第５章　技術的検討

第５章　技術的検討

5.1　グリッド延伸による電化

（１）要求される基礎資料

本格調査を開始するに当り、「Water Resources Management Plan and Hydro Power Master Plan Update」(NORAD 支援)及び前述した「地方電化プログラム Phase-Ⅲ」(ADB 支援)の完成が待たれるところである。DOE での聴取によれば、前者は 2003 年 5 月に、後者は同 8 月に最終成果が提出される予定である。

また、全国レベルの地方電化マスタープラン調査を所定の期間内(24 ヶ月間の予定)に実施するためには、全国をカバーする地形図はもとより、デジタルマップを活用した GIS 技術の適用が不可欠である。現在、ブータンでは、可住地域をカバーする 1/50,000 地形図を基に作成したデジタルマップが、国家計画委員会(Planning Commission; PC)の管理の下で関係各部局に配布され、各種計画立案に利用されている。このデジタルマップを作成する際に使用された原図は 1960 年代編集の 1:50,000 地形図で、データ内容が最近の状況に合わなくなってきたことから、内務省の測量・地籍部においては、改訂版 1/50,000 地形図(20 葉程度)及び同 1/25,000 地形図(15 葉程度)を基に、デジタルマップ主要部分の改訂作業を実施しているところである。改訂作業は第 8 次 5 カ年計画期間内で行われる予定であるが、マッピング担当責任者によれば、今回調査時点でその過半がデジタル化を完了しており、最終確認作業等を含めても後 1～2 年以内(現状の要員で処理すれば 2 年程度、近々に増員要請が認められれば 1 年以内)に完了する見込みである。

ブータンにおけるデジタルマップの取り扱いと配布の方法等は、以下に示すとおりである。

1) 旧版作成と配布の流れ

① 旧版作成：Land Use Planning Project, Ministry of Agriculture
② 使用データ：1960 年代編集の 1:50,000 地形図(インド支援により作成)
③ 監理：Planning Commission(PC)
④ 管理：Central Statistical Coordination
⑤ 配布：National GIS Coordination (関係各部局に配布)
⑥ 使用：各部局の使用目的に合わせて GIS を拡充しつつ計画作成等に使用

2) 改訂版作成と配布の流れ

① 改訂作業：Division of Survey & Land Use Registration, Ministry of Home Affairs
② 使用データ：1991 年の SPOT 衛星画像データ(Swedsurvey 作成)
③ 監理～使用：完成後は上と同じ流れで各部局に配布される。

（2）解析ツール

送配電系統計画を立案するために必要な解析ツールは各種利用されているが、ブータンの電力セクターでは、以下に示す各ソフトウェアを保有･運用している。

マスタープラン調査に際して、C/P 機関が使い慣れたソフトウェアを使用することができれば、効率的な調査の実施に有効である。BPC での聴き取り調査結果は次の通りであった。

この点については、我が国で用いられているソフトウェアとの比較検討を行う必要がある。

1) システム計画関連ソフトウェア

PTI 製の PSS シリーズを保有･運用している。

① PSS Adapt(Power System Simulation Adapt)：負荷解析用
② PSS E：送電計画解析用
③ PSS U：配電計画解析用
④ MiPower(インドのコンサルタント会社から入手)：Load Flow, Short Circuit 及び Coordination 解析等に使用。単結図作図可能
⑤ その他：WASP の導入を検討中

2) GIS 関連

デジタルマップデータと共に国家計画委員会(PC)から支給されたものである。

① Arc Info 2.1
② Arc View 3.1
③ Arc GIS 8.1

3) その他

① AUTOCAD 2000
② Comfor III(UNIDO からの支給)：Techno-Economical Analysis 用
③ Hydata(英国製)：水文･気象データ解析用

なお、上記の各種ソフトウェア及び基礎データは、DOE と BPC で共有している。

（3）オフグリッド電化プランとの関連

今回要請されている地方電化マスタープラン調査は全国の 20 県を対象とするものであり、調査期間内に全県の未電化村落を全て実地調査の対象とすることは現実的ではないことから、代表的な数地点をモデルサイトとして選定し、小水力ポテンシャル、太陽光ポテンシャル、需要原単位、支払可能額、その他社会･経済指標等に関して現地調査を実施し、モデルプラン（6.3(1)に要件を記述）を作成することが適当と判断する。

2000 ヶ所あるとされる未電化村を数地点で代表させることの妥当性については議論の分かれるところではあるが、マスタープラン調査が実施期間と予算の制約を受ける以上はやむを得ないものと考える。調査に当っては、例えば、①グリッドに比較的近距離(架線距離で 5～10km 程

度以内：送電中の電圧降下を考慮し、送電線建設単価 US$10,000/km～US$15,000/km)に位置し、送電線延伸が可能な村落，②グリッドからは遠いが近傍に独立電源が期待できる村落(群)、及び、③グリッド延伸並びに独立電源のいずれも期待できない村落(群)等の数パターンに類型化(必要に応じ、各分類をさらに細分化)した後、それぞれの分類に適したモデル地点の選定とモデルプラン作成に工夫を凝らして 6.3(2)に述べる作業を行って、2020 年に向けたマスタープランの立案に反映させるといった手法が考えられる。

モデルサイトの選定基準等については、少なくとも第 9 次 5 カ年計画終了時点(2007 年)での系統延伸の到達予定範囲と未電化村落の配置を把握することが、的確な電化対象地域及び電化手法（オングリッド電化かオフグリッド電化か）の枠組み並びにモデルサイト選定基準の設定にとって不可欠である。また、未電化村落の地理的状況，社会･経済状況等に関するデータベース（DB）作成（5.1(1)項並びに 6.3 節参照）が必須である。

この観点から、S/W 調査においては、前述（3.2(2)項並びに 5.1(1)項参照）した ADB 支援の地方電化計画(RE-Ⅲ)と NORAD 支援案件の調査成果の確認及びアクセスを確保するための道路整備状況の再確認が、全ての議論の出発点となろう。

（4）小水力ポテンシャルインベントリの作成

現在、従来から検討されている設備容量 150MW 以上の水力ポテンシャルサイトについて、ノルウェー(NORAD)の支援により水力開発マスタープランへの再検討が加えられている（「Water Resources Management Plan and Hydro Power Master Plan Update」）。同調査の最終報告書は 2003 年 5 月に上梓される予定である。この成果は、本件本格調査において、グリッドへの連系を考慮した新規水力開発計画(すなわちグリッドの再延伸)並びに中規模以上の独立ミニグリッド形成計画に寄与することとなろう。

ブータン国政府が掲げる「2020 年までに世帯電化率 100%達成」を実現するためには、最終的には系統供給を目指すとしても、当面はオフグリッドでの小規模水力開発が当然必要となるが、現状では小水力ポテンシャルの整理は行われていない。今回調査により、DOE 内部に全国の水力ポテンシャルサイトを把握している職員の存在(Hydro－met Division に採用されて以来 20 数年奉職している Mr.Basnet)が偶然明らかになったが、本格調査実施時には、同氏の全面的協力を求めて可能な限り全国小水力ポテンシャルの整理を行い、その成果を上述したモデルサイト調査に反映させる等して、効率的な電源開発計画の立案に努めるべきである。

（5）送配電技術基準の統一化･規格化

C/P 機関との面談時に先方から出された発言の中に、ADB の支援により実施中の地方電化プログラム(RE)においては、各フェーズで支援国が異なり(Phase-I はニュージーランド、Phase-II はインド、Phase-III はオーストラリア)、送配電技術基準も各支援国の基準が適用されていて、全体としての統一がとれていない。これでは、BPC としても運用上不都合であるので、少なくとも送配電に関してだけでも技術基準の統一を図りたいとの意向が示されており、本格調査実施時には配慮が必要である。

