Electrification	Grant	1995-1999	1.373	
	Mini Hydel Kellungchu	Grant	1999-2002	-	
	Rongchhu (Kellungchhu) HPP (200 kW)	Grant	2001	-	
Swedish Fund/GEF	Sustainable Mini/Micro Hydropower Development for Rural Electrification	Grant	1999-2003	0.392	
Government of Norway (NORAD)	Water Resource Management Plan and Hydro Power Master Plan Update	Grant	2002-2004	-	
	Feasibility Study of Mangdechu HPP (360 MW)	Grant	1998-2000	-	
	Mangdechhu HPP (600 MW)	F/S completed	1998	-	
Government of Austria	Rangjung Hydropower Project	Grant	1993-1996	6.415	
	Upper Basochhu Hydropower Project (Phase-1 24 MW)	Grant	1996-2000	14.435	
	Upper Basochhu Hydropower Project (Phase-1 24 MW)	Loan	1996-2000	13.633	
	Lower Basochhu Hydropower Project (Phase-2 38.6 MW)	Grant	2004-	-	Under Construction
	Lower Basochhu Hydropower Project (Phase-2 38.6 MW)	Loan	2004-	-	

Source: Power Data 2000-01, DOP of MIT, etc.
Note: As for the utility capacity in Bhutan, 100 kW and below is defined as Mini/Microhydro, and 100 kW-1 MW as Mini Hydro.

5.6 Roadway Development Planning

In the formulation of the electrification plan in Bhutan, it is important to consider to how to provide electric power to the precipitous mountain areas of which the country consists. When providing electricity to the areas without roads, construction and maintenance is very difficult because of restraints of the availability of applicable materials or utilities, and eventually affects the materialization of the plans. Therefore, the preparation of the rural electrification master plan needs to proceed in consistency with the existing roads and future roadway planning.

In Bhutan, the road network has rapidly developed since the first road development that enabled vehicles to pass in 1959. The FYP on roadway construction started by RGoB in 1961, and 9th FYP (2002-2007) has been in progress. The total length of the roads is about 3,746 km (including 1,558 km of highways). Most of the roads were constructed by DANTAK (a Division of the Indian Border Roads Organization of the Indian Army), and almost all the highways and local roads and approximately 40% of the branch roads have been paved.

Many rural villages, however, are still not able to access to the main roads. In such a situation, the master plan for the roadway planning with assistance of ADB was prepared. This will involve 10th FYP to 13th FYP (2008-2027) and aims at the construction of 2,465 km of roads includes local roads requested by the Dzongkhags. This also includes the Second East-West Highway. When it is accomplished, the rate of the local people who can get home from the roads within a half day on foot will become 30%.

The roadway management and roadway development planning in Bhutan are not unitary managed. Each road is managed by the ministry as shown below:

(1) Ministry of Works and Human Settlement: national highways, district roads, and feeder roads

(2) Ministry of Agriculture: farm, power tiller, and forestry roads

(3) Ministry of Education: school roads

(4) Ministry of Trade and Industry: mining, exploration, industry and power roads

(5) Ministry of Information and Communication: telecommunication roads

(6) Ministry of Health: roads to the basic health units and dispensaries

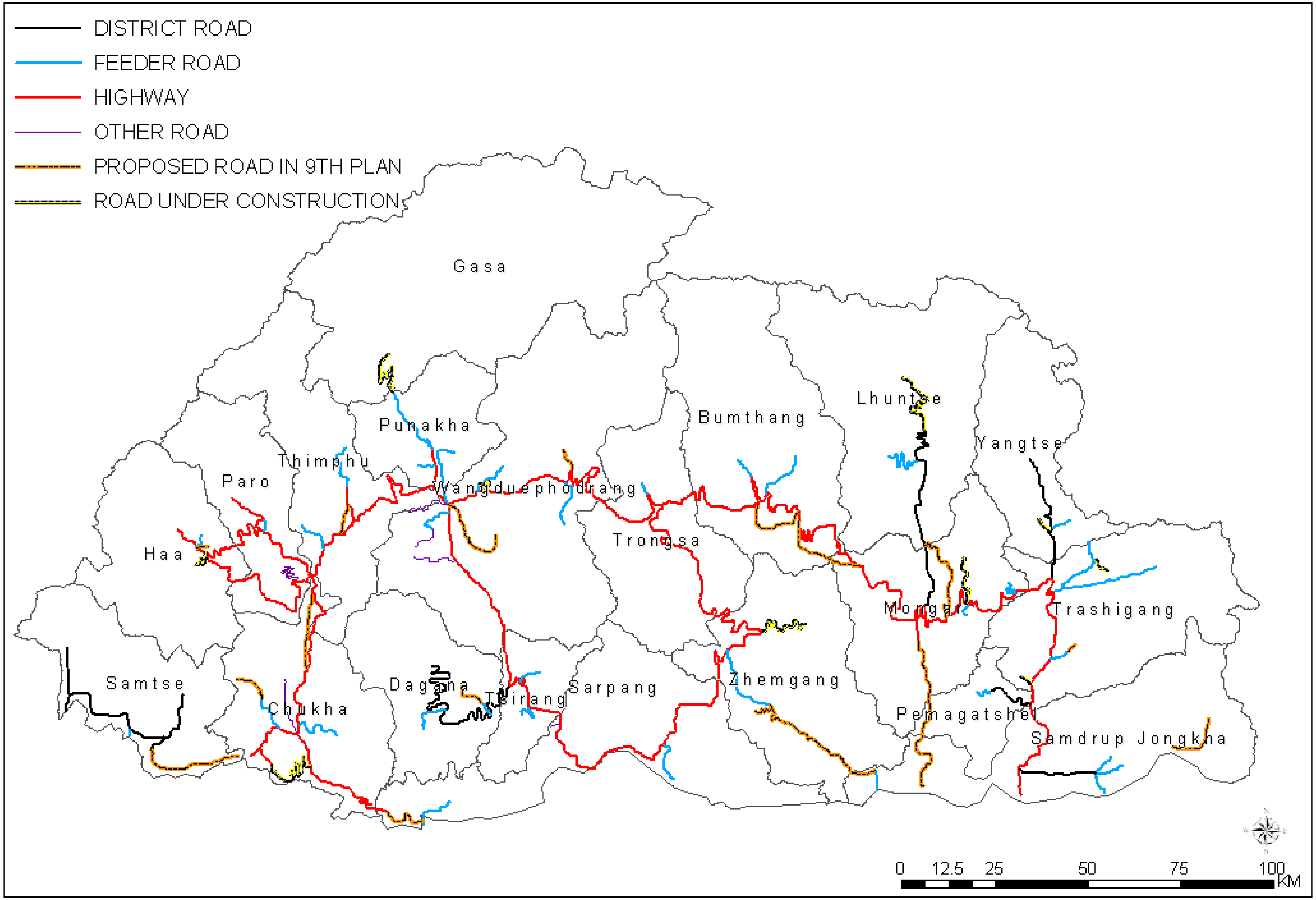
Department of Planning looks after overall planning and coordination, but the management and development planning does not have consistency at present. In addition, the roads and bridges have been constructed properly independently by the donor organizations such as World Bank, UNDP, Government of India, and the Government of Japan etc, detailed information on these existing roads is not grasped.

As for the management of existing road data, these ministries apply almost the same method, but there is no precise and detailed information on GIS or topographical maps other than sketches or simple charts. This is common to the Department of Roads, Ministry of Agriculture, and Ministry of Information and Communication. In the roadway master plan

(**Figure-5.6.1**) by ADB/TA mentioned previously, information is only in the form of sketches in which each city is simply connected with a line and the approximate distance between the cities is shown. Therefore, it cannot be consistent with the GIS data which is prepared in this study.

Consequently, in the phase of specifying the electrification area and formulating the distribution expansion plan, the detailed expansion routes and timing for those implementation need to be determined by identifying the correct locations of existing roads and the roadway development plan.

In addition, the Road Act passed by the National Assembly in 2004 for the first time in Bhutan. The classification of roads, technical criteria and authority of roads will be set down for the unified management of all the roadways in Bhutan by the Department of Roads. Several years would be still required for such unitary management to function enough. The issue previously noted has been recognized to be important in Bhutan.



Source: Road Planning & Management Strengthening Project (ADB/TA) Final Report

Figure-5.6.1 Roadway Network in Bhutan

CHAPTER 6 PRESENT STATE OF THE INFORMATION AND COMMUNICATIONS SECTOR AND THE DEVELOPMENT PLAN

6.1 Information and Communications Associated with Rural Electrification

In rural electrification projects, it is generally difficult to make a profit by only providing power for lighting. It is important to produce various other benefits from electrification, in addition to simply providing electricity. To make this study more effective, the feasibility of number associated activities was examined. This allowed identification of potential benefits that can be brought to rural areas. Maximizing these benefits will help to ensure implementation of the project.

a) Some of the benefits that brought by rural electrification include: Savings as a result of reduced consumption of candles and oil for lamps;

b) Improvement of living standards by having reliable lighting; Creation of time for study; Increased income through having time for side jobs and making handicrafts at home;

c) Reduction in the consumption of fuel wood used for cooking and heating;

d) Health improvement brought about by the reduction of smoke caused by fuel wood use;

e) Time savings due to release from the burden of collecting fuel wood and drawing water; etc.

By incorporating information and communications into rural electrification, various added values will be obtained for both projects in the future. In particular, the availability of the information and telecommunications infrastructure will provide assistance to the local government by allowing networking of the local and the national governmental organizations. It will also provide villagers with access to remote medical care, and bring distance education to the villages. Therefore, development of the information and communications network in parallel with the rural electrification project is expected to be very effective.

a) As for the benefits, other than those mentioned above, it is expected that there will be new possibilities such as: Application to agriculture and creation of new industries; Improvement in production;

b) Remote education and medical care in combination with IT and communications;

c) Improvement in local governmental services;

d) Information transmission from rural areas;

e) Learning about trends in the market;

f) Transmission of information on climate and disasters; and

g) Improvement in public security.

However, rural electrification by itself has little benefit if consumers do not have electric lamps and appliances. On the other hand, if the information and communications network was developed in areas that do not have an adequate and stable power supply, this would provide little benefit to the villagers. Accordingly, development of the information and communications networks together with rural electrification provides synergistic benefits. It is also more economical than developing each service separately, as it allows the sharing of utilities and equipment.

6.2 Present State of Information and Communications Networks and Development Plans

6.2.1 Present State of Information and Communications Network

Telephone, TV, radio and the Internet are used as communication methods. The introduction of these services requires larger electric power capacity than is required simply for lighting. However, expansion of information and communication network contributes the improvement of the communication environment.

Telecommunication Network

The present communications network of Bhutan Telecom Ltd. (BTL) was developed through grant aid from Japan since 1991. The network is based on microwave systems. However, the system will soon reach full capacity because of increased demand for data transmission requirements of the network. In June 2004, BTL started to use optical fiber cables installed along the 66 kV transmission lines to build up the transmission network. In Japan, optical fiber cables, which are more reliable than microwaves, are used as the main lines and microwaves are used as standby (sub line). Installation/extension of the optical fiber cables are also expected in Bhutan.

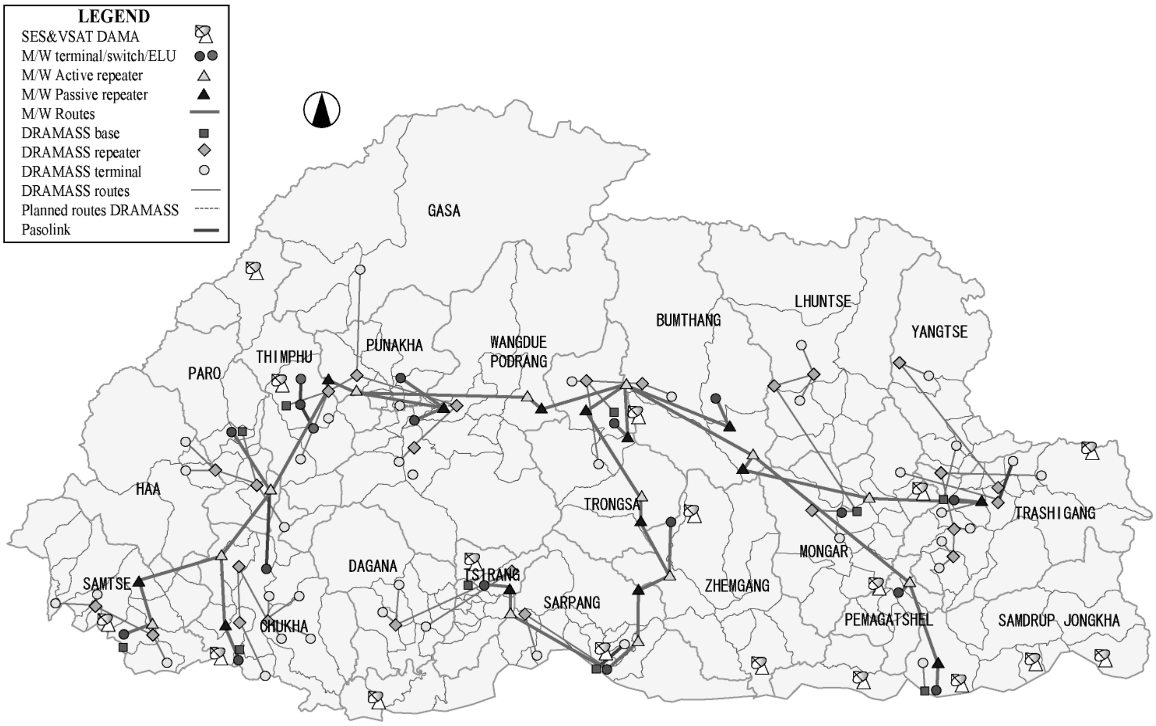
The upgrade work of the microwave transmission network between Thimphu and Trashigang is expected to be completed by September 2005. This network will be upgraded from a PDH[1] system, having a maximum capacity of 34 Mbps, to a SDH[2] system, which will have a maximum capacity of 155 Mbps. The PDH system equipment that is to be removed form the Thimphu to Trashigang link will be used to replace an existing DRMASS[3], which has an even lower capacity.