5.2 再生可能エネルギー技術

（1）気象観測データ

再生可能エネルギー発電の多くは日射・風況・雨量等の自然現象を直接利用することから、そのポテンシャルを評価するためには、エネルギー供給源の大きさを科学的に把握する必要があり、気候に関するデータは年毎に変動するため、長期間のデータの集積が必要となる。

a) 気象観測ネットワーク

ブータンでは気象観測ネットワークとして 84 の気象観測所で気象一般データを採取し、12 の農業気象観測所で農業用データ及び全国各地に設置された 21 カ所の流量観測所から成る。

- 気象観測所：雨量、気温、日照時間等の測定
- 農業気象観測所：風向、風速、相対湿度、土壌温度等の測定
- (Primary) Gauging Station；河川流量など

図-5.1 と表-5.1 に気象観測所所在地と一級及び二級流量観測所リストをそれぞれ示す。

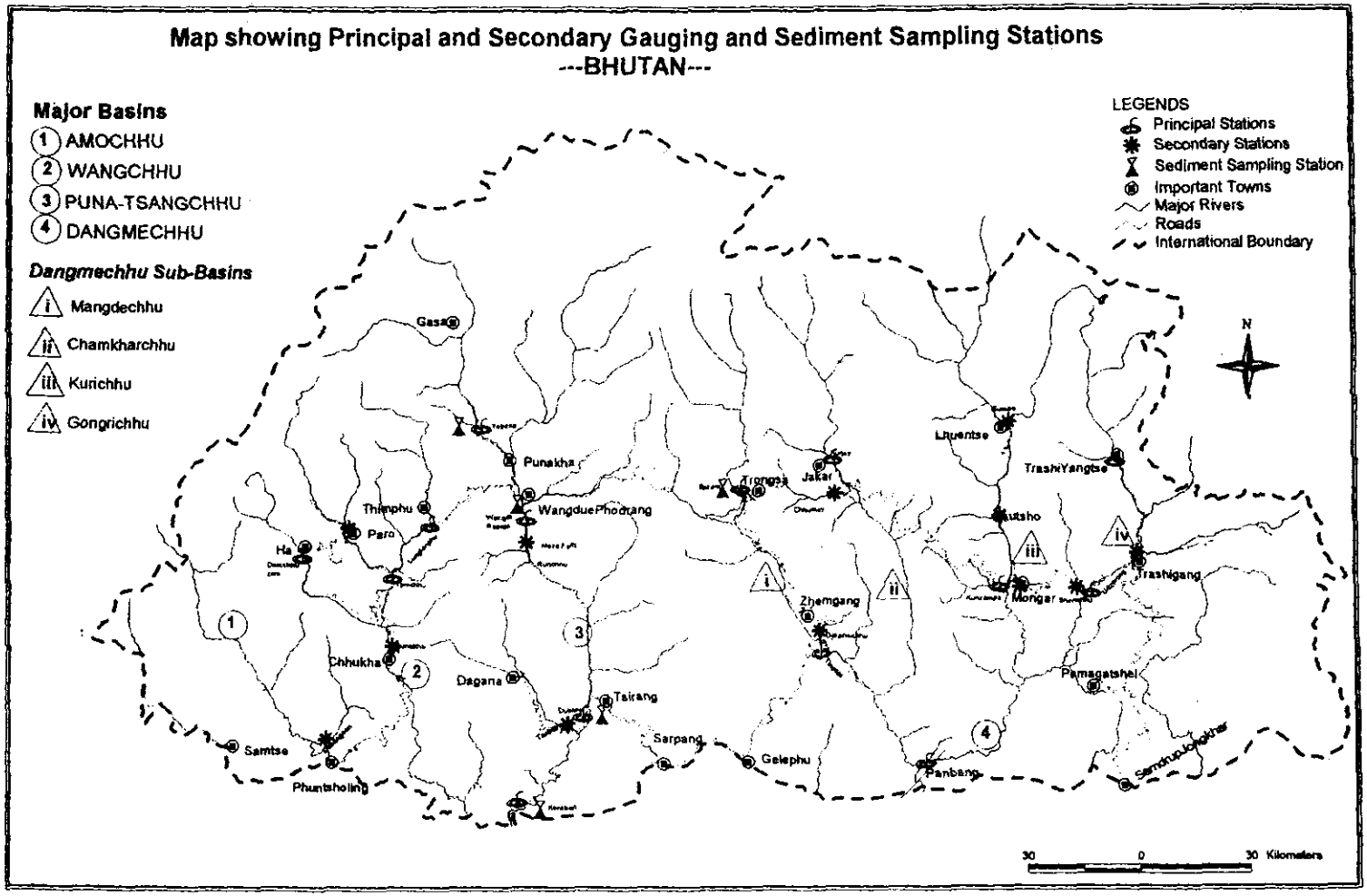


図- 5.1　ブータンの一級および二級流量観測所所在地

表- 5.1　ブータン一級及び二級流量観測所リスト

Primary Gauging stations

Station Name	Latitude	Longitude	Altitude (m)	Catchment Area (km²)	Status	Year of Record (period)	Remarks
Doyagang on Ammochhu					Continuing as Sec. Station	2001-2002	Not usible
Lungtenphug on Wangchhu	27:26:48 N	89:39:40 E	2260.0	663.0	In function	1991-2001	good+
Damchhuzam						1991-1999	good+
Tamchhu on Wanchhu	27:15:30 N	89:31:68 E	1990.0	2520.0	Signal cable stolen, not functioning	1995-98	ok-
Yebesa on Mochhu **	27:37:59 N	89:49:03 E	1230.0	2302.0	In function	1991-2001	good+
Wangdirapids on Phochhu + Mochhu **	27:27:45 N	89:54:11 E	1190.0	5640.0	In function	1991-2001	good+
Dobani on Sankosh **	27:00:38 N	90:04:27 E	265.0	8050.0	In function	1992-2001	good-
Bjizam on Mangdechhu **	27:31:28 N	90:27:17 E	1848.0	1390.0	In function	1994-2001	good+
Tingtibi on Mangdechhu (S) Best						1987-2001	good-
Tingtibi on Mangdechhu	03:08:44 N	18:41:36 E	565.0	3200.0	Continuing as Secondary Station, due to unstable river bed	1991-2001 Change in 1998	DM bad
Kurjey on Chamkharchhu	27:35:13 N	90:44:13 E	2588.0	1350.0	In function	1991-2001	good+
Kurizampa on Kurichhu **	27:16:26 N	91:11:37 E	519.0	8600.0	In function	1991-2001	good+
Trashi Yangtse on Kholongchhu (Old)	27:36:42 N	91:29:35 E	1707.0	837.0	Closed	1991-1998, 99 mis.	good+
Trashi Yangtse on Kholongchhu (New)	27:35:20 N	91:29:31 E	1647.0		In operation	1991-1999	Bad
Uzorong on Gongri	27:15:38 N	91:24:50 E	554.0	8560.0	In function	1992-2001	Good-, DM ok-
Also Sediment Sampling Stations							
Secondary Gauge Station:							
Hachhu	27:22:32 N	89:17:28 E	2700.0	323.0	In function		
Paro on Paro Chhu	27:25:98 N	89:24:30 E	2225.0	1049.0	In function	1987-2001,	From 95 ok
Bunakha on Wangchhu	27:07:86 N	89:32:40 E			In function		
Mazafall on Rurichhu	27:13:80 N	89:55:20 E		61.0	In function		
Sumpa on Khomachhu	27:39:34 N	91:12:46 E	1145.0	641.0	In function		updated
Autsho on Kurichhu	27:25:59 N	91:10:38 E	814.0	8453.0	In function	1987-2000	good-
Lingmethang on Maurichhu	27:15:11 N	91:11:15 E	536.0				updated
Sherichhu on Sherichhu	27:15:19 N	91:24:36 E	542.0		In function	1992-2000	good-

b) PV システムに関連する気象データ

PV システムに関連するデータとしてなるべく多くの地点での（水平面）日射量値(kWh/m²/day)が必要となるが、ブータンではそのデータは存在しない。1992 年に 3 台の日射量測定用計器を設置し 1995 年まで観測したが、コンピュータトラブルでデータを失ってしまったため使えるデータは存在していないとの記録がなされている（前出、UNIDO/SPPD Project）が、同資料の添付資料に“Insolation (kWh/m²/day)の値”が示されている（表- 5.2)。一方 DOE では、現在年間を通じた日平均日射量の暫定値として、4kWh/day/m² を全土に適用している。この暫定値と表-5.2 示されるデータの間には当然乖離が見られる(図-5.2)。

表-5.2　地域ごとの月平均日射量

	地域						（単位：kWh/m2/day）	
緯度	27.5	28.5	27.5	27.5	26.5	26.5	26.5	
経度	89.5	89.5	90.5	91.5	89.5	90.5	91.5	
10年平均	A	B	C	D	E	F	G	平均
推定地名	Gasa							
1月	3.77	3.56	3.72	3.64	3.97	3.88	3.84	3.8
2月	4.54	4.45	4.42	4.23	4.63	4.51	4.40	4.5
3月	5.26	5.13	5.08	4.80	5.38	5.25	5.05	5.1
4月	5.69	5.68	5.42	5.08	5.71	5.47	5.22	5.5
5月	5.65	6.06	5.35	5.08	5.20	4.88	4.73	5.3
6月	5.29	5.95	5.03	4.83	4.62	4.37	4.30	4.9
7月	4.36	4.78	4.26	4.18	3.93	3.87	3.86	4.2
8月	4.28	4.46	4.17	4.08	4.11	3.99	3.99	4.2
9月	4.09	4.40	3.94	3.80	3.78	3.65	3.64	3.9
10月	4.48	4.61	4.34	4.17	4.36	4.25	4.15	4.3
11月	4.30	4.34	4.28	4.21	4.26	4.24	4.21	4.3
12月	3.61	3.43	3.60	3.58	3.78	3.73	3.72	3.6
年平均	4.6	4.7	4.5	4.3	4.5	4.3	4.3	4.5

出典：UNIDO/SPPD Project Report

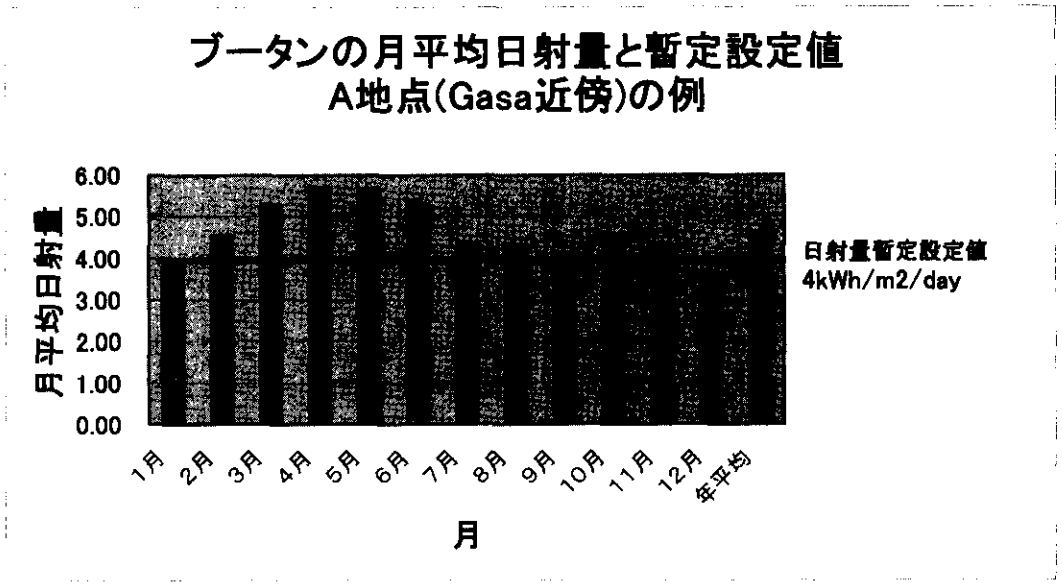


図-5.2 ブータンの月平均日射量と暫定設定値

c) 日照時間記録データ

今回の調査で次の5地点における日照時間記録データを入手した。

- Phuntsholing
- Para
- Damphu
- Bhur
- Shimtokha

入手資料より観測所別月平均日照時間記録を表-5.3に示す。

日本気象協会の「研究成果報告書(NEDO/平成3年)」に提示されている計算式により、これらのデータよりある程度日射量を推定できる可能性もある。この計算式は多項式から成っており、各係数の取り方など、気象協会の指導が必要となると思われる。

表-5.3　観測所別月平均日照時間記録

測定箇所		測定年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
Phuntsholing	月別日照時間合計	1996	102.90	161.80	143.24	[illegible]	105.03	100.10	46.00	72.70	106.70	175.30	[illegible]	NA
		1997	[illegible]	[illegible]	NA	[illegible]	[illegible]	70.00	65.80	92.70	63.10	196.00	195.70	177.00
		1998	151.71	176.10	[illegible]	159.60	161.30	14.50	[illegible]	[illegible]	91.81	140.20	220.10	244.50
		1999	245.60	167.90	141.40	[illegible]	159.50	189.40	181.20	79.30	128.30	174.20	256.10	254.70
		2000	162.00	163.90	138.90	159.10	147.40	59.10	56.70	99.40	109.20	224.50	157.90	187.01
		2001	180.40	115.60	190.20	153.10	130.40	55.70	46.10	132.00	85.10	182.00	199.70	NA
	月別平均日照時間		5.44	5.53	4.95	5.24	4.54	2.72	2.55	3.07	3.25	5.87	6.86	6.96

測定箇所		測定年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
Paro	月別日照時間合計	1996	213.50	178.00	237.90	249.30	199.60	155.50	139.50	179.70	[illegible]	228.90	228.10	227.00
		1997	211.10	142.60	243.60	163.10	191.60	[illegible]	[illegible]	152.80	149.90	256.40	242.40	193.20
		1998	256.60	243.50	215.00	220.50	200.80	136.20	85.30	112.90	199.10	217.10	250.00	170.90
		1999	267.40	244.90	277.20	246.40	186.90	163.41	203.40	151.30	176.20	236.70	205.24	200.80
		2000	212.40	194.90	207.30	202.00	[illegible]	[illegible]	44.22	[illegible]	[illegible]	163.50	162.90	164.50
		2001	193.10	165.20	206.10	[illegible]	76.50	94.20	82.30	84.70	[illegible]	203.50	157.50	NA
	月別平均日照時間		7.28	6.88	7.46	7.21	5.52	4.58	3.58	4.40	5.84	7.02	6.92	6.17