The number of telephone lines subscribers is 31,896 (as of June 2005) and the dissemination level of telephone lines (number of lines as a percentage of the population) is only 4.3%. There are 14,155 subscribers in the Thimphu exchange area, which is the capital of Bhutan, and 5,533 subscribers in Phuntsholing, which is a border town of Bhutan. These two areas contain more than 60% of the subscribers of Bhutan. There is a plan to increase the saturation level of telephone lines to 7% by 2007.

9th Five Year Plan (FYP) has set a target to cover the entire the country, and BTL is implementing a project for extension of the telephone network to the rural areas. A total of 81 Gewogs are covered now, and another 90 Gewogs will be covered by the end of 2006.

1 Plesiochronous Digital Hierarchy
2 Synchronous Digital Hierarchy - It has more capacity and can handle not only telephone but also TV transmission.
3 Digital Radio Multiple Access Subscriber System

According to the plan, almost all Gewogs will be covered by 2007. WLL[4] will mainly be used for the rural telephone network. BTL has selected the most suitable technology, such as WLL, VHF or VSAT[5] for each area based on consideration of geographical factors. BTL has advised the Study Team that expansion of physical lines (copper lines) to rural areas is too expensive. The present network is shown in **Figure-6.2.1** and the systems are **Table-6.2.1** below.



Bhutan Telecommunications Network

Prepared by JICA Study Team

Figure-6.2.1 Network of Bhutan Telecom Ltd. (As of March, 2004)

Table-6.2.1 Communications System of Bhutan Telecom Ltd. Network

System	Capacity	Positioning at BTL's Network
SDH STM-1 155 Mbps Optical Fiber/Microwave	1,890 voice channels or four channels of TV	SDH system has more capacity than PDH system. It is used as backbone for Thimphu, Paro and Phuntsholing on OPGW and on microwave from Thimphu to Trashigang
PDH 34 Mbps Microwave	480 voice channels	Backbone of telephone network mainly consists of this system. Most of town that has Dzongkhag administrations are connected by the system.
PDH 8 Mbps Microwave	120 voice channels	
DRMASS (2E1)	60 voice channels	Mainly this system is used to branch lines. Some capital towns of Dzongkhag also connected by the system.
CorDECT WLL	12 voice channels	This system is/will be used to connect villages to extend telephone network to rural areas.

Prepared by JICA Study Team

<u>GSM Mobile Phone</u>

4 Wireless Local Loop
5 Very Small Aperture Terminal

GSM[6] phone services were started in Bhutan in November 2003. The service area was originally only along the national highway from Thimphu to Paro and Phuentsholing. However, now Punakha, Wangduephodrang, Gelephu and Samdrup Jongkhar are also covered. The number of subscribers to the service is approximately 28,500 in July 2005, and the number is still increasing rapidly. There are complaints because of congestion in the mobile network, especially at night. BTL has started the expansion work to increase the capacity and overcome the congestion problem.

Internet

DRUKNET is a unit of BTL is the main ISP[7] in Bhutan. People have been able to connect to the Internet, mainly through the Telephone network, since June 1999. Services are available in almost all areas covered by the telephone network. The main users are government organizations, because most private companies and the general population don't have computers. DRUKNET offers leased line services. However, only a few government organizations are users of the service. The number of DRUKNET users was 500 when the service was started, however, it had increased to 3,335 dial-up users and there were 34 leased line users by June 2005. Although DRUKNET has four international connections by satellite, the fee for the connection is expensive. Because of this, the monthly fee for subscribers is expensive, especially for the leased line users.

Most of ministries and public corporations have LAN[8] connected with Internet by leased line, however, some of Dzongkhag administrations are just getting it. Some ministries, departments and public corporations have a network system or plan to connect the central government and offices at the Dzongkhag level individually. But systems are generally designed to be dial-up because leased lines are too expensive. Expansion of information network can bring big possibilities to promote computerization and decentralization.

There are no ADSL[9] services, which is popular in Japan. Experimentation is going on in Japan with PLC[10] systems that use power transmission or distribution lines as the data transmission lines for broadband connections. This technology is only used in Bhutan as a communication line between substations or other BPC bases. Two private companies have started ISP using VSAT.

6.2.2 Development Plan for Expansion of the Information and Communications Network

OPGW[11] has been already installed with almost all transmission lines in the western region of Bhutan. This was installed by BTL on towers owned by Bhutan Power Corporation (BPC). The agreement between these two companies allows BPC to receive maintenance, lease fees, and the right to use 12 of the 24 fiber cores.

6 Global System for Mobile communications
7 Internet Service Provider
8 Local Area Network
9 Asymmetric Digital Subscriber Line
10 Power Line Carrier
11 Optical-fiber Composite Overhead Ground Wire

At present, BPC and BTL are discussing future plans to extend the OPGW network to the eastern area via Gelephu in southern Bhutan. Additionally, the ICT[12] policy document "Bhutan ICT Policy & Strategy" (BIPS) also mentions the joint installation of an optical fiber network and transmission lines. The BIPS document states that transmission lines installed in the future will also have OPGW.

BTL plans to expand the network at least to all Gewog centers by 2020. This will be done as a replacement of facilities installed under the "Rural Telecommunication Project", would be obsolete by then. Additionally, the DIT[13], under MOIC[14], also wants to continue discussions about installation of OPGW with concerned organizations and cable TV operator. DIT plans to have discussions about budgets/funding with other concerned ministries and also donor countries.

According to DIT, OPGW network should have two lines, not only with the east-west transmission lines but also along the east-west highway to make it more reliable. Additionally it has a plan to install optical fiber to Kolkata in India. The optical fiber system will to replace the existing international Internet connection by satellite with an optical fiber system to reduce monthly cost. DIT says there is no detailed plan for expansion of the optical fiber network, however it plans to use it for TV broadcasting, education and the medical field.

The e-Post project run by Bhutan Post in corroboration with ITU[15], UPU[16] and the Government of India is progressing now. The overview of the project is shown in **Table-6.5.1**. Stable power supply and high speed Internet connection can bring much benefit for such project.

6.3 Present State of TV Networks

BBSC (Bhutan Broadcasting Service Corporation) started TV broadcasting in June 1999. It's the only TV station in Bhutan. The present state and development plan for the TV network is as follows.

6.3.1 Present State of TV Networks

People in Thimphu can get broadcast TV programs directly, however, there are only 35,000 TVs in Bhutan[17]. Now they can watch BBSC TV programs in Phuntsholing area in same timing as Thimphu because of OPGW line between Thimphu to Phuntsholing, however the local cable TV operator broadcasts BBSC programs that come from BBSC on videocassettes in another areas. Because of this, programs from BBSC are broadcasted one to four days

[12] Information and Communications Technology
[13] Department of Information Technology
[14] Ministry of Information and Communication
[15] International Telecommunication Union
[16] Universal Postal Union
[17] Media Impact Survey 2003, Ministry of Information and Communication

behind. They hope to expand the TV network. Now all cable TV operators in Bhutan must broadcast BBSC TV programs.

There are 34 operators in Bhutan serving almost all 20 Dzongkhags except for Gasa Dzongkhag. They broadcast not only BBSC, but also Indian, Chinese, British, American and Korean channels like DDI, CCTV, BBC, CNN, and Arirang. A few operators broadcast NHK, Japanese TV. All programs except BBSC come from satellite. Fees for users to subscribe to cable TV are 300 Nu. per month. 30% of this goes to the government. The source of income for the BBSC is contributions from the government and advertisements.

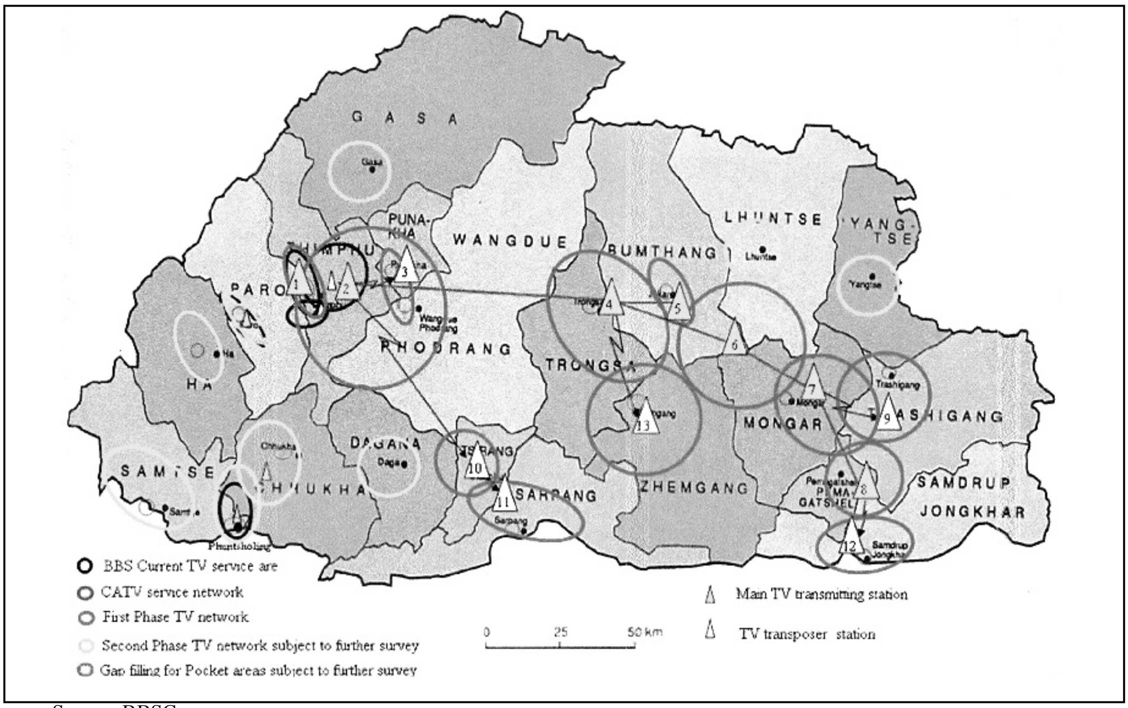
BBSC TV broadcasts programs for only one hour when it started in June 1999, but it broadcasts programs for eight hours now (Dzongkha: Six hours, English: Two hours). It plans to extend the hours, but it will have to improve the quantity/quality of the programs an expert working for BBSC says. The government expects BBSC to carry the role of perpetuating the unique culture/traditions and unification of the will of the people. However TV is regarded as just entertainment and the policy for TV is made by executives of BBSC and the will of the government is not clear, an expert says.

On the other hand, BBS radiobroadcasts programs for 11 hours by FM and shortwave. (Consisting of five ours of Dzongkha and two hours each of English, Shashopakha and Nepalese) People can listen to the radio programs throughout almost all of Bhutan, therefore BBSC is popular in Bhutan. Shortwave is not clear because of area or timing. Now BBSC is expanding the FM network with assistance of DANIDA, Denmark.

6.3.2 Development Plan for Expansion of TV Networks

Satellite has advantages for the expansion of the broadcasting network, especially in a mountainous country like Bhutan. Actually there is a plan to install broadcasting satellite by assistance of ITU. But Bhutan doesn't have any satellites. This means other countries control the network. Because of this, BBSC has great expectations for the optical fiber network. They believe that having their own network is necessary to improve skills. To put these thoughts into action, they've requested free loans from the government of Japan to install 13 TV rely stations using SDH microwave network managed by BTL, optical fiber cable or off-air systems.

Planned area of BBSC's program distribution is shown in **Figure-6.3.1**.



Source: BBSC

Figure-6.3.1 Planed Area of BBSC's Program Distribution

Upgrading/expansion of the broadcasting network can make real-time broadcasting and broadcasting from local areas possible. It can be expected improvement on the quantity and quality of programs and information. BBSC has a plan to buy a car that has the facility to relay-broadcast through Japanese funding. BBSC did a 10 hours live relay broadcast of an archery final match on 3rd July 2004 from Thimphu. It was the first live relay broadcasting by BBSC. A JICA expert assigned for BBSC says, "BBSC's skill is coming up surely."

There are a lot of schools located distant from road/telephone networks or facing a shortage of teachers. Expansion of the broadcasting network is expected to be helpful in the education through broadcasting educational programs. If two-way communications become available, the benefits of the expansion will be great in education, agriculture and weather, environment conservation, preventing disaster, telemedicine, strength of health and sanitation.

6.4 Present State and Development Program for Communication Systems in the Power Sector

6.4.1 Present State and Development Program for Communication Facilities

Present State

Operation and maintenance of Chukha, Kurichhu, and Basochhu-I hydropower stations are managed by Chukha Hydro Power Corporation Ltd. (CHPCL), Kurichhu Hydro Power Corporation Ltd. (KHPCL), and Basochhu Hydro Power Corporation Ltd. (BHPCL), respectively, under the jurisdiction of Board of Directors. BPC is responsible for management and operation of the power transmission facilities and distribution networks in all of Bhutan.

The power system in Bhutan is divided in two; the western system, involving Chukha and Basochhu power stations and the eastern system involving Kurichhu power station. The systems are not interconnected at present. A PLC telecommunication system connects all power stations and HV and MV substations in each system for transmitting various information relating to the system operation. The PLC system is a method of communicating utilizing the power conductors of transmission lines.

VHF radios are provided for back up of the PLC system. Also, hand carried VHF telephone equipment is widely used for the maintenance works on transmission lines. The distance of VHF is limited. In order to expand the reach, provision of relaying stations is to be completed during 2004. Microwave communications are not used for the power sector. Since interconnection between the western and eastern power systems is not completed, PLC system is not applicable between both systems and each system is obliged to operate its facilities individually.

Future Development Plans

In order to increase the capacity of information and to improve the present inefficient system operation due to inferior tone quality of the PLC system, DOE/BPC has decided to employ optical fiber cable that has a huge transmitting capacity and superior tone quality to the power system.

All the existing transmission lines above 66 kV level are provided with galvanized overhead GW[18] over the whole length of the lines for protecting power conductors from lightning strikes. The said OPGW is a galvanized steel stranded ground-wire containing optical fiber cable inside and has the same protecting function for power conductors. Replacement of the existing GW with OPGW is able to improve communication capacity greatly. The OPGW applied by DOE/BPC is capable of 24 fiber cores (strands).