測定箇所		測定年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
Damphu	月別日照時間合計	1996	141.60	182.60	199.10	252.20	152.80	123.30	76.00	139.90	146.70	240.70	233.80	260.70
		1997	206.00	121.00	181.10	172.60	184.10	115.60	140.50	121.80	125.70	268.20	226.00	218.40
		1998	211.50	228.10	176.50	219.30	229.40	84.30	63.40	55.70	168.30	211.10	244.60	269.10
		1999	277.20	242.00	255.80	194.60	139.50	133.10	79.80	111.70	141.00	212.20	262.60	232.50
		2000	215.50	235.90	213.40	200.30	180.70	115.00	110.10	[illegible]	151.30	262.10	213.10	NA
		2001	214.90	214.30	282.60	239.10	163.00	126.70	141.40	144.70	138.70	222.20	244.90	230.80
	月別平均日照時間		6.81	7.20	7.03	7.10	5.64	3.88	3.29	3.70	4.83	7.62	7.92	7.82

測定箇所		測定年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
Bhur	月別日照時間合計	1996	[illegible]	[illegible]	[illegible]	94.00	[illegible]	153.00	197.00	166.50	106.20	[illegible]	85.00	52.00
		1997	189.30	148.70	[illegible]	NA	184.30	37.10	117.90	110.09	133.30	246.59	197.30	185.60
		1998	169.90	202.00	142.10	199.90	110.80	42.20	37.20	36.20	82.20	140.30	233.50	265.60
		1999	267.30	185.50	185.90	132.70	122.80	58.22	31.10	67.20	134.80	211.40	240.90	290.80
		2000	184.00	209.60	[illegible]	91.30	91.20	65.00	51.52	81.00	132.00	[illegible]	151.90	NA
		2001	184.00	203.10	[illegible]	[illegible]	133.20	[illegible]	[illegible]	[illegible]	115.40	[illegible]	[illegible]	NA
	月別平均日照時間		6.42	6.73	5.29	4.32	4.14	2.37	2.80	2.97	3.91	6.43	6.06	6.40

測定箇所		測定年	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
Simtokha	月別日照時間合計	1996	[illegible]	220.40	[illegible]	[illegible]	209.00	124.20	115.30	151.50	[illegible]	224.50	219.70	230.50
		1997	216.70	161.30	203.50	171.80	188.00	142.50	183.90	153.20	162.50	238.00	230.70	216.40
		1998	237.20	232.20	193.90	187.12	[illegible]	111.30	46.10	66.70	146.10	174.90	183.40	209.53
		1999	240.30	232.00	235.90	190.90	117.20	113.00	104.20	108.40	173.00	190.80	212.10	185.90
		2000	193.40	209.00	171.00	187.10	138.20	69.00	119.02	164.90	149.70	173.90	159.40	174.51
		2001	145.01	161.10	139.40	155.30	156.50	184.90	191.10	78.30	105.50	147.40	177.90	147.90
	月別平均日照時間		6.66	7.15	6.09	5.95	5.22	4.14	4.08	3.89	4.91	6.18	6.57	6.26

出典：Ministruy of Energy, RGoB

d) 風況データ

農業気象観測所データに「風向・風速」観測データがあるようであるが、今回の調査では入手できなかった。しかしながら前掲 UNIDO/SPPD Project レポートによれば、ブータンの幾つかの地域では“ほとんどの期間で 3~5m/sec という風況”があり、これらの地域では潜在的風力発電の可能性があると思われる。しかしながら、信頼に値する科学的な裏付けられたデータがないため、商業的な開発が行われない状況である。同資料に掲載されている風速データを示すが、”B”地点のように、年間平均がほぼ 4.8m/sec、月平均風速が 4m/sec を越える月が 9 ヶ月にもなることを考えればかなり風況がよく、低カットイン速度を持つ小型風力発電機の適用も考えられる。

表-5.4　地域ごとの月平均風速

	地域						（単位：m/sec）	
緯度	27.5	28.5	27.5	27.5	26.5	26.5	26.5	
経度	89.5	89.5	90.5	91.5	89.5	90.5	91.5	
10年平均	A	B	C	D	E	F	G	平均
推定地名	Gasa							
1月	4.53	5.27	4.5	4.59	2.59	2.29	2.27	3.72
2月	4.83	5.61	4.63	4.47	2.8	2.39	2.25	3.85
3月	4.98	5.81	4.75	4.53	2.87	2.46	2.31	3.96
4月	4.45	5.19	4.21	4.01	2.5	2.19	2.09	3.52
5月	3.75	4.43	3.52	3.34	2.15	1.9	1.81	2.99
6月	3.45	4.34	3.37	3.31	1.98	1.81	1.76	2.86
7月	3.25	3.97	3.24	3.24	1.88	1.74	1.72	2.72
8月	3.03	3.64	2.97	2.89	1.82	1.65	1.59	2.51
9月	2.95	3.65	2.88	2.83	1.76	1.59	1.55	2.46
10月	3.73	4.33	3.53	3.26	2.09	1.85	1.74	2.93
11月	5.01	5.68	4.84	4.49	2.69	2.37	2.23	3.90
12月	4.8	5.58	4.78	4.76	2.63	2.35	2.33	3.89
年平均	4.06	4.79	3.93	3.81	2.31	2.05	1.97	3.27

出典：UNIDO/SPPD Project Report

（2）ハイブリッド発電システム導入の可能性

ブータンの辺境地域の離れて散在する家庭への配電線の延伸はマイクログリッドであっても困難である。しかしながら、数百メータ以内の比較的密集した集落を形成している場合には再生可能によるハイブリッドシステムによるミニグリッドの導入も考えられる。つまり、

1. 辺境部といえども高い電力需要が要求され、政策決定サイドも高い電力需要を容認せざるを得ない。大きな家の構造、大家族構成からいって、照明ランプ(FL-10W x 4~7 セット)、ラジオ、トーチランプなどの電源は必須である。更に、学校・BHU・僧院がある集落には、それら公共的活動のための電力需要が必要になる。
2. マイクロ水力発電を適用するような水流には必ずしも十分な量の貯水部を取ることが可能とは限らないので、季節的な変動を受けやすい。エネルギー源としては、水力・太陽光・風力などに限定されるが、その何れも年間を通して十分といえない場合もあり、各エネルギー源に補完的な関係がある地域もある。
3. 少なくとも 2020 年までには系統線の延伸が見込まれることを前提にし、系統の到来時にその再生可能エネルギーシステムが、ブースターステーションとして運転が継続できること。再生可能エネルギー発電装置はそのまま利用できる系統技術対応型のインバータが一般的になってきているので、特別の費用支出は不要である。

このようなことを考慮に入れれば、再生可能エネルギー間のハイブリッド発電システムの導入・適用が考えられてもよい。次にその例を示す。

ァ．PV－マイクロ水力ハイブリッド発電システム

本システムはNEDOが国際共同実証開発プロジェクトの一環として行ったもので、雨期・乾期のある地域でPV発電とマイクロ水力発電をハイブリッド化し、お互いの短所を補う安定電源としてシステムを構築するプロジェクトである。

- 実施期間：FY1997~2000
- カウンターパート：Electricity of Vietnam (ベトナム電力公社)
- ハイブリッド電源負荷：一般村落電源
- 発電容量：PVシステム(100kWp)、マイクロ水力発電システム(25kW)
- 最大出力：125kW、最大発電量：約900kWh/day

本システムの特長を次に示す。

a) PV及びマイクロ発電の各システムを交流側で連系したこと：一般に系統連系システムは、系統側にほぼ無限大の電力需要とそれに対応する発電系が存在することにより成り立っている。従って、出力容量がほぼ同程度のPVシステムとマイクロ水力発電システム間の交流連系運転は、出力や需要負荷の変動が頻発するために制御不能となり、システムそのものが運転不可能となる。従って、これらのハイブリッド運転の場合は、直流側で連系するのが普通であるが、特殊な制御システムの導入により交流側連系システムの運転が可能となった。

b) 交流側連系の利点：PV単独システムではシステムの出力変動と負荷の変動に対応するため比較的大きな電力貯蔵装置（バッテリーバンク）が必要となるが、本システムではマイクロ水力発電システムとPVシステムの出力バランスを取るための電力貯蔵装置となり、これを比較的に小型化することが可能になる。または、従来の容量であれば、その寿命を延ばすことが可能になる。

c) ブータンにおける普及の可能性：最大マイクロ水力発電システムの出力＋αの範囲内で電力供給が出来るため、ブータンの場合のように需要家当たりの大きな電力需要に対応することが可能になる。また、系統線が延伸されたとしても、バッテリーバンクの更新せずにそのまま系統連系運転に移行でき、系統のエネルギー供給ステーションとして継続して使用することが可能になる。いわば辺境地区で十数年も前から“系統電源”を享受することが出来ることになる。

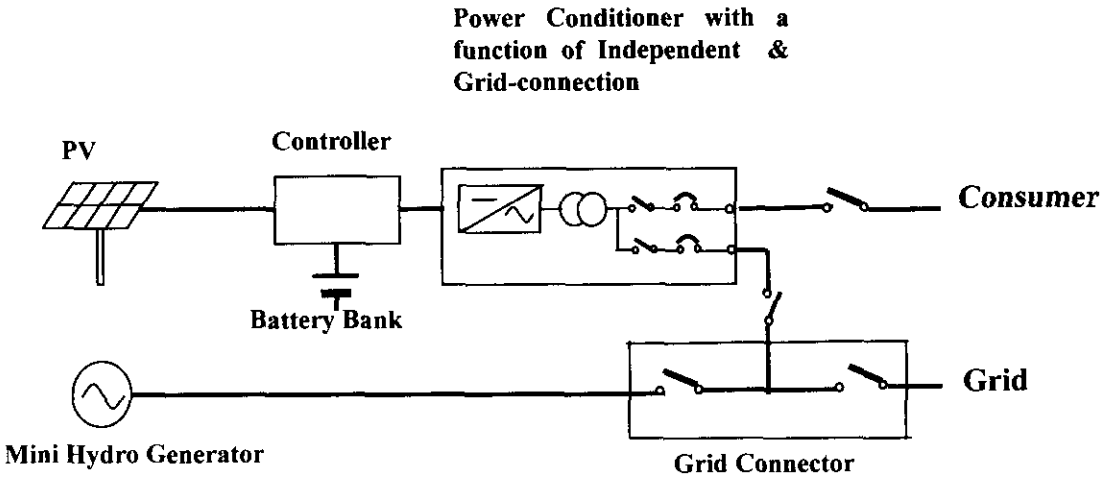


図- 5.3　PV－マイクロ水力ハイブリッド発電システムスケルトン

イ．PV＋風力発電システムを中心としたハイブリッドシステム

a)電力需要量設定

電力算定の基本条件を次の通りとする。

- サイト："A 地区"（Gasa 近郊）
- 集落の家屋数：30 軒
- 均等負荷条件
- 集落内に学校・基礎医療所・役所がそれぞれ 1 施設がある。
- ミニグリッドによる配電

b) 計画条件

1.モデル風力発電機としてウイスパーH900 (岩中電気製作所)のデータを使用した。

2. 概略容量算定のため、風力側の効率を 100%として計算した。PV 容量計算は通常の効率を考慮に入れ計算した。

c) 計算結果

- 風力発電機容量：1kW タイプ
- PV システム容量：1.9kW

の容量があれば、"A 地区" 30 世帯の電力需要量 7kWh/day、出力容量 1kW のミニグリッドに対し電力を供給できるようである。

d) PV 容量計算法

①所要太陽電池容量, C [kW]

$$C=Co \times Pd \times M / Rm / So / Ko / (K1^* K2^* K3^* K4^* K5^* Km) / 1000$$

ここで,

Co: PV パネル容量, ここでは 54[W/set]

So: PV パネル面積, ここでは 0.4[m^2/set]

Pd: 電力需要量, [kWh/day]

M: 将来の増加係数, 1.2　(20%の増加を見る)

Ko: 太陽電池パネルのエネルギー変換効率,ここでは 13.5% (54W, 04m^2)

K1: 温度上昇に伴う出力低減係数,

低減率: 0.5%/deg,

基準温度: 25℃

K1=1—0.005 x (T—28), 表面温度 T=60℃とすると K1=0.84

K2: 太陽電池面汚染による出力低減率, 1.0

K3: バッテリーの充放電効率, 0.83

K4: 制御器を含む直流回路損失, (1-Loss Factor)=0.9

K5: インバータ効率、0.9

Km: その他の低減係数など, 0.9, その他具体的に的に計算する必要あり

Rm: 傾斜面日射量

②傾斜面日射量、R_m [kWh/m^2/day]

換算式は次の通り。

$$R_m = R_{hm} X \{Cos(\theta_l + \theta_m - \theta_o) / Cos(\theta_l + \theta_m)\}$$

ここで、

R_m : 傾斜面日射量、kWh/m^2/day

R_{hm}: 水平面全天日射量、kWh/m^2/day

θ_l: 太陽電池設置点の緯度、但し南半球の場合にはマイナス(-)となる

θ_m: 太陽高度補正角度で次表による。但し南半球の場合にはプラスとマイナス符号が逆になる。

θ_o: 太陽電池設置角度

太陽高度補正：

表－5.5 太陽高度補正値表

月	1	2	3	4	5	6
θ_m, 度	21.2	12.9	2.4	-9.5	-18.7	-23.3
月	7	8	9	10	11	12
θ_m, 度	-21.7	-14.3	-3.9	8.2	18.3	23.2

(注) 南半球の場合にはプラスとマイナス符号が逆になる。

表-5.6　ハイブリッド機器容量算定表

			Wind Power Generation				PV Power Generation					
			風況	風力発電システム			PV発電システム		PV容量計算			
月	日数	月間負荷量	月平均風速		台数	発電量	負荷分担		日射量	太陽高度補正	傾斜面日射量	PV容量
	day	kWh/m	m/sec	kWh/m	Set	kWh/Month	kWh/M	kWh/d	kWh/m2/d	deg	kWh/m2/d	kWp
1	31	207	4.53	65	1	65	142	4.6	3.77	21.2	5.01	1.11
2	28	187	4.83	84	1	84	103	3.7	4.54	12.9	5.59	0.80
3	31	207	4.98	91	1	91	116	3.8	5.26	2.4	5.98	0.77
4	30	201	4.45	62	1	62	139	4.7	5.69	-9.5	5.98	0.95
5	31	207	3.75	34	1	34	173	5.6	5.65	-18.7	5.61	1.20
6	30	201	3.45	26	1	26	175	5.9	5.29	-23.3	5.1	1.39
7	31	207	3.25	23.5	1	23.5	183.5	6	4.36	-21.7	4.25	1.70
8	31	207	3.03	17	1	17	190	6.2	4.28	-14.3	4.37	1.71
9	30	201	2.95	16	1	16	185	6.2	4.09	-3.9	4.45	1.68
10	31	207	3.73	34	1	34	173	5.6	4.48	8.2	5.31	1.27
11	30	201	5.01	91	1	91	110	3.7	4.3	18.3	5.55	0.80
12	31	207	4.8	81	1	81	126	4.1	3.61	23.2	4.9	1.01