BPC planned to replace all existing GW furnished on 66 kV transmission lines in the western system with OPGW, and the replacement work expect 66 kV Chuzom-Ha section has been completed as of February 2005. But, terminal equipment and accessories necessary for connecting the OPGW among power stations, substations, and other base stations for actual operation of OPGW communication are not provided yet. However, OPGW network among 10 existing substations in Thimphu with Chubachhu control center is scheduled to start the operation from June 2005.

BPC will utilize the OPGW system mainly for SCADA[19], tele-metering, tele-control, and voice communications for control and management of its power system. Besides, BPC is examining utilization of surplus cores in the installed OPGW for other business. Utilizing

[18] Ground Wires
[19] System Control and Data Acquisition

OPGW system, DOE plans to establish a NLDC[20] in the Thimphu area for data collection, data analysis, control and management of the comprehensive system operation.

Although application of the OPGW to the eastern power system is not planned at present, BPC intends to provide OPGW to all new transmission lines in both the western and eastern systems. Besides, BPC has a plan to provide optical fiber cables on the supports of the 33 kV distribution lines in Thimphu for the purpose of voice communications, collection of system information and network operation. However, there is no plan to provide the OPGW to the lines interconnecting with the Indian grid at present, and the existing PLC communication system will be used continuously.

6.4.2 Cooperation between BPC and Bhutan Telecom Ltd. for OPGW Operation

By installing the OPGW to HV transmission lines in the western power system, efficient utilization by the domestic telecommunications sector will be achieved. However, for this to be realized, BPC and BTL need to work together so that the installation and operation will be successful. An agreement for cooperation was concluded on November 18, 2002 between BPC and BTL. BPC will manage the power sector components and BTL will manage the communications sector components of the OPGW network. A summary of the parts of this agreement that relate to allocation of expenses and sharing the business generated through use of the OPGW facilities is as follows:

(1) BTL bears the expense of material cost for OPGW and replacement works of GW with OPGW. BPC furnishes the existing steel towers from its assets.

(2) BTL should execute replacement of GW with the OPGW on live lines. Should there be any forced outage during the execution of the replacement works, any revenue loss should be compensated to BPC by BTL in accordance with the prevailing tariff; export tariff would apply if the export line is affected, and domestic tariff would apply if the domestic line is affected. (No outage has occurred, luckily.)

(3) On completion of the project, the ownership of OPGW assets should rest with BTL.

(4) BPC is responsible for maintenance of transmission line facilities concerned and BTL is responsible for maintenance of OPGW facilities concerned.

(5) Capacity of optical fiber cable in OPGW shall be 24 strands. Twelve (12) strands each would be allocated for use of BPC and BTL for their own business.

(6) BTL should offer 12 strands to BPC free of charge.

(7) The terminal equipment at the designated drop points (separating point of 24 strands to 12 strands each) should be purchased, owned, operated and maintained by the respective parties.

(8) BTL should pay 3% of the cost of OPGW (excluding terminal equipment and its associated accessories) to BPC as an annual charge for maintenance and lease charges.

[20] National Load Dispatching Center

(9) The fibers so allotted to BPC should be exclusively used for the power sector operation and maintenance, and BPC should not run any business or enter into any form of contract/agreement with a third party which could bring direct competition in the business of BTL unless and otherwise permitted by the Telecom Act.

(10) Should BPC or any of its subsidiary(-ies) be allowed to participate in telecommunication services or lease the lines to other telecom operators in future by the Bhutan Telecommunications Authority (BTA), the revenue so generated shall be belonging to BPC.

(11) If replacement of the OPGW would be needed during the effective contract period of 40 years, BTL should execute the replacement at its own expense.

(12) The lease rate of BTL to BPC should be reviewed every ten (10) years.

This agreement is limited to the western power system. If the system will be developed in other areas, new agreements will be required. BTL currently utilizes the 12 strand optical fiber cable mainly for voice circuits instead of microwave circuits. BTL started the actual operation of 4 strands out of the 12 strands for telecommunications-purpose in the Thimphu-Phuentsholing and Thimphu-Paro sections from June 2004. BTL plans to lease their 12 strands of the OPGW lines to Bhutan Broadcast Services Corporation (BBSC).

OPGW was installed as part of the recently completed 220 kV transmission line constructed between Basochhu-II and Simtokha substation, which is an asset of BPC.

6.5 Activities of Donors in the Information and Communications Sector

Table-6.5.1 below summarizes the activities of various donor groups that relate to the information and communications sector.

Table-6.5.1 Activities of Donors in the Information and Communications Sector

JICA (Japan)	• *Local Network Expansion Technology Improvement and Human Development Project* - Equipment provision and technical assistance for construction of the telephone network expansion in Thimphu, Paro, Phuentsholing and other major towns (JICA supplied 40 million Yen for construction machines. The number of telephone subscribers reached 31,896 at the end of June 2005 compared to 17,000 subscribers in December, 2001.) A training center was established and it now conducts training courses with BTL. • *Dispatch of experts, JOCVs and senior volunteers* - As of 30th June, 2004 18 members had been dispatched to assist various ministries, BTL, BBSC, and others).
UNDP	• *Pilot Public Access to Information and Services Project (00031978)* – Installation of a pilot access point where people can access the Internet to get information and services, and running a campaign to promote the benefits of such a facility/system (2004/03-2004/12) • *Institutional Capacity Building and Policy Support for the Ministry of Communications (BHU/02/010)* – Establishment of essential infrastructure to build the government's ICT policy (2002/09-) • *UNV Support for ICT Capacity Building in Bhutan's Public Sector (BHU/02/BV01)* – Dispatch of 5 UN Volunteers to increase human resources in the field (2002/11-2004/11, Funded by Japanese Trust Fund) • *E-business Piloting and Readiness for Rural Women Artisans and Enterprises (BHU/03/003)* • *Instruction in business and skills for working women* in local areas and training them about e-commerce for government officers and corporation staff (2003/08-, Funded by Japan Women in Development Fund/UNDP) • *Planning an Information Network for Good Governance (BHU/00/004)* – Building network system between the central government and Dzongkhag administrations, and conducting workshops about computer use for officers in 20 Dzongkhag administrations and others (2000/11-, Funded by Japan Human Resource Development Fund)
DANIDA (Denmark)	• *Expansion of the FM network* – Strengthening of the radio network and expansion of the service area of FM services. • Rural Telecommunication Project – Installation of 10 telephone lines to each Gewog.
Government of India	• *e-Post Project* – Installation of Internet connection for 38 of 110 post offices to start services like facsimile and e-mail (Project with ITU/UPU.) • *Thimphu Wide Area Network* – Building an optical fiber Wide Area Network (WAN) between ministries in Thimphu. • *Local Area Network for 20 Blocks* – Installation of a Local Area Network (LAN) to each Dzongkhag administration. • *Multipurpose Community Centers in 10 Selected Rural Areas* – Installation of ten pilot tele-centers to provide public telephone, facsimile and Internet services. (Project with DIT and Bhutan Post.)

Prepared by JICA Study Team

6.6 Present State and Possibilities of Information and Communications Networks in Local Governance

As mentioned previously, some ministries, departments and public corporations already have a network system, or have plans to connect the central government and each Dzongkhag office. However, the existing systems are generally designed as dial-up access systems because leased lines are too expensive. Some ministries and departments still exchange data on floppy disk, or paper via the postal service.

All Dzongkhag administrations have telephone lines and facsimile, including Gasa Dzongkhag, which currently does not have on-grid power. The Dzongkhag administrations use computers on a daily basis, however, LAN and Internet have only recently become available in most Dzongkhags.

On the other hand, there are many Gewog centers that power distribution lines or the telephone lines have not reached. According to BTL, now a telephone service is available in 81 of 201 Gewogs. BTL has plans to increase the number Gewogs that have a telephone service to 171 by the end of 2006 and 199 by the end of 2007 by “Rural Telecommunication Project”.

At present, JICA Local Government and Decentralization Project to strengthen the system of local governance, skill development of officers, and installation of necessary equipment is under way. According to an official of JICA Bhutan Office, telephones are an essential facility for Gewog centers. JICA will supply typewriters and buildings for the Gewog center, but computers will not be supplied for Gewogs. Although some Gewogs requested a supply of computers, this was not approved because of lack of on-grid power supply.

A stable power supply and expansion of the communications network can give great benefit to infrastructures like Gewog centers, schools, bases of agriculture, medical facilities like hospitals and others. It should make decentralization effective.

CHAPTER 7 PRESENT STATE OF NON-ELECTRIFIED VILLAGES

7.1 Overview of Village Baseline Survey for Rural Electrification

The Village Baseline Survey for Rural Electrification (hereinafter referred to as the "Survey") was locally subcontracted and conducted for all non-electrified villages in the whole country, which are to be electrified after 9th Five Year Plan (FYP) and therefore are targeted by the Study. The Survey was carried out to: (a) identify the location of the non-electrified villages and those number of households; (b) collect data of general conditions in the non-electrified villages and the sampled non-electrified households and; (c) integrate the collected data into a GIS database. Further, in order to clarify future power demand, use of electricity, and issues for operation and maintenance of power supply system, some typical electrified villages were sampled from both on-grid and off-grid villages. The Survey was extended to those villages to: (a) collect data of general conditions on the sampled electrified villages and households and (b) integrate the collected data into a GIS database. The framework of the Survey is summarized in **Table-7.1.1.**

Table-7.1.1 Framework of Village Baseline Survey for Rural Electrification

Items	Contents	
Objectives of the Survey	• For all non-electrified villages to be electrified after 9th FYP, the data on: (a) the location; (b) overview of villages and households; (c) actual status of use of alternative energies; and (d) opinions on electrification at village and household levels; were all collected and put into a GIS database. • To clarify the issues of the non-electrified villages, the typical villages electrified by on-grid and off-grid power supply systems were sampled, and the data on: (a) the general data on electrified villages and households; (b) use of alternative energies; (c) power demand; and (d) operation and maintenance of power supply systems; were all collected and put into a GIS database.	
Survey Area	Non-electrified Villages	• All non-electrified villages to be electrified after 9th FYP (excluding the area where a field survey is geographically difficult to conduct and/or also the restricted areas).
	Electrified Villages	• Typical villages electrified by the grid, mini/micro hydropower, and solar systems.
Types of the Survey	Non-electrified Villages	• Village location survey (full-scale survey for 1,716 villages). • Village survey (full-scale survey for 1,716 villages). • Household survey (sample survey for 627 households).
	Electrified Villages	• Village survey (sample survey for 15 villages and 5 villages each for the grid, mini/micro hydropower and solar). • Household survey (sample survey for 75 households and 5 households in each village).
Survey Methods	Non-electrified Villages	• Village survey (interview survey with village head and GPS measurement). • Household survey (interview survey with household head).
	Electrified Villages	• Village survey (interview survey with village head) • Household survey (interview survey with household head)
Survey Items	Non-electrified Villages	• Village survey (location, access, industries, public and commercial facilities, price of alternative energies, development priorities, and weather information). • Household survey (household income and expenditures, status of use, source and consumption of alternative energies, and willingness to pay)
	Electrified Villages	• Village survey (access, industries, public and commercial facilities, power supply status, power demand, electrification benefits, and price of alternative energies. • Household survey (household income and expenditures, power demand, tariff payment, electrification benefits and use, source, and consumption of alternative energies).
Survey Output	Non-electrified Villages	• Summarizing of the survey results and preparation of the GIS database.
	Electrified Villages	• GIS-based maps showing location of the surveyed non-electrified villages, including administrative boundaries at Dzongkhag and Gewog levels. • Summary of the survey results and data preparation for a GIS database.

Prepared by JICA Study Team

7.2 Definitions of Village

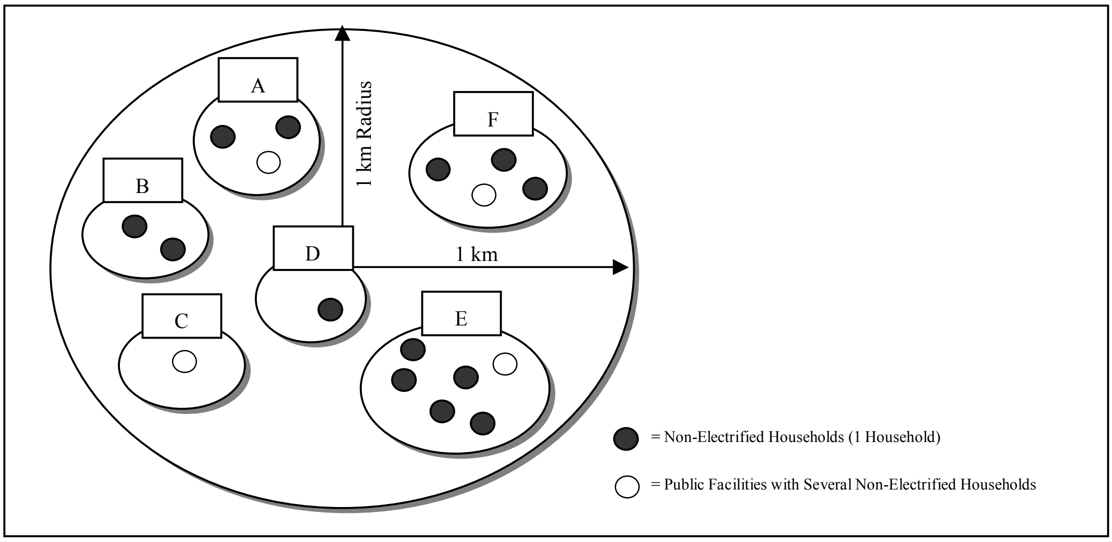
The lowest local administrative unit in Bhutan is Gewog. Regarding the term "village", no official definitions or rules have been encountered. Under the circumstances, the Study identified a "village" as a "power demand point" in the following four ways:

(1) Regular village: this is a kind of a "village" that is generally perceived as a "regular village" and composed of a certain number of households located in a close distance one another with a certain degree of accumulation of households and located relatively separately from the other surrounding villages.

(2) Isolated village with only a single or several households: this kind of a "village" is commonly located on the slope or on the top of a mountain in a very distant area, isolated from the other surrounding villages in distance and composed of either only a single or several households.

(3) Isolated village with only public facilities: this kind of a "village" is also commonly located on the slope or on the top of a mountain in a very distant area, isolated from the other surrounding villages in distance and. It is a village with only public facilities, such as a village temple or government facilities, and with a certain number of people who are always living there. With the request of DOE, this kind of a place is also considered as a "village", to be a "power demand point", and considered as a "household" in the Study.

(4) Compound village: this is a "village" with several small villages and/or public facilities located roughly within a 1 km radius from the place where placing of a transformer is assumed appropriate and considered as a "village" to be a "power demand point." In a GIS database of the Study, this kind of a village is stated as "A/B/C/D/E/F village" with all names written (refer to illustration below). The concept of a "compound village" is illustrated in **Figure-7.2.1.**



Prepared by JICA Study Team

Figure-7.2.1 Concept of Compound Village (A/B/C/D/E/F)

7.3 Overview of Survey Results

7.3.1 Survey Results on Non-Electrified Villages

(1) Number of Villages, Households, and Population of Non-Electrified Villages

Based on the survey results, there are 1,716 non-electrified villages to be electrified after 9th FYP. The number of households and population is 29,942 and 225,658, respectively in 2004. The number of the non-electrified villages and their population by district is summarized in **Table-7.3.1**. Further, the list of all non-electrified villages surveyed are provided in **Appendix A-I**.

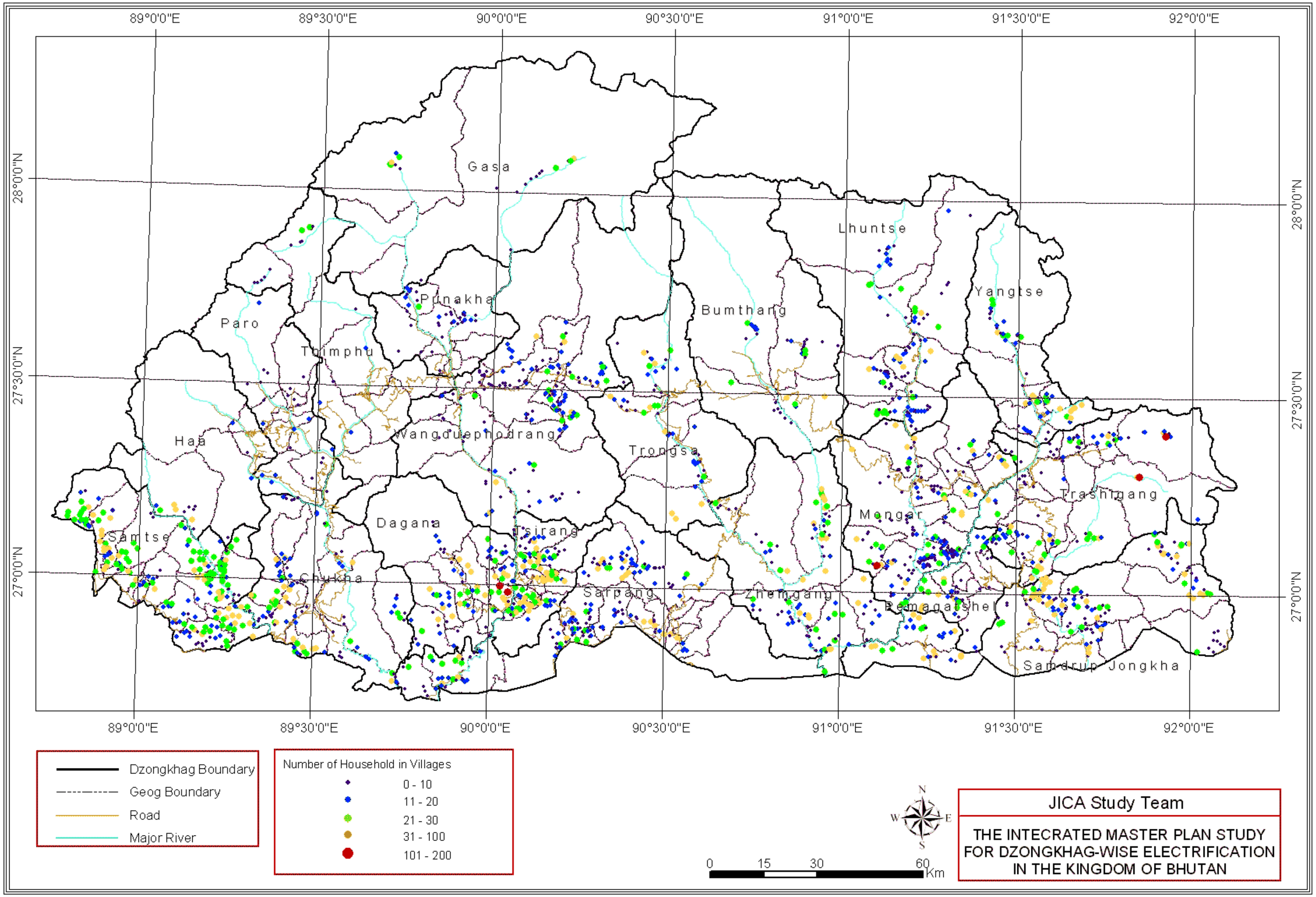
Table-7.3.1 Number of Villages, Households and Population of Non-Electrified Villages

Dzongkhag Name	No. of Non-Electrified Villages		No. of Non-Electrified Households		No. of Non-Electrified Population	
		%		%		%
Thimphu	16	(0.9)	132	(0.4)	908	(0.4)
Chukha	108	(6.3)	1,814	(6.1)	12,319	(5.5)
Haa	15	(0.9)	248	(0.8)	1,663	(0.7)
Paro	22	(1.3)	162	(0.5)	1,250	(0.6)
Samtse	181	(10.5)	4,318	(14.4)	33,757	(15.0)
Tsirang	86	(5.0)	2,186	(7.3)	18,922	(8.4)
Dagana	82	(4.8)	1,765	(5.9)	12,442	(5.5)
Punakha	35	(2.0)	263	(0.9)	2,089	(0.9)
Gasa	21	(1.2)	331	(1.1)	1,936	(0.9)
Wangduephodrang	155	(9.0)	1,714	(5.7)	12,167	(5.4)
Bhumthang	35	(2.0)	446	(1.5)	3,137	(1.4)
Sarpang	162	(9.4)	2,570	(8.6)	19,116	(8.5)
Zhemgang	92	(5.4)	1,627	(5.4)	17,637	(7.8)
Trongsa	49	(2.9)	860	(2.9)	7,214	(3.2)
Lhuntse	103	(6.0)	1,377	(4.6)	8,827	(3.9)
Mongar	183	(10.7)	2,662	(8.9)	18,617	(8.3)
Pemagatshel	33	(1.9)	650	(2.2)	4,794	(2.1)
Samdrup Jongkhar	177	(10.3)	3,573	(11.9)	25,853	(11.5)
Trashigang	105	(6.1)	2,087	(7.0)	15,175	(6.7)
Yangtse	56	(3.3)	1,157	(3.9)	7,835	(3.5)
Total	**1,716**	**(100.0)**	**29,942**	**(100.0)**	**225,658**	**(100.0)**

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

(2) Location of Non-Electrified Villages

Through the GPS measuring undertaken in the non-electrified village survey, the locations of all identified non-electrified villages were shown on a GIS-based map and is illustrated in **Figure-7.3.1.**

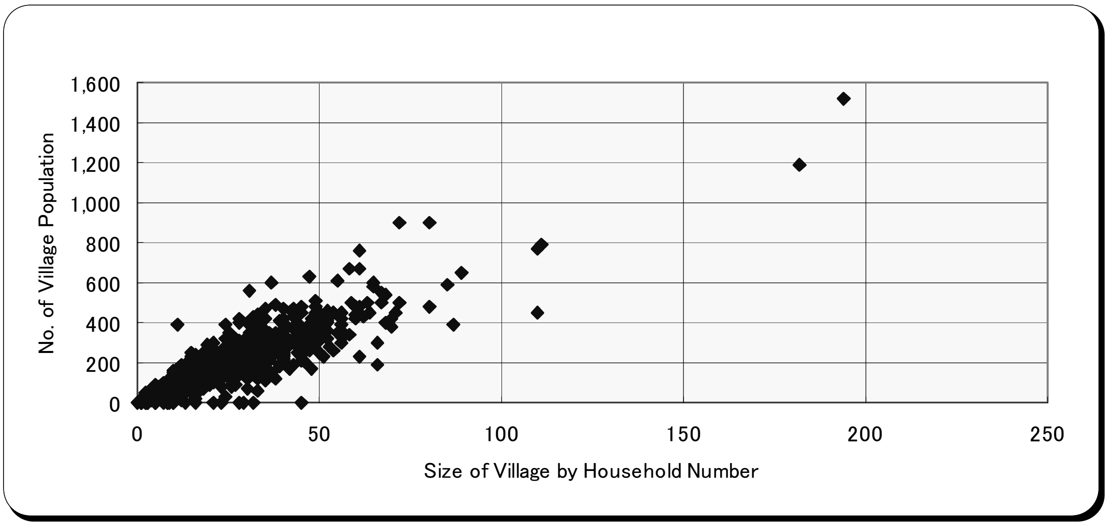


Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

Figure-7.3.1 Location of Non-Electrified Villages to be Electrified after 9th Five Year Plan

(3) Non-Electrified Villages by Number of Households and Population

The number of households per non-electrified village (average: 17.5, maximum: 194, minimum: 1) and also the population per non-electrified village (average: 131.6, maximum: 1,517, minimum: 1) are shown in **Figure-7.3.2.**



Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

Figure-7.3.2 Dispersion of Non-Electrified Villages by Number of Households and Population

(4) Overview of Non-Electrified Villages

The average figures of all major survey results on all non-electrified villages surveyed (1,716 villages) are summarized in **Table-7.3.2.** The Dzongkhag-wise figures of those are provided in **Appendix A-I-1.**

Table-7.3.2 Overview of Non-Electrified Villages

Major Items		Total Average
Average Number of Family Members		7.5 persons / Household
Average Annual Growth Rate of the Number of Households 1998-2003		2.6%
Vehicular Road to Village		Average Walking Time to Vehicular Road (6.1 Hours), Passable in Dry Season (44.1%), Passable in Rainy Season (52.2%)
Mode of Transportation, Average Traveling Time and Average Fare by Taxi & Bus to Dzongkhag Headquarters		Walking (83.2%, 8.5 Hours), Bus & Taxi (69.8%, 2.7 Hours, 123 Nu.), Other vehicles than Bus & Taxi (1.2%, 9.1 Hours).
Mode of Transportation, Average Traveling Time and Average Fare by Taxi & Bus to Gewog HQ		Walking (95.0%, 3.1 Hours), Bus & Taxi (8.3%, 1.1 Hours, 73 Nu.), Other vehicles than Taxi & Bus (0.3%, 0.9 Hours)
Major Cash Income		Wages/Employment (87.8%), Dairy Products (81.6%), Vegetables (57.5%), Cash Crops (45.6%), Fruits Crops (40.3%), Food Crops (35.2%), Weaving (21.4%), Basket Making (14.7%), Wooden Utensils (5.7%)
Unit Price of Alternative Energy		LPG 14 kg (347.4 Nu./Cylinder), LPG 4 kg (168.0 Nu./Cylinder), Diesel Oil (23.0 Nu./Litter), Kerosene (14.4 Nu./Litter), Dry Cell Battery (11.2 Nu./Piece), Candle (3.0 Nu./Piece)
Facilities in the Village	Public Facilities	Temple (34.8%), Health Facilities (11.8%), School (10.7%), Gewog Office (4.3%)
	Commercial Facilities	Shops (8.8%), Hotel and Restaurant (8.8%)
Priority Development Sector (Top 3 Sectors)		Transportation (43.8%), Power (43.5%), Water Supply (6.6%)
Possible Cooperation of Villages for Electrification		Construction of Distribution Line (93.2%), Observation and Reporting of Distribution Line (76.5%), Meter Reading and Tariff Collection (13.1%)
Weather Condition in Villages	Maximum Days for Continuous Rain	Average (4.2 Days), Longest (15.0 Days), Shortest (0.5 Days)
	Maximum Days for Continuous Cloudiness	Average (2.9 Days), Longest (15.0 Days), Shortest (0.5 Days)
	Maximum Days for Continuous Snowing	Average (1.6 Days), Longest (7.0 Days), Shortest (0.3 Days)
	Villages with continuous Wind	394 Villages (22.9%)
	Villages with continuous and Strong Wind	48 Villages (2.8%)

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note) Percentage (%) shown in the table indicates a percentage of the number of applicable villages against the total number of all non-electrified villages surveyed (1,716 villages).

(5) Overview of Non-Electrified Households

The average figures of major survey results on all sampled non-electrified households surveyed (627 households) are summarized in **Table-7.3.3.** The same figures by Dzongkhag are provided in **Appendix A-I-1.**

Table-7.3.3 Overview of Non-Electrified Households (1/2)

Major Items		Total Average
Average Number of Family Members		8.5 Persons / Household
Average Annual Household Income		28,481 Nu.
Average Monthly Household Expenditures		Food (714 Nu.), Clothing (387 Nu.), Fuel (238 Nu.), Transportation (141 Nu.), Housing (15 Nu.), Remittance (122 Nu.), Others (117 Nu.).
Average Holding of Agricultural Land		Wet Land (1.2 Acre), Dry Land (3.1 Acre)
Major Use of Alternative Energies		Kerosene (Lighting: 97.0%), Diesel Oil (Milling: 4.5%), Candle (Lighting: 7.2%), Dry Cell Battery (Radio: 70.2%, Lighting: 60.9%, Security: 45.1%), LPG (Cooking: 5.3%), Firewood (Cooking: 99.7%, Heating:81.7%).
Use of Alternative Energies - Kerosene - Diesel Oil - Candle - Dry Cell Battery	Average Interval of Purchasing	Kerosene (Every 78 Days), Diesel Oil (Every 63 Days), Candle (Every 136 Days), Dry Cell Battery (Every 51 Days).