計算基礎データ	総出力	kW	0.87	太陽電池	A地点緯度	27.5	deg
	総負荷量	kWh/day	6.69		PV設置角	20	deg
					電池容量	54	W
					面積	0.4	m2
					変換効率	13.5%	
					K 係数	0.5	
					設備余裕	1.2	

表－5.7　需要算定

	負荷機器		Household			School			BHU			Monastry		
		出力	数量	時間	負荷量	数量	時間	負荷量	数量	時間	負荷量	数量	時間	負荷量
	機器名	W	Set	h/day	Wh/day	Set	h/day	Wh/day	Set	h/day	Wh/day	Set	h/day	Wh/day
1	FLランプ	18	5	7	630	10	6	1080	4	8	576	10	10	1800
2	FLランプ	10	2	8	160	3	8	240	2	8	160	5	24	1200
3	Torch L	5	2	2	20	5	3	75	2	2	20	5	5	125
4	Cassette	10	1	6	60	3	5	150	1	6	60	1	8	80
5	Fan	100	0	0	0	2	6	1200	2	8	1600	2	8	1600
6	その他	30%			0			0			0			0
計			出力:	169	870		605	2745		406	2416		605	4805
施設数			30	HH		1	set		1	set		1	set	

総出力　kW　0.87 =ROUNDUP((Y30+AB31+AE32+AH32)/1000,1)

総負荷量　kWh/day　6.69 =ROUNDUP((X30*W31+AA30*Z31+AD30*AC31+AG30*AF31)/1000,2)

表- 5.8　PV アレイ傾斜角に対する PV アレイ容量の変化

（最大値を示す）

月	0deg	5deg	10deg	15deg	20deg	25deg	30deg	45deg
1	1.47	1.34	1.24	1.24	1.11	1.06	1.03	1
2	0.98	0.92	0.87	0.87	0.8	0.78	0.76	0.75
3	0.87	0.83	0.8	0.8	0.77	0.76	0.76	0.76
4	1	0.97	0.96	0.96	0.95	0.95	0.97	0.99
5	1.19	1.18	1.18	1.18	1.2	1.23	1.27	1.31
6	1.34	1.34	1.35	1.35	1.39	1.43	1.49	1.56
7	1.66	1.65	1.65	1.65	1.7	1.74	1.8	1.88
8	1.74	1.72	1.7	1.7	1.71	1.74	1.77	1.83
9	1.82	1.76	1.72	1.72	1.68	1.67	1.68	1.7
10	1.5	1.42	1.36	1.36	1.27	1.24	1.23	1.22
11	1.04	0.96	0.89	0.89	0.8	0.77	0.75	0.74
12	1.37	1.24	1.14	1.14	1.01	0.96	0.93	0.9

5.3 新エネルギー技術

ブータンのエネルギー需要には単に“照明”ばかりではなく“熱源”に対する需要が大きいのは、その自然環境からいって当然であろう。従って、電化の際には“照明”と“熱源”を考慮に入れなければならない。すなわち“熱源”として日常の炊飯・煮炊き+給湯、特に冬季の暖房負荷まで考慮されなければならないので、地方電化電化計画では 1 軒当たり最低 2kW 程度は見ておく必要があるといわれている。一般に、熱負荷は照明負荷に比べ桁違いに大きく、俗に“太陽電池ではお湯は沸かせない”のであり、煮炊き・給湯と暖房負荷のためには、再生可能エネルギーとして“太陽熱”の直接利用がよく、この分野での試みがブータンにおいても進められている（資料：Kuensel 紙、November 19, 2002)。しかしながら、太陽熱で発電ということになると、ブータンでは不可能と考えてよい。

発電と熱という高負荷対応型のシステムで、我が国で開発または実用化されようとしている新エネルギー技術の中から燃料電池とスターリングエンジンを紹介する。これらは、何れも発電過程で熱の発生が大きいシステムであり、より環境負荷の少ないシステムである。

（1） 燃料電池発電システム

水(H_2O)を電気分解すると水素(H_2)と酸素(O_2)が発生する。その逆反応を工業的に行って電気を発生させるシステムが燃料電池システムの基本である。熱化学方程式で表すと次のようになる。

$$H_2(gas) + 1/2\ O_2(gas) = H_2O(liquid) + 68.3kcal/mol$$

つまりこれは反応熱 68.3kcal/mol は生成する水(H_2O)の熱含量（エンタルピー）が水素と酸素の当量分の熱含量より低いために熱として放出されるのである。

実際の燃料電池の種類は、表-5.5 に示すように、電池の形式により電解質・電荷担体動作温度・使用可能燃料等異なってくる。原燃料として純粋水素というのはなく天然ガス・ナフサ・メタノール・LPG 等が一般的であるが、固体酸化物型燃料電池のように動作温度が900~1000℃と高い場合には石油・石炭を原料にすることも可能である。何れの燃料を使うにしても前処理で燃料の改質をし、H_2 と炭素化合物の形にし反応媒体へと供給される。従って、これら燃料電池システムからは直流電力の他に膨大な量の熱が発生されるため、その有効利用が肝要となる。

一方、ブータンでは将来更に大型の水力発電所も建設される可能性もあろう。しかし、その急峻な地形とブータンの環境保護政策から大型貯水池を作れない可能性がある。このような発電所では、大型燃料電池発電所の併設により合理的な発電量調整が出来る可能性が有ると思われる。すなわち、雨期・乾期の発電ギャップを埋めるために雨期の降雨が多い時期に水力発電により発生する電力で電気分解を行い、水素を発生させ、その水素を液状化し専用地下坑に保管する。冬季の乾期（10~3 月）に液状水素を原料として燃料電池に供給し、電力と熱を利用することの可能性は否定できないであろう。これにより、

- 巨大発電所に併設された水素発生プラントと水素利用型大型燃料電池発電所が稼

動

- 完備された道路網により水素ボンベの運搬も可能になり、辺境地域の小型燃料電池発電所への燃料の供給

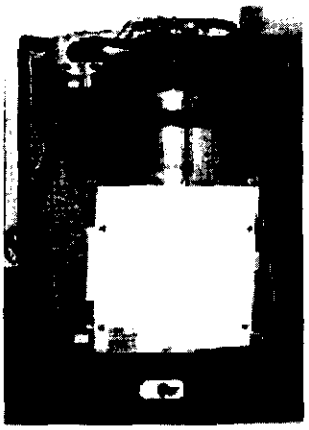
将来、このようなことも可能になろう。そして、少なくともブータン政策決定サイドの目線はそのようなものであるようだ。

しかしながら、液体水素にするために要するエネルギーとその保存のために消費するエネルギーは莫大なものとなることを考慮に入れると、どのようなエネルギーバランスになるのかは専門家の綿密な熱計算に委ねられ、更に実用化のための実証研究が必要である。

（2） スターリングエンジン発電システム

スターリングエンジンに理論は古くから知られており、シリンダ内の作動ガスを加熱／冷却することで膨張／収縮させ、ピストンを往復運動させてクランク機構で回転運動として取り出す。また、スターリングエンジンは外燃機関であるため、燃料の燃焼はエンジンの外部で行われるため、内燃機関などに比べ燃焼のコントロールが容易で、燃焼後の排気ガスは、内燃機関に比べてきれいである。我が国では、オイルショック後環境問題などへの関心の高さもあり、再度スターリングエンジンの持つ理論熱効率の高さ、熱源を選ばないこと、低温でも作動可能であるという特徴が大いに注目の的となっている。