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) N/A = Not Applicable
Note 2) Percentage (%) shown in the table indicates a percentage of the number of applicable households against the total number of sampled non-electrified villages surveyed (627 households).

Table-7.3.3 Overview of Non-Electrified Households (2/2)

Major Items			Total Average
Use of Alternative Energies - Kerosene - Diesel Oil - Candle - Dry Cell Battery	Average Volume of Purchasing at a Time		Kerosene (9.4 Litters), Diesel Oil (25.9 Litters), Candle (18.4 Pieces), Dry Cell Battery (8.0 Pieces).
	Average Unit Price		Kerosene (14 Nu./Litter), Diesel Oil (22 Nu./Litter), Candle (4 Nu./Piece), Dry Cell Battery (11 Nu./Piece)
	Mode of Transportation	Walking	Kerosene (92.8%), Diesel Oil (4.3%), Candle (6.2%), Dry Cell Battery (85.8%).
		Bus & Taxi	Kerosene (25.7%), Diesel Oil (2.6%), Candle (1.6%), Dry Cell Battery (12.6%).
		Asking Someone for a ride	Kerosene (0.2%,), Diesel Oil (N/A), Candle (N/A), Dry Cell Battery (N/A).
	Average Time by Mode of Transportation	Walking	Kerosene (6.6 Hours), Diesel Oil (5.4 Hours), Candle (3.7 Hours), Dry Cell Battery (6.5 Hours).
		Bus & Taxi	Kerosene (1.6 Hours), Diesel Oil (1.3 Hours), Candle (1.4 Hours), Dry Cell Battery (2.0 Hours).
		Asking Someone for a ride	Kerosene (10.0 Hours), Diesel Oil (N/A), Candle (N/A), Dry Cell Battery (N/A).
	Average Fare by Taxi & Bus		Kerosene (106 Nu.), Diesel Oil (115 Nu.), Candle (209 Nu.), Dry Cell Battery (88 Nu.).
Use of Alternative Energies - LPG	Average Holding of LPG Cylinder		14 kg (2.0 Cylinders), 4 kg (2.0 Cylinders)
	Average Frequency of Refilling LPG		LPG 14 kg (Every 3 Months), LPG 4 kg (Every 3 Months).
	Average Amount Paid for Refilling		LPG 14 kg (335.7 Nu.), LPG 4 kg (165.0 Nu.).
	Mode of Transportation for Refilling		Walking (3.3%), Bus & Taxi (5.7%), Asking Someone for a ride (0.2%).
	Average Traveling Time		Walking (5.1 Hours), Bus & Taxi (2.6 Hours), Asking Someone for a ride (24.0 Hours)
	Average Fare by Taxi & Bus		167.5 Nu.
Use of Alternative Energies - Firewood	Average Volume of Current Stock		Backload (35.9 Units), Truckload (1.2 Units)
	Average Duration Current Stock will last		Winter (55.2 Days), Summer (70.7 Days).
	Use of Firewood	Winter	Cooking (72.7%), Heating (17.7%), Lighting (1.3%), Others (7.9%).
		Summer	Cooking (86.7%), Heating (3.0%), Lighting (1.3%), Others (8.2%).
	Ways of Collecting Firewood		Purchasing (0.2%), Hiring Wood Gatherers (21.4%), Family Members (90.6%).
	Average Frequency of Purchasing / Hiring Someone / Collecting by Family Members		Purchasing (Every 1 Year), Hiring (Every 9.2 Months), Family Members (29.7 Days for Every 4.6 Months).
	Average Number of Hiring Someone / Collecting by Family Members		Hiring (10.1 Persons), Family Members (3.1 Persons).
	Average Duration of Collecting by a Hired gatherer / Collecting by Family Members		Hiring (4.6 Days), Family Members (4.2 Days).
	Average Volume of Collection	Hiring Someone	Backload (120.6 Units), Truckload (2.1 Units).
		Collecting by Family Members	Backload (119.4 Units), Truckload (1.6 Units).
	Average Amount Paid for Hiring Someone		82.5 Nu./Day/Person
Willingness to Pay	Maximum Amount the Household Would Pay		Less than 100 Nu. (23.1%), 100-200 Nu. (55.5%), More than 200 Nu. (21.2%).
Electric Appliances Wishing to Purchase			Light (99.7%), Rice Cooker (95.4%), Water Heater (93.8%), Radio (81.0%), Curry Cooker (81.0%), Room Heater (55.2%), Television (51.4%), Electric Iron (46.1%), Cooking Stove (41.9%), Electric Fan (34.4%), Refrigerator (28.2%).

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) N/A = Not Applicable
Note 2) Percentage (%) shown in the table indicates a percentage of the number of applicable households against the total number of sampled non-electrified villages surveyed (627 households).

7.3.2 Survey Results on Electrified Villages

(1) Overview of Electrified Villages

The average figures of major survey results on sampled electrified villages surveyed (15 villages) are summarized in **Table-7.3.4.** The same figures by Dzongkhag are provided in **Appendix A-I-2.**

Table-7.3.4 Overview of Electrified Villages

Major Items		Total Average
Average Number of Family Members		6.7 Persons / Household
Average Annual Growth Rate of the Number of Households 1998-2003		3.4%
Vehicular Road to Village		Average Walking Time to vehicular Road (10.5 Hours)
Mode of Transportation, Average Traveling Time and Average Fare by Taxi & Bus to Dzongkhag Headquarters		Walking (24.0%, 12.7 Hours), Bus & Taxi (52.0%, 2.9 Hours, 138 Nu.), Other Cars than Bus & Taxi (N/A).
Mode of Transportation, Average Traveling Time and Average Fare by Taxi & Bus to Gewog Headquarters		Walking (100.0%, 1.8 Hours), Bus & Taxi (N/A), Other Cars than Bus & Taxi (N/A).
Major Cash Income		Wages/Employment (56.0%), Dairy Products (44.0%), Cash Crops (32.0%), Vegetables (28.0%), Fruits Crops (20.0%), Food Crops (20.0%), Weaving (12.0 %), Basket Making (N/A), Wooden Utensils (N/A).
Unit Price of Alternative Energy		LPG 14kg (348.2 Nu./Cylinder), LPG 4 kg (120.0 Nu./Cylinder), Diesel Oil (21.7 Nu./Litter), Kerosene (13.3 Nu./Litter), Dry Cell Battery (10.8 Nu./Piece), Candle (3.0 Nu./Piece).
Facilities in the Village	Public Facilities	Temple (66.7%), School (66.7%), Health Facilities (60.0%), Gewog Office (33.3%).
	Commercial Facilities	Shops (93.3%), Hotel & Restaurant (53.3%).
Status of Power Supply Services	Electrification Ratio within the Village	72.3 %
	Average Duration of Power Supplied	Rainy Season (21.6 Hours), Dry Season (24.0 Hours).
	Villages Experiencing Blackouts	8.0%
	Average Occurrence of Blackout in 2003	Rainy Season (7.5 Times), Dry Season (1.0 Times).
	Average Duration of Blackout in 2003	Rainy Season (1.5 Hours), Dry Season (10.5 Hours).
Benefits Gained through Electrification		Increase in Household Income (86.7%), Decrease in Household Expenditures (73.3%), Increased Hours of Education (100.0%), Increased Hours of Productivity Activities (100.0%), Improvement in Health (100.0%), Decrease in Consumption of Firewood (60.0%).
Type of Milling Facilities in the Village	Rice Mill	Electricity (8%), Diesel Generator (24%).
	Flour Mill	Electricity (8%), Diesel Generator (12%%), Water Driven (4%).
	Saw Mill	Electricity (4%).

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) N/A = Not Applicable
Note 2) Percentage (%) shown in the table indicates a percentage of the number of applicable villages against the total number of sampled electrified villages surveyed (15 villages).

(2) Overview of Electrified Households

The average figures of major survey results on sampled electrified households surveyed (75 households) are summarized in **Table-7.3.5.** The same figures by Dzongkhag are provided in **Appendix A-I.**

Table-7.3.5 Overview of Electrified Households (1/3)

Major Items	Total Average
Average Number of Family Members	7.1 Persons / Household
Average Annual Household Income	43,942 Nu.
Average Monthly Household Expenditures	Food (997 Nu.), Clothing (381 Nu.), Electricity (66 Nu.), Fuel (400 Nu.), Transportation (265 Nu.), Housing (15 Nu.), Remittance (139 Nu.), Others (268 Nu.).
Average Holding of Agricultural Land	Wet Land (2.7 Acre), Dry Land (5.9 Acre).
Major Use of Alternative Energies	Electricity (Lighting: 93%, Cooking: 41%), Kerosene (Lighting:56%), Diesel Oil (Milling: 8%), Candle (Lighting: 28.%), Dry Cell Battery (Lighting: 51%, Radio: 36%, Security: 35%), LPG (Cooking: 33%), Firewood (Cooking: 89%, Heating: 69%).

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) N/A = Not Applicable
Note 2) Percentage (%) shown in the table indicates a percentage of the number of applicable households against the total number of sampled electrified households surveyed (75 households).

Table-7.3.5 Overview of Electrified Households (2/3)

Major Items				Total Average
Use of Alternative Energies - Kerosene - Diesel Oil - Candle - Dry Cell Battery	Average Interval of Purchasing			Kerosene (157 Days), Diesel Oil (34 Days), Candle (59 Days), Dry Cell Battery (63 Days).
	Average Volume of Purchasing at a Time			Kerosene (7.0 Litters), Diesel Oil (36.4 Litters), Candle (6.3 Pieces), Dry Cell Battery (9.4 Pieces).
	Average Unit Price			Kerosene (13 Nu./Litter), Diesel Oil (21 Nu./Litter), Candle (6 Nu./Piece), Dry Cell Battery (11 Nu./Piece).
	Mode of Transportation	Walking		Kerosene (38.7%), Diesel Oil (4.0%), Candle (25.3%), Dry Cell Battery (60.0%).
		Bus & Taxi		Kerosene (29.3%), Diesel Oil (9.3%), Candle (N/A), Dry Cell Battery (4.0%).
		Asking Someone for a ride		Kerosene (2.7%,), Diesel Oil (N/A), Candle (N/A), Dry Cell Battery (N/A).
	Average Time by Mode of Transportation	Walking		Kerosene (11.6 Hours), Diesel Oil (0.9 Hours), Candle (2.9 Hours), Dry Cell Battery (10.7 Hours).
		Bus & Taxi		Kerosene (2.2 Hours), Diesel Oil (1.9 Hours), Candle (N/A), Dry Cell Battery (0.7 Hours).
		Asking Someone for a ride		Kerosene (5.3 Hours), Diesel Oil (N/A), Candle (N/A), Dry Cell Battery (N/A).
	Average Fare by Bus & Taxi			Kerosene (107 NU), Diesel Oil (89 Nu.), Candle (N/A), Dry Cell Battery (63 Nu.).
Use of Alternative Energy - LPG	Average Holding of LPG Cylinder			14kg（1.5 Cylinders）、4kg（N/A）
	Average Frequency of Refilling LPG			LPG 14kg (Every 2.0 Months), LPG 4kg (N/A).
	Average Paid Amount for Refilling LPG			LPG 14kg（338 Nu.）、LPG 4kg（N/A）
	Mode of Transportation for Refilling			Walking (N/A), Bus & Taxi (26.7%), Asking Someone for a ride (6.7%).
	Average Traveling Time			Walking (N/A), Bus & Taxi (3.7 Hours), Asking Someone for a ride (42.0 Hours).
	Average Fare by Bus & Taxi			124 Nu.
Use of Alternative Energies - Firewood	Average Volume of Current Stock			Backload (28.8 Units), Cubic Feet (120.0 Units), Truckload (1.3 Units).
	Average Duration Current Stock will last			Winter (80 Days), Summer (105 Days).
	Use of Firewood	Winter		Cooking (63%), Heating (37%), Lighting (N/A), Others (24%).
		Summer		Cooking (85%), Heating (12%), Lighting (N/A), Others (29%).
	Ways of Collecting Firewood			Purchasing (8.0%), Hiring a wood gatherer (36.0%), Family Members (56.0%).
	Average Frequency of Purchasing / Hiring Someone to gather / Collecting by Family Members			Purchasing (Every 1 Year), Hiring (Every 10.4 Months), Family Members (18 Days out of Every 5 Months).
	Purchasing Firewood	Average Purchasing Volume		1.3 Truckload
		Average Amount Paid		3,383 Nu.
		Mode of Transportation for Purchasing		Walking (N/A), Bus & Taxi (6.7%), Asking Someone for a ride (N/A).
		Average Time by Mode of Transportation		Walking (N/A), Bus & Taxi (1.2 Hours), Asking Someone for a ride (N/A)
		Average Fare by Bus & Taxi		1,363 Nu.
	Collecting Firewood by Hiring Someone or Family Members	Average Number of Hiring Someone / Collecting by Family Members		Hiring (6.9 Persons), Family Members (3.7 Persons).
		Average Duration of Hiring Someone / Collecting by Family Members		Hiring (6.9 Days), Family Members (N/A).
		Average Volume of Stock	Hiring Someone	Backload (102.3 Units), Cubic Feet (461.3 Units), Truckload (1.2 Units).
			Family Members	Backload (69.3 Units), Cubic Feet (15.0 Units), Truckload (1.9 Units).
		Average Paid Amount for Hiring Someone to gather		106.3 Nu./Day/Person
Benefits Obtained through Electrification				Increase in Household Income (80.0%), Decrease in Household Expenditures (70.7%), Increased Hours of Education (93.3%), Increased Hours of Productivity Activities (88.0%), Improvement in Health (97.3%), Decrease in Consumption of Firewood (50.7%).

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) N/A = Not Applicable
Note 2) Percentage (%) shown in the table indicates a percentage of the number of applicable households against the total number of sampled electrified households surveyed (75 households).

Table-7.3.5 Overview of Electrified Households (3/3)

Major Items		Total Average
Amount of Monthly Electricity Bill	Average Amount	Winter (107.9 Nu.), Summer (92.8 Nu.).
	Maximum Amount	Winter (375.5 Nu.), Summer (600.0 Nu.).
Amount of Monthly Electricity Bill in 2003	Average Amount	December (94.1 Nu.), September (83.3 Nu.), June (79.9 Nu.), March (83.0 Nu.), January (94.2 Nu.).
	Maximum Amount	December (364.0 Nu.), September (270.0 Nu.), June (392.0 Nu.), March (305.0 Nu.), January (296.0 Nu.).
Amount of Monthly Consumption of Electricity in 2003	Average Consumption	December (117.0 kWh), September (91.8 kWh), June (84.9 kWh), March (96.2 kWh), January (105.0 kWh).
	Maximum Consumption	December (403.0 kWh), September (341.0 kWh), June (318.0 kWh), March (344.0 kWh), January (352.0 kWh).
Punctuality of Making Monthly Payment		Paying Every Month (92.0%), Not Paying Every Month (8.0%).
Mode of Transportation for Making Payment	Mode of Transportation for Payment	Walking (46.0%), Bus & Taxi (42.0%), Asking Someone for a ride (N/A).
	Average Traveling Time	Walking (3.9 Hours), Bus & Taxi (1.0 Hour), Asking Someone for a ride (N/A).
	Average Fare by Bus & Taxi	60 Nu.
Status of Solar Power Systems Installed in the Village	Panel Size	55 Wp (4 Villages), 50 Wp (1 Village).
	Average Number of Panels	2.0 Panels
	Average Capacity of Batteries	97 Ah
	Average Number of Batteries	1 Battery
	Average Duration of Power Supply	Rainy Season (4.1 Hours), Dry Season (5.6 Hours).
	Average Duration of Electric Bulbs	2.6 Days

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) N/A = Not Applicable
Note 2) Percentage (%) shown in the table indicates a percentage of the number of applicable households against the total number of sampled electrified households surveyed (75 households).

7.3.3 Current Status and Considerations on Electrification of Non-Electrified Villages

Based on the results of the Survey, the considerations to be made toward electrification of the non-electrified villages are summarized in **Table-7.3.6.**

Table-7.3.6 Current Status and Considerations on Electrification of Non-Electrified Villages

Issues	Current Status	Considerations to Electrification
Most non-electrified villages to be electrified from now on are assumed to be located in the areas where transport of construction materials are difficult.	Walking time to the nearest vehicular roads of the surveyed non-electrified villages is averaged at 6.1 hours. Further, about a half of these roads (41.1%) are not passable even during the dry season (these roads have been damaged by rains and/or landslides are assumed to remain unrestored.).	The same issue mentioned in the left column has been already acknowledged during the implementation of rural electrification projects through ADB/RE-1, RE-2 and RE-3. Most non-electrified villages to be electrified from now on are assumed to be located in a far distant area. Therefore, specification (size, weight, cost, etc.), a means of transport, construction costs of a transformer to be installed shall be well considered in the planning stage.
High possibility of continued consumption of a lot of alternative energies at the electrified households is assumed.	Surveyed electrified households are still consuming a lot of alternative energies: kerosene (lighting: 56%), firewood (cooking: 89%, heating: 69%), candle (lighting: 28%), in addition to electricity (lighting: 93%, cooking: 41%). Of estimated monthly income of electrified households (Nu. 3,662), 10.9% or Nu. 400 was spent for alternative energies, and Nu. 66 for electricity. Further, only about a half of the surveyed electrified households (51%) stated that consumption of firewood was decreased.	Most non-electrified households to be electrified from now on are assumed to be located in a far distant area and have limited income sources (64.8% lower than that of the electrified households that are situated in the areas where electrification was relatively easier due to geographical setting). Because of this, the purchasing power of the non-electrified households for electric appliances (lighting, cooking and heating utensils) is assumed to be lower. Further more, considering that a lot of alternative energies are still consumed in the electrified households, these situations shall be well considered in demand forecast for the non-electrified households.

Prepared by JICA Study Team

7.4 Status of Living Standard of Non-Electrified Villages

From the survey results, the data that indicate living standard of the non-electrified villages were selected as indicators. Comparisons made between the non-electrified and electrified villages by selected indicators are summarized in **Table-7.4.1.**

Table-7.4.1 Comparison of Living Standard between Non-Electrified and Electrified Villages

Comparing Items			Comparison Indicators		Proportion of the subject item in Non-Electrified Villages (Compared to Electrified Villages)
			Non-Electrified Villages	Electrified Villages	
Average Annual Household Income			28,481 Nu.	43,942 Nu.	About 64% of Electrified Villages
Average Holding of Agricultural Land		Wet Land	1.2 Acre	2.7 Acre	About 44% of Electrified Villages
		Dry Land	3.1 Acre	5.9 Acre	About 53% of Electrified Villages
Facilities in the Village	Public Facilities	Temples	34.5%	60.6%	The number and availability of public and commercial facilities in non-electrified households are found to be quite low compared to electrified villages.
		Health Facilities	11.5%	60.0%	
		Schools	10.6%	66.7%	
		Block Offices	4.1%	33.3%	
	Commercial Facilities	Shops	8.7%	93.3%	
		Hotels & Restaurants	8.7%	53.3%	

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)
Note 1) Percentage (%) shown in the table indicates a percentage of the number of applicable villages against the total number of all non-electrified villages surveyed (1,716 villages).
Note 2) Average Annual Household Income was obtained from non-electrified household survey (627 households). The data was taken from the non-electrified village survey (1,716 villages).

Based on the results of the comparison shown in **Table-7.4.1**, an overview of living standards of non-electrified villages is summarized in **Table-7.4.2**.

Table-7.4.2 Overview of Living Standard of Non-Electrified Villages

Assumed Situations of Living Standard	Brief Explanations on Living Standard
Limited Access to means of Livelihood	Agricultural land area of the non-electrified villages, which is a basis for a means of livelihood, is about 50% lower than that of the electrified villages. Cash income obtained from selling agricultural products, excluding self-consumption, is assumed to be limited (an average annual household income of the non-electrified households is about 65% of the electrified villages).
Low Accessibility to Social Services	Most non-electrified households targeted by the Study are located in a far distant area and have very limited access to public facilities, compared to the electrified villages. In order to have access to social services such as education and health services, people of the non-electrified villages need to get to a Gewog center where most of the public facilities are basically available. In particular, if people need to go to a hospital, they need to go to a Dzongkhag center where a hospital is located. Further, commercial facilities are very limited in distant villages.
Low Accessibility to areas Outside the Village	Accessibility to the non-electrified villages by car is found low, and an average traveling time by walking to a vehicular road is about 6.1 hours. Further, about 44% of access roads are not passable in the dry season, so that access to the non-electrified villages is found limited. In addition, the mode of transportation of the majority of the villagers in non-electrified villages to Gewog and Dzongkhag centers is by walking, so that it takes a quite long time to get these places, particularly to a Dzongkhag center.

Prepared by JICA Study Team

7.5 Number of Non-Electrified Villages and Households Targeted for Electrification

Based on the results of the Survey, the number of the non-electrified villages and households to be electrified is summarized in **Table-7.5.1.** The number of the targeted non-electrified villages is 1,745 in total (the number of households and population is 30,064 and 226,394, respectively). It should be noted, however, that the non-electrified households in some electrified villages (37 households) were excluded from the target villages because only low-voltage distribution lines are required to be placed by BPC.

Table-7.5.1 Number of Non-Electrified Villages and Households to be Electrified after 9th Five Year Plan

	Category	Number of Non-Electrified Villages	Number of Non-Electrified Households	Remarks
Target Villages for Electrification	Non-Electrified Villages to be Electrified after 9th FYP Identified by the Survey	1,716	29,942	-
	Non-Electrified Villages Not Surveyed Due to Security Reasons	13	85	These villages and households in are in Sarpang and Samdrup Jongkhar.
	Villages with Nomads	16	37	These villages and households in Thimphu and Paro shall be electrified with portable lights.
	Total	**1,745**	**30,064**	-

Source: Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

7.6 Estimation of Total Number of Electrified Households for 100% Electrification Ratio Achieved

7.6.1 Overview of Electrified Households

In order to estimate the total number of the electrified households when 100% electrification ratio is achieved, the number of households electrified as of June 2004 (the number of electrified households is 39,311) is first summarized in **Table-7.6.1**, according to the data on rural and urban electrification prepared by DOE.

Table-7.6.1 Number of Households Electrified As of June 2004

Area	FiveYear Plan / Power Corporation	Electrified Households	
		Number of Electrified Households (Actual Figure)	Accumulated Number of Electrified Households (Actual Figure)
Rural Area	6th FiveYear Plan	7,360	7,360
	7th FiveYear Plan	5,476	12,836
	8th FiveYear Plan	8,822	21,658
	9th FiveYear Plan (as of June 2004)	447	22,105
	Sub-Total	**22,105**	**22,105**
Urban Area	Bhutan Power Corporation	15,508	-
	Tala Hydro Power Corporation	950	-
	Chukka Hydro Power Corporation	576	-
	Kurichu Hydro Power Corporation	172	-
	Sub-Total	**17,206**	**-**
Total (Rural Area + Urban Area)		**39,311**	**-**

Source: Data on rural and urban electrification (DOE, 2004),

Note 1) For information, the number of public and commercial facilities electrified is 4,530 (2,728 facilities in rural area and 1,802 facilities in urban area.

7.6.2 Estimation of the Number of Electrified Households for 100% Electrification Ratio Achieved

According to the number of the electrified households as of June 2004 mentioned in Section 7.6.1 and also the number of the non-electrified households to be electrified after 9th FYP mentioned in the Section 7.5, the total number of the electrified households (the total number of electrified households is 83,951) is estimated when 100% electrification ratio is achieved in the national target year of 2020 and summarized in **Table-7.6.2.**

Table-7.6.2 Estimated Number of Households When 100% Electrification Ratio Achieved

	Number of Electrified Households	Accumulated Number of Electrified Households	Remarks
6th - 9th Five Year Plans (as of June 2004)	39,311	39,311	Number of households is an actual figure.
9th FiveYear Plan (from July 2004 to the end of 2007)	14,576	53,887	Number of households is a planned figure.
From 10th Five Year Plan to the Year 2020.	30,064	83,951	Results of the Survey.
Total	**83,951**	-	

Sources: Data on rural and urban electrification (DOE, 2004), Village Baseline Survey for Rural Electrification (JICA Study Team, 2004)

CHAPTER 8 PRACTICAL USE OF GIS IN PREPARING THE MASTER PLAN

8.1 Introduction of GIS

The Dzongkhag -wise electrification master plan covers the whole of Bhutan. The studies undertaken for preparing the master plan used various spatial data. Spatial data contain both location information, e.g. the X, Y and Z coordinates of a village or a substation, and other information that relate to location, e.g. the name of a village and number of households in the village.

A Geographic Information System (GIS) was used in the master plan to efficiently manage the spatial data on a computer. GIS is a tool that can be used for creating, editing and managing spatial data that comprises positional information and associated attribute data. GIS can be utilized for making digital maps and also for analyzing the data. Analysis can be done either spatially, e.g. finding what distribution line feeders are located within a particular Dzongkhag, or be based on the data attributes, e.g. finding all feeders that are longer than 10 km. Using GIS enables the work of creating, correcting and updating spatial data required for the Study to be done easily.

A comprehensive spatial database was constructed as part of the master plan. The GIS data include existing spatial data, such as topographic base maps, satellite images, etc., and the new spatial data obtained during the master plan, such as the location of villages, substations and tap-off points that was determined by GPS survey. The database size is very large and it needed to be continually corrected, updated, and augmented during progress of the Study. Therefore, managing the database efficiently was an important task for the master plan.

8.2 GIS Data Creation Situation in Bhutan

The Department of Survey and Land Records under Ministry of Agriculture is in the process of digitizing the 1:50,000 scale topographic maps that cover Bhutan. This work involves converting the information shown on paper maps into digital format. The current progress of this work is shown in **Table-8.2.1** and **8.2.2** below.

Table-8.2.1 Current Progress of Map Digitizing in the Dept. of Survey and Land Records

Completed	In Progress		Total
34 Paper Maps	47 Paper Maps		81 Paper Maps
	Topographic map	Non-Topographic map	
	19 Paper Maps	28 Paper Maps	

Prepared by JICA Study Team

Table-8.2.2 GIS Data List -Created from the Topographical Map

Item	Feature Type	Attribute Data	Comments
Contours	Line	ID, Elevation	1:100,000 (Thimphu)
Rivers	Line	ID	
Roads	Line	ID	
Buildings	Point	ID, Category	

Prepared by JICA Study Team

Although GIS data prepared by the Department of Survey and Land Records of the Ministry of Agriculture was planned to be utilized in the master plan, the use of these data was not possible because the work was not completed yet. Therefore, the master plan used GIS data prepared by the Ministry of Agriculture as a basic data layer for the master plan.

The organization which has responsibility for collecting and coordinating GIS data in Bhutan is the Department of Survey and Land Records in the Ministry of Agriculture. In addition, many other organizations create their own GIS data, such as the Ministry of Agriculture, World Wildlife Fund (WWF), local consultants, etc. However, since each organization creates GIS data independently, the accuracy of the data is not uniformed and management of the data is not coordinated. External users of the data do not have access to metadata that describe basic information about the data, such as the base data, the data accuracy, the date of data creation, and so on. Moreover, the coordinate systems are different among the various organizations and local consultants since an international standard coordinate system is not used in Bhutan.

8.3 The GIS Database

8.3.1 Existing GIS Data and Its Practical Use

The Study Team obtained copies of existing GIS data, such as administrative boundaries, roads, and rivers, from the Ministry of Agriculture at the beginning of the master plan. These GIS data layers were created by an overseas consultant using satellite images (Landsat™) as the base map. Unfortunately, metadata details, such as the date that the satellite images were acquired, accuracy of the mapping, and so on was not clear. The Study Team used these GIS data as base layers for mapping. In utilizing these data, the Study Team updated and transformed these data as follows:

1) Change the coordinate system into an international standard coordinate system (UTM Zone 46N, WGS84 datum), and
2) Update of the administrative boundary data for Dzongkhags and Gewogs.