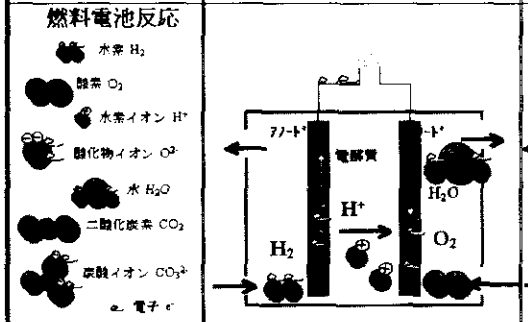
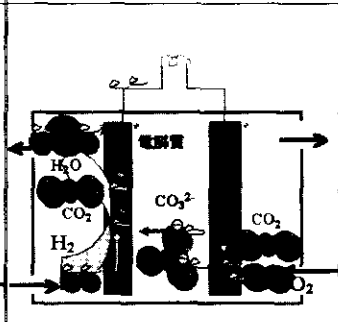
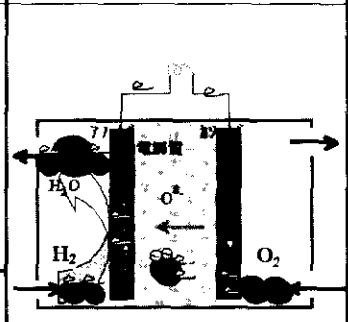
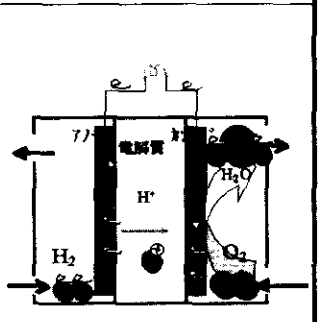
電力を暖房用・給湯用熱源として使わなければならないブータンでは、スターリングエンジン発電システムの適用の潜在的可能性があると考えられる。しかしながら、その実用化には、ブータンにおける熱源を何に求めるかが問題であり、集落の排泄物の処理過程または動物飼育残滓物から得られる、メタンガスなどであろうと推定される。その他、道路網の完備により LPG が安価に供給される時には、スターリングエンジン発電システムが系統線延伸より価格が遙かに安くなる必要が有ろう。



家庭用小型発電装置
電気出力：0.75kW、熱出力：5kW 相当

表- 5.9　タイプ別燃料電池システムの概要

燃料電池の種類と特徴

燃料電池の種類 / 項目	リン酸型燃料電池 Phosphoric Acid Fuel Cell PAFC	溶融炭酸塩型燃料電池 Molten Carbonate Fuel Cell MCFC	固体酸化物型燃料電池 Solid Oxide Fuel Cell SOFC	固体高分子型燃料電池 Polymer Electrolyte Fuel Cell PEFC
電解質	リン酸 H_3PO_4	溶融炭酸塩 $(Li_{0.62}K_{0.38})_2CO_3$	安定化ジルコニア ZrO_2+Y_2O_3	高分子イオン交換膜
電荷担体	水素イオン　H^+	炭酸イオン CO_3^{2-}	酸化物イオン O^{2-}	水素イオン H^+
動作温度	150 ～ 220℃	600 ～ 700℃	900 ～ 1000 ℃	室温 ～ 150℃
使用可能燃料	水素、天然ガス、ナフサ、メタノール	天然ガス、石油、石炭	天然ガス、石油、石炭	水素、天然ガス、ナフサ、メタノール
燃料電池反応				
●アノード反応 ●カソード反応	●$H_2 \rightarrow 2H^+ + 2e^-$ ●$1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$	●$H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$ ●$1/2O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$	●$H_2 + O^{2-} \rightarrow H_2O + 2e^-$ ●$1/2O_2 + 2e^- \rightarrow O^{2-}$	●$H_2 \rightarrow 2H^+ + 2e^-$ ●$1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$
主な材料	炭素材料	ニッケル、ステンレス鋼	セラミクス	高分子膜、炭素材料
特　徴	・排熱の給湯・冷暖房への利用で高い総合効率が得られる。 ・白金触媒を必要とする。一酸化炭素により触媒の活性が低下する。 ・MW級の大型化がなされている。	・一酸化炭素も燃料として利用可。 ・高温動作のため触媒を必要としない ・排熱利用により総合効率を80%程度まで高めることができる。 ・MW級の大型化がなされている。	・一酸化炭素も燃料として利用可。 ・高温動作のため触媒を必要としない ・円筒型および平板型がある。 ・排熱利用により総合効率を80%程度まで高めることができる	・高い出力密度 ・白金触媒を必要とする。一酸化炭素により触媒の活性が低下する。 ・低温動作のため選択できる材料が豊富
内部改質	利用不可	利用可	利用可	利用不可
発電効率	～ 45%	45 ～ 60%	50%以上	～ 50%
利用形態	分散電源、オンサイト、中規模発電所	大規模集中発電所、オンサイト(内部改質型)	大規模集中発電所、オンサイト(内部改質型)	燃料電池自動車、オンサイト型

4.4 オフグリッド導入の課題

ブータンは今年より“2020年までに完全電化”というスローガンを掲げ歩みだした。しかしブータンが置かれた厳しい自然環境を考慮すれば、そのプロセスは単純ではないと思われる。特に、電化が遅れる辺境地域の住民にとっては、電化されるまでかなりの時間を待たなければならないのは耐え難いと感ずるに違いない。これらを少しでも緩和することの出来る、独立型ミニグリッド水力発電ないしは簡便なPV・風力発電システムの導入が必要になろう。このことは、系統の延伸政策に反することではなく、むしろ十分な電力の到来を早めることに他ならないのである。

ア．辺境地域電化の基本は公共施設電化と抱き合わせで行う

ADB の電化影響調査の結論として、「電化は、教育や保健医療へのアクセスなど村の生活改善とセットで始めてその電化の効果が上がる」と述べられている。この点、現在行われているブータン政府が関与するプロジェクトの多くは、“寄宿学校・BHU・僧院”などの電化が優先的に行われ、ついで需要家への配分と言うプロセスで行われていることは注目に値する。このことは辺境電化の基本姿勢である。

イ．辺境電化推進組織を作る

辺境電化、特にPVシステムによる局所電化の場合にはDOE以外に農業省・教育省など多くの省が関与する場合が多い。勿論これまでも、お互いに連携を取って行われているのであるが、“完全電化”という視点から見て総合的に判断が出来、しかも実施の方法・手段など統一した対応が可能な組織を作る必要がある。ブータンでは政府機関の職員の配備も十分ではないので、外国援助機関からの派遣も含めて構築する必要があるかも知れない。

ウ．データベースの整備

再生可能エネルギー利用を効率的に適用するためには、そのエネルギーの源である降雨量・太陽光・風況などの基礎データが必要であることは言を待たない。またこれら再生可能エネルギーは一様でなく、年によりばらつくため長期のデータ計測が必要となるので、恒久的な観測態勢の整備が必要となる。この場合、これらのデータの計測点は多ければ多い程良いのであるが、当初は10箇所程度から始め、逐次必要に応じて必要な地点に追加設置を行うようにする。また簡易型の計測システムの設置も考慮する必要がある。調査期間中に、数セットの計測セットを導入し、データ解析の手法を実際に示す必要があろう。