At the beginning of the master plan, there was no common coordinate system used in Bhutan. Therefore, the Study Team used the Universal Transverse Mercator (UTM) coordinate system, which is a recognized coordinate system used throughout the world. This coordinate system was adopted for all GIS data prepared during the Study.

After the Study had started, a GIS Working Group was formed in Bhutan. However, the Working Group has not yet reached a consensus about which coordinate system should be used as the standard for Bhutan. Discussion about setting up an original coordinate system for Bhutan has been one of the main activities of this Working Group. When the new Bhutan coordinate system is set up, it will be possible to convert all GIS data prepared in the master plan from UTM Zone 46N (WGS84 datum) coordinates into the new coordinate system that is established in Bhutan.

The Dzongkhag and Gewog administrative boundary data were updated with guidance under the DOE. Various reports and statistical data were referred to for obtaining current information about the boundary location and the administrative data relating to each area.

8.3.2 Creation of a National Contour Map

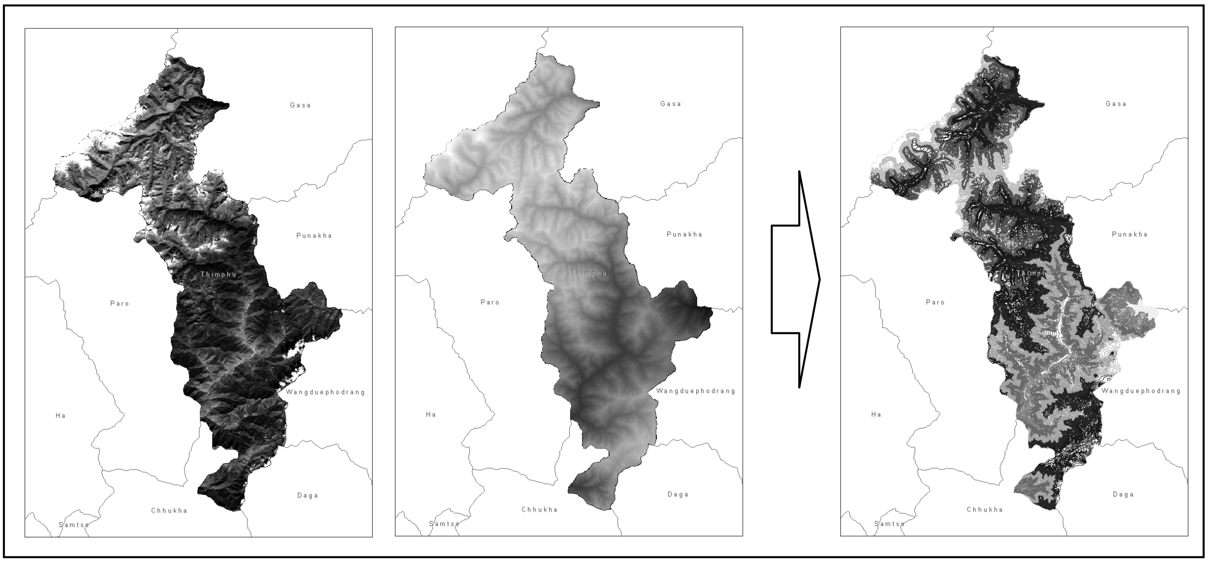
The master plan needed elevation data to calculate the 3D length of electricity distribution lines. However, as a result of investigations, it became clear that there was no existing data in Bhutan which satisfied the above-mentioned conditions of accuracy and reliability. Therefore, the Study Team created a GIS contour map of the whole of Bhutan using satellite images.

The satellite images were ASTER data supplied by the Earth Remote Sensing Data Analysis Center (ERSDAC) in Japan.

The advantages of using ASTER data are as follows:

1) It is possible to derive topographical data (contour lines).
2) The data accuracy is unified by using the same sensor images for all of Bhutan.
3) The maximum elevation error is less than 15 meters (the officially quoted value), so it is possible to satisfy the accuracy of the master plan.

In order to cover all of Bhutan, 25 ASTER images are needed. However, because the ASTER instrument is an optical sensor, it can not obtain images of the ground surface when clouds are present. Therefore, it was necessary to purchase two or more images of some locations (especially in mountainous areas) to obtain complete cloud-free coverage of Bhutan. As a result, the Study Team needed to purchase a total 40 images to create the contour map. The process of creating the contour map is illustrated in **Figure-8.3.1** below.



Prepared by JICA Study Team

Figure-8.3.1 An Example of Contour Creation from ASTER Data (Thimphu Dzongkhag)

8.3.3 Newly Acquired GIS Data

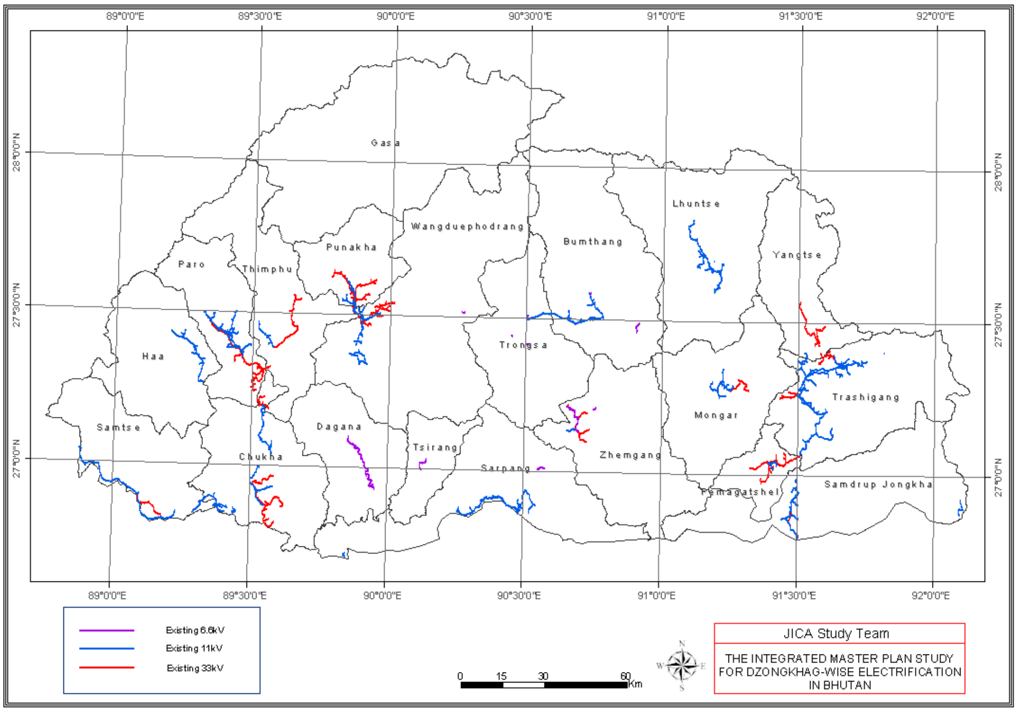
Two new sets of GIS daata were obtained in order to formulate the master plan. These data were added to the GIS database. These two sets of new data were as follows:

1) Existing power distribution facility position information for the whole country, and
2) Non-electrified village position information for the whole country

As for the existing power distribution facility position information, the Study Team conducted a training course on the basic use of Global Positioning Systems (GPS) for DOE and BPC. Based on this training, BPC obtained existing power distribution equipment position data (latitude/longitude) for the whole country. The surveyed facilities include power distribution pylons, transformers, switchyards, etc. BPC also obtained attribute information about each facility, such as voltage, transformer capacity, etc., which needed for the master plan. A map showing the location of existing electricity distribution lines is shown in **Figure-8.3.2** below.

In addition, the position of each non-electrified village was determined by a local consultant. This work was defined as the Village Baseline Survey described in Chapter 7. The consultant determined the village location by using GPS. The consultant also obtained village attribute information such as number of households needed for determination of the required transformer capacity, etc. These data were also added to the GIS database of the Study. A map showing the location of the non-electrified villages is shown in **Figure-7.3.1**, already presented in Chapter 7.

The results of the power distribution facility survey and Village Baseline Survey were made available to the Study Team and were incorporated in to the GIS database of the master plan.



Prepared by JICA Study Team

Figure-8.3.2 Newly Acquired GIS Data for Existing Distribution Lines (Whole of Bhutan)

8.3.4 Composition of the GIS Database

The GIS database built by the Study Team comprises the following data:

1) Existing GIS data obtained from concerned organizations;

2) Newly created data, by referring to various reports and statistics;

3) A national contour map, created from ASTER satellite images.

4) Newly acquired data for existing power distribution facilities and non-electrified village data;

5) Power line extension plan (ADB/RE-3) data; and

6) Power line extension plan (the master plan) data.

The composition of the GIS database is shown in **Table-8.3.1** below. The associated database structure is shown in **Figure-8.3.4** below.

Table-8.3.1 GIS Data Base

	Item	Data format	Attribute Data	Base Data	Note
The existing data (with updating)	Land use	Polygon	Land use	Remote sensing image	Under updating work
	Rivers	Line	ID	Remote sensing image	
	Roads	Line	ID	Remote sensing image	
	Elevation	Line	Elevation		
	Administrative boundary Dzongkhag, Gewog	Polygon	ID, Area	—	Updated by DOE
	Basins	Polygon		Remote sensing image	
	National Parks	Polygon	Name, Area	—	
	Forest management	Polygon	Name, Area	—	Paper Map
	Corridors	Polygon	ID, Area	—	
	ADB/RE-3 data Distribution Line, Position	Point Line	Voltage, distance	GPS	Local consultant creation / GIS data is Re-created
New acquisition	Elevation data (Contours)	Grid Line	Elevation	Satellite image (ASTER)	
	Non-electrified Village	Point	Name, No of Houses, etc	GPS	On/Off grid by economic evaluation
	Power distribution facilities position	Point	Pole position, substation position	GPS	
New creatio	Master Plan Power distribution facilities position	Point	Voltage, length, etc.		
		Line	On/off grid, feeder phase, economic information etc.		

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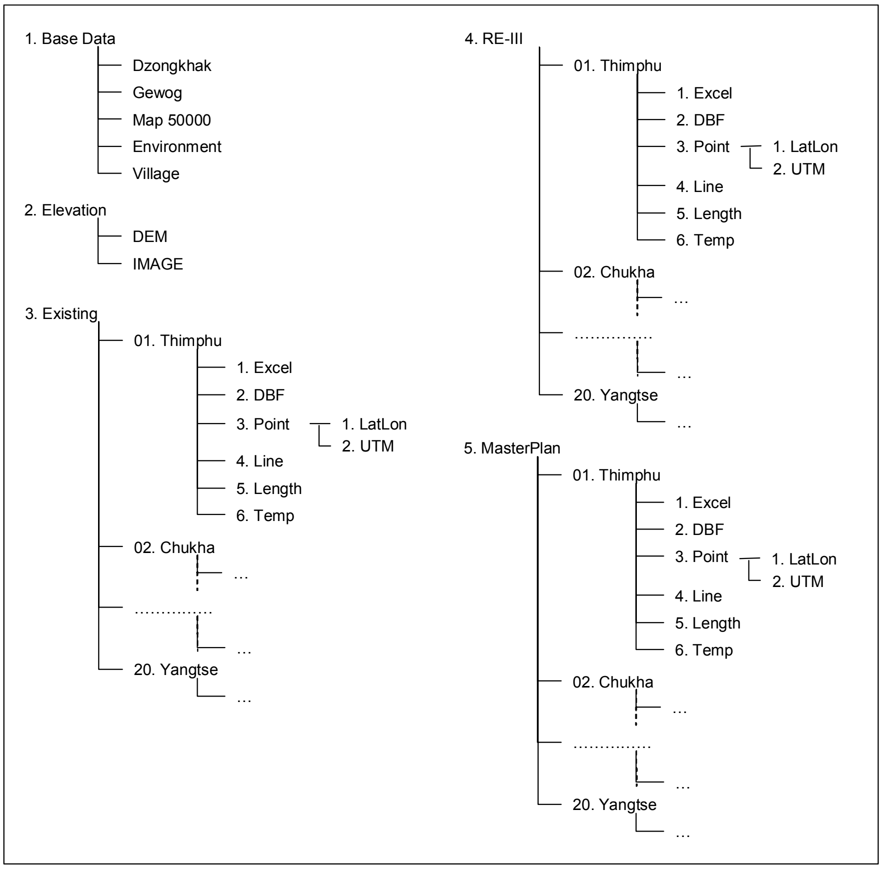


Prepared by JICA Study Team

Figure-8.3.4 GIS Database Structure

8.4 The Interface with Other Programs

The Study Team also used the GIS as a tool for managing the database. The master plan data, which is examined in GIS, should be handed over to other programs used in the master plan, such as the power flow analysis program, and economic optimization program. The master plan data were analyzed again by other programs, and then the results of the examination were reflected in the GIS. Therefore, an interface with other programs needed to be set up.

The form of the interface and the items set up for the power flow analysis program and the economic optimization programs are described in the following sections.

8.4.1 Interface with the Power Flow Analysis Program

The power flow analysis program required that the data exchange between GIS and the analysis program be performed by using a Microsoft Excel spreadsheet. The data that were transferred from the GIS to the power flow analysis program are listed in **Table-8.4.1** below. A sample of the Excel spreadsheet is shown for reference in **Table-8.4.2** below.

Table-8.4.1 Data List for GIS Data Transfer to the Power Flow Analysis Program)

NO	Data Item
1	Existing infrastructure ID
2	Tap-off position
3	Conductor size
4	Substation position
5	Length (2D)
6	Length (3D)

Prepared by JICA Study Team

Table-8.4.2 Sample of the Excel Spreadhseet

(GIS Data for the Power Flow Analysis Program)

POLE__#	VOLTAGE_LEVEL	TAP_OFF	Privious Pole#	SIZE	SUBSTATION	ELEVATION	X	Y	2D Length (m)	3D Length (m)	2D SUMUP Length	3D SUMUP Length
S10H1	11kV			DOG		1,412	192,631.79315	3,028,125.51552	154.33	154.34	154.33	154.34
S10H2	11kV	Yes	S10H1	DOG		1,410	192,776.74906	3,028,178.47630	60.89	62.26	215.61	217.24
S10H3	11kV		S10H2	DOG		1,423	192,717.68204	3,028,193.25957	90.73	90.87		
S10H4	11kV		S10H3	DOG		1,418	192,793.22835	3,028,243.51331	63.98	64.11		
S10H5	11kV	Yes	S10H4	DOG		1,414	192,833.10763	3,028,293.54668	113.29	117.46	441.61	458.09
S10H6	11kV		S10H5	RABBIT		1,445	192,784.14313	3,028,395.71126	73.03	73.58		
S10H7	11kV		S10H6	RABBIT		1,454	192,738.00655	3,028,452.32510	86.93	88.99		
S10H8	11kV		S10H7	RABBIT		1,473	192,708.34515	3,028,534.04200	89.04	93.96		
S10H9	11kV		S10H8	RABBIT		1,503	192,668.72952	3,028,613.78862	79.30	84.10		
S10H10	11kV		S10H9	RABBIT	Yes	1,531	192,642.86300	3,028,688.75550				

Prepared by JICA Study Team

In the power flow analysis program, the distance information is a very important element. Therefore, it was necessary to calculate not only the 3D distance between power distribution pylons, but also the distance to tap-off positions, the distance to substations, and the distance to the position where the conductor size was to be changed, etc.

All of these data were calculated by using the elevation data in the Excel spreadsheet that was transferred to the power flow analysis program.

8.4.2 Interface with the Economic Analysis Program

In the master plan, GIS was used in order to create the route for new distribution lines. First of all, the Study Team connected all the non-electrified villages to the electricity grid (Option-1, All on-grid). The separation of on-grid villages and off-grid villages was determined by economic evaluation. This economic evaluation was gradually changed, according to the situation, and the data were updated frequently, as needed. Therefore, it was important for this master plan to make an interface with GIS and economic optimization program.

The economic optimization program required that the data exchange between GIS and the economic optimization program also be performed using a Microsoft Excel spreadsheet. The data that were transferred from GIS to the economic optimization program are listed in **Table-8.4.3** below.

Table-8.4.3 Data List for GIS Data Transfer to Economic Optimization Program)

NO	Data Item
1	Existing infrastructure ID
2	Line voltage
3	Conductor type
4	ABS, SVR. Numbers of transformer, position of the transformer
5	Village ID
6	Tap-off position
7	Distribution line location
8	Environment type data for distribution line location

Prepared by JICA Study Team

The economic evaluation program identified the on/off grid of the non-electrified villages and determined the implementation phase for the electrification, based on the above data. The economic calculation was done by Visual Basic in Microsoft Excel, and the results were transferred back to the GIS database. The data fed back to GIS is shown in **Table-8.4.4**.

Table-8.4.4 Data List for GIS Data Transfer to Economic Analysis Program)

NO	Data Item
1	Distance between villages, tap-off-villages, and between tap-off's
2	Household of 2003, 2007, 2012, and 2020
3	Peak demand, energy demand
4	Benefit and cost for on-grid
5	Benefit and cost for off-grid
6	Evaluation result of on/off-grid
7	Feeder information including households, length, and cost
8	Phase of implementation of feeders

Prepared by JICA Study Team

The Study Team held a training course for DOE and BPC engineers to explain the process of updating the GIS data and reflecting the results of the economic analysis. The details of this training course are described in Section 8.5.2 below (Technolgy Transfer and Counterpart Training).

8.5 The GIS User and Data Management

8.5.1 The GIS User and its Capability

The installation of GIS in the counterpart organization was a very important component of the master plan. The main analysis work done for the master plan used GIS as a tool for data creation, data examination, database management, and data transfer. Therefore, the Study put a high priority on technology transfer. The purpose of this technology transfer was to assist the counterparts to acquire the ability to prepare the master plan by themselves using GIS, and to update the master plan data by themselves in case the condition is changed.

Although there were a few counterparts who had prior knowledge of GIS when the training started, none of them had used GIS in actual business usage. Moreover, no one had used the particular GIS software (ArcGIS) that was used in the Study. Therefore, the technology transfer and training in the operation of the GIS software were important components of the Study. Consequently, enhancement of the counterparts' GIS skills at the initial stage was important. An outline of the technology transfer work related to GIS that was done by the Study Team, and an evaluation of the counterpart training, is provided in the following sections.

8.5.2 Technology Transfer and Counterpart Training

In the Study, the counterparts initially learnt the concept of GIS and the function of GIS, and then they tried to acquire the operation skills needed to use the GIS software.

The purpose of this technology transfer was not make them GIS operators, but to make them GIS managers who could do GIS work by themselves.

In the First Stage, the Study Team held a training course to describe the basic concept of GIS and the basic operation of GIS software. This course was run over four days, from January 19 to 23, 2005 as listed in **Table-8.5.1** below. A total of nine engineers from two organizations participated in this training. The counterparts in this training course not only had knowledgeable of GIS, but also knowledge of what related to power distribution plans and environmental impact surveys. It was successful to enable them to understand the structure of the database used for the Study.

Table-8.5.1 Training Course Details for the First Stage

GIS Operation Training

- Date: January 19, 20, 21, 22, 23, 2005 (five days)
- Time: 10:00-13:00, 14:30-17:00
- Place: BPC
- Participants: DOE: Mr. Karma P Dorjee, Ms. Dechen Wangmo, Ms. Wangmo
  BPC: Mr. Sunil Rasaily, Mr. Ujjiwal Deep Dahal, Mr. Tshering Tenzin, Ms. Dechen Dema, Mr. Nepal
  JICA Study Team: Ms. Usuda
- Contents: Basic operation of GIS software, GIS use in other fields, data editing, basic concept of the Study data, data creation for the Study.

Prepared by JICA Study Team

In the Second Stage, the participants in the advanced course for GIS training were only GIS counterparts. This was so that the trainees would have access to more specialized knowledge and greater operational capability. This would allow them to learn the function of GIS operation capability more completely. Five engineers participated in the GIS training carried out in the Second Stage. There were two engineers from DOE and three engineers from BPC. The details of training course are listed in **Table-8.5.2** below.

Table-8.5.2 Training Course Details for the Second Stage

1. Explanation of the District Electrification Technique, and Introduction of GIS
   - Date: June 17, 18, 2005 (two days)
   - Time: 10:00-13:00, 14:30-17:00
   - Place: BPC
   - Participants: BPC; Mr. Sunil Rasaily, Mr. Ujjiwal Deep Dahal, Mr. Tshezing Tenjin
     JICA Study Team: Mr. Shiraki, Ms. Usuda

2. GIS Training
   - Date: June 27, 28, 29, 30, 2005 (four days)
   - Time: 10:00-13:00, 14:30-17:00
   - Place: DOE
   - Participant: DOE: Mr. Karma P Dorji, Ms. Dechen Wangmo, Ms. Wangmo
     BPC: Mr. Ujjiwal Deep Dahal
     JICA Study Team: Ms. Usuda

Prepared by JICA Study Team

The Study Team did not conduct additional formal GIS training in Bhutan in addition to the Second Stage. However, the Study Team collaborated with both counterpart organizations

(DOE and BPC) to provide informal technology transfer during whole process of the master plan.

Based on the following criteria, it was judged that the target aim of the technology transfer and counterpart training had been achieved:

1) The counterparts can make a nationwide distribution line extension plan using GIS, and this was completed through the collaborative activities between DOE and BPC.
2) The counterparts made presentations about the methodology and usage of GIS for distribution line extension planning in the 2nd Workshop and the 3rd Workshop (see below). The counterparts prepared these presentations by themselves.

In the Study, there were two GIS technology transfer components: one was basic knowledge of GIS; and the other was the methodology for creating GIS data required for the master plan. There was no plan to provide a training course on updating the database and database management, since training for this work was not included in the technology transfer specification defined in the study TOR. However, the Study Team recognizes the importance of the sustainability of the GIS database and proposed that additional training in the management and maintenance of the database be provided to the counterparts. As a result, the Study Team held a one-month training course in Japan during May, 2005. This augmented the counterpart training that had previously been done in Bhutan. A total of five engineers participated in this training; two were engineers from DOE and two were engineers from BPC. In addition, one participant was an engineer from the Department of Surveys and Land Records in the Ministry of Home Affairs. This Department is responsible for integrating GIS data in Bhutan. The purpose of participation in this training course was for the counterparts to understand the data that was produced by the Study. In addition, it would enable the counterparts to provide advice, and become GIS specialist of Bhutan, when the comprehensive maintenance and management of the database is required in the future. This means that the database prepared by the Study will not only belong to DOE and BPC, but also to the whole of Bhutan, which will benefit the entire country. Details of the counterpart training provided in the 3rd Workshop are listed in **Table-8.5.3** below.

Table-8.5.3 Training Course Details for the Third Workshop

Basic operation of GIS software and updating and maintenance of GIS data
- Date: from May 9 for one month (two weeks for GIS training)
- Time: 10:00-13:00, 14:00-18:00
- Place: Nippon Koei Kojimachi Office
-Participant: DOE: Mr. Ngawang Choeda, Mr. Hari Prasad Sharma BPC: Mr. Ujjiwal Deep Dahal, Ms. Dechen Dema Dep. Of Survey: Mr. Shankar JICA Study Team: Mr. Nishimaki, Ms. Usuda, Ms. Nakagawa
-Contents: Basic operation of GIS software, GIS use in other fields, data editing, VBA programming, GIS data update to reflect the economic evaluation

Prepared by JICA Study Team

DOE and BPC trainees are evaluated to obtain enough understanding of the utility of GIS through the Study. In addition, GIS has been incorporated into their daily work. DOE sent two engineers who worked with the Study Team to learn GIS in the one month overseas GIS training course so that they could further develop their ability. Recently, BPC has set up a new section which is concerned with GIS. This section is using GIS widely for their work tasks. One of the approaches that they have taken is to map the location of their low voltage facility positions using GPS. They are making a database for Thimphu and Paro Dzongkhag by using a similar approach to that was applied in the Study.

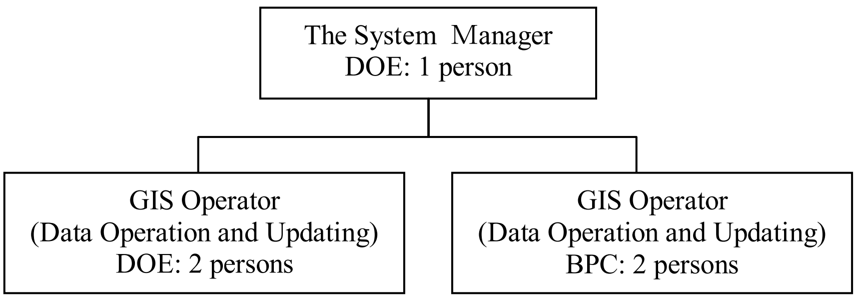
As mentioned above, it can be judged that the recognition of GIS capabilities and the potential use of GIS in Bhutan was facilitated through the master plan. The Study Team has a plan to update the database, not only for the master plan, but also for other sectors in Bhutan. Moreover, by updating the accuracy of the GIS data, this will directly improve the accuracy of the master plan. As an example, the acquisition of detailed current road data will not only improve the accuracy of the distribution line plan, but will also be useful for the phase wise decision of the master plan implementation. In addition, the acquisition of data and accuracy improvement of the data related to environmental protection will be very beneficial for Bhutan, as the nation has given environmental protection a very high priority.

The data which are needed to determine the actual electricity distribution line plan extends to several other sectors. Thus, it can be said that upgrading the master plan database is also beneficial to other sectors in Bhutan, and for the whole Bhutan nation.

8.5.3 Management, Operation and Maintenance of GIS

In the Study, three GIS training workshops were carried out for the GIS counterparts of DOE and BPC. While most of the counterparts had not previously used GIS for actual work, they were able to study GIS during the training for workshops. As a result, the counterparts could considered the master plan of the electricity distribution lines by themselves create GIS data and build the database. However, the database created in the master plan is flexible, and it can be updated according to future changes in various situations. The database updating work needs to be done continuously. Therefore, in order to make the master plan a reality, it can be said that construction, operation, and maintenance of the GIS database is indispensable.

The Study Team has proposed a management organization for the GIS database in Department of Energy, as shown in **Figure-8.5.1** below. The organization and the number personnel needed for maintenance and management of a database are shown.



Prepared by JICA Study Team

Figure-8.5.1 Management and Operation & Maintenance of GIS

8.6 Feasibility of GIS Database in the Other Fields

The database built in the master plan consists of spatial data that covers all of Bhutan. After a GIS database is created, it is feasible to utilize the database, not only in the master plan, but also in other projects. Therefore, the Study Team expects that the database built by the master plan will be utilized for various other usages in Bhutan. Other sectors which could use the GIS database for various purposes are indicated below:

Forestry	**Environment**	**Urban Planning**
- Forest change	- Pollution mapping	- Land use zoning
- Forest land ownership	- Environmental impacts	- Regulation monitoring
- Forest management	- Land use change	- Recreation areas
- Fire risk assessment	- Baseline surveys	- Infrastructure mapping
- Forest economics	- Illegal dumping	- Green resource mapping
Agriculture	**Nature Conservation**	**Disaster Support**
- Farming regulation	- Reserve management	- Pre-disaster planning
- Farm ownership	- Wetlands	- Disaster management
- Farm land change	- Wildlife management	- Relief work
- Crop type mapping	- Biodiversity	- Food distribution
- Crop yield estimation	- Habitat mapping	- Shelter management
Water Resources	**Health**	**Hazards**
- Channel networks	- Hospital location	- Landslides
- River management	- Health statistics	- Earthquakes
- Catchments management	- Disease source mapping	- Forest fires
- Algae mapping	- Locality correlation	- Floods
- Navigation hazards	- New facilities planning	- Pollution management
Waste Disposal	**Spatial Data Management**	**Transportation**
- Incinerator location	- Cadastral mapping	- Parking management
- Landfill location	- Land tax compliance	- Traffic management
- Chemical disposal site	- Facilities management	- Road sign placement
- Garbage collection	- Buried pipes and cables	- Traffic hazard identification
- Recycling depots	- Utilities	- Road management