また、このことは今回のブータン側との協議でも“日射量の測定”に関する強い要望があった。

エ．その他

OM 技術者の養成プログラムの作成及びバッテリー再生技術とその体制の確立のためのプログラムの作成が必要である。

第6章　地方電化マスタープラン調査の構想

第６章　地方電化マスタープラン調査の構想

ここでは地方電化マスタープラン調査の内容に関する今回の協議結果とそれに基づき作成された本件調査の計画案について解説する。

6.1　調査の果たすべき役割

M/M 作成の過程でこのマスタープラン調査の位置づけを行った。(Key roles expected for Master Plan の項を参照) マスタープラン作成の目的はすでに述べた通りであり、これをもとに第１０次５カ年計画以降に具体的な地方電化プロジェクトが実施される。したがって、この調査自体は第９次期間中に完成させる必要がある。

これまでの配電線延長による地方電化事業は市街地とその周辺部を対象としており、設備設計も市街地の条件に対応したものとなっていた。すなわち、一戸当たりの需要を 2kW と想定していたことなどがその例である。しかし、今後は地方の農村部が対象となっていくため、このような市街地を対象とした設計条件については生活パターンや所得水準の違いなども考慮して見直す必要がある。このため、家庭用の電力需給についてエネルギーベストミックスや DSM の検討を行うほか、DOE が第９次期間中に実施する地方電化に関連する作業とも連携をとる必要がある。

マスタープラン調査の内容として、グリッド電化については各村落までの 11kV 以上の中圧/高圧送電系統計画図を作成することとしており、したがってその後に実施される F/S では低圧配電線のみについて詳細な設計作業が必要になる。

さらに調査実施のタイミングとしては、理想的には第１０次５カ年計画の策定が開始される 2005 年まで終了させることが望ましい。(調査スケジュール暫定案 参照)

6.2　調査の目的

調査の目的として要請書に示されていたのは以下の項目であった。

a) Preparation of demand map of non-electrified area
b) Observation of wind and solar energy in the areas where grid extension seems to be not feasible and preparation of these potential map
c) Formulation of appropriate development plan of rural power supply for the non-electrified areas considering all the option of renewable energy with priority ranking list, and cost estimates
d) Presentation of integrated operation and maintenance system for sustainable power supply in rural areas
e) Execution of basic level of study to the villages highly prioritized
f) Accepting voluntary activities for pilot plants, demonstration plants, and/or actual plants installation and/or operation from private enterprises and any other

government or multilateral organizations under the coordination of the Study to effectively use the information and formulate integrated master plan, if any

調査の大目的が 2020 年までに行うべきグリッドとオフグリッドによる電化計画をそれぞれ作るということであるため、その前提となる a）は必要不可欠である。b）については全国的に気象データが蓄積されていることが確認できたため調査期間中に追加測定する必要性は低い。c）および d）については問題ないが、特に d)に述べられている設備の維持管理については、故障時はもとより需要が超過した場合の対処方法などについても明確な方針や対処マニュアルなどを要望している。こういった維持管理について日本側からの技術移転を行うことは建設されるシステムの sustainability を高めるために有効であると考えられる。e)についてはいくつかのモデル村落について社会経済調査を行い、電化へのニーズなどを把握するという趣旨である。また、これに関連して特にオフグリッド地方電化のケースについて村落が独立して持続可能な維持管理を行えるようなアイデア（例えば cooperative の提案など）を要望している。f）については何らかのパイロット事業を想定したものであるが、このマスタープラン調査の趣旨からパイロット事業を含むことは困難との理解で一致した。

以上のように、要請書にある調査目的をレビューし、今回の調査で明らかとなった事項を踏まえて、本件調査の目的について DOE との協議により以下の通り整理しなおした。

(1) Evaluate supply-demand structure and cost effectiveness of the present power supply
(2) Preparation of demand map of non-electrified villages by GIS technology
(3) Socio-economic survey at remote villages to identify the social needs for and expected benefits from rural electrification
(4) Formulation of on-grid and off-grid combined development plan of rural power supply for the non–electrified areas up to the year 2020 with cost estimates
(5) Recommendation of operation and maintenance organizations/guidelines for sustainable power supply in rural areas
(6) Preparation of social development programs targeting remote villages to achieve self-sustainable power supply system
(7) Technology transfer of rural electrification technology with an emphasis on environmental protection and forest preservation

(1)については、調査の前提条件を整理するという観点から、新たに追加したものである。ここでは現在の電力需給構造と費用対効果について評価し、電力に偏りすぎている家庭のエネルギー需給について、LPG の普及拡大、太陽熱利用など他のエネルギー源とのベストミックス、さらに電気料金の適正化プラン、電力需要の時間的シフトや省エネといった Demand Side Management などについて検討し、また一戸当たり 2,000 ドルという配電線延長の投資効率についても他の社会投資との比較なども含めてその妥当性について再検討するという趣旨である。そ

の結果、電力需要原単位や配電線延長工事の上限コストなどが明確となり、マスタープラン作成作業が定量的に可能となる。

(2)は要請書の目的 a)に対応するものであり、ブータン全土を対象に村落単位でのマスタープラン調査とするという条件から、全国の未電化村落を調査し、その位置や住宅戸数などについてのデータを収集する必要がある。このデータをどのようにまとめるかであるが、これについては最近の GIS 技術の発達によってデジタルマップにすることが容易となっている。既にブータンの地形図もデジタル化されているため、このような地図の作製は十分可能であり、その後の送配電計画立案作業にも非常に使いやすいものとなる。

(3)は要請書の目的 e)に対応するものであり、地方村落において電化へのニーズや電化後のメリットなどについて社会経済調査を行うという趣旨である。

(4)はこのマスタープランの最終成果物であるブータン全国をカバーする 2020 年までの地方電化プランをグリッドとオフグリッドに分けてコスト試算を含めて作成することを明確にしたものである。

(5)は要請書の目的 d)に対応するものであり、地方部での電力供給 (グリッド及びオフグリッド) の適切な維持管理手法についての提案を行うという趣旨である。

(6)は先方から要望された、オフグリッド電化の場合に cooperative 組織やマイクロファイナンス制度など村落単位で持続可能な独立運営による電力供給システムの確立のための社会開発プログラムを提案するという趣旨である。

(7)は先方から要望された、地方電化の場合における環境との調和、森林保護に関する技術・ノウハウの移転を行うという趣旨であり、水力発電所や送電線など山岳地帯での開発において必要となる環境配慮設計を意味している。一例としては送電線鉄塔の設計において基礎部分を小さくすることなどがあげられる。

6.3 作業項目と作業フロー

以上のような基本的部分について合意したため、要請書及び今回の調査における確認事項に基づき、このマスタープラン調査の内容について試案を作成した。以下にその内容を解説する。

(1) 調査の構成

この調査は2段階に分けて行う。すなわち、マスタープラン作成に必要なデータ収集のほか、GIS 地図、グリッド設計用ソフト、オフグリッドモデルプランなどの作成を行う第1段階と、こういった材料をもとに全国 20 県の未電化村を対象にした地方電化マスタープランの作成を行う

第２段階であり、グリッド電化の対象範囲を定めてグリッド延伸プラン（11kV 以上を対象とした single line diagram）を作成し、その外側ではオフグリッドプランを作成する。この両者を合体したものが全国の地方電化マスタープランとなる。このマスタープランは DOE として初めての全国レベルの電化計画となるもので、これを各５カ年計画策定ごとに見直し、より具体的な事業計画にブレークダウンしていくというのが基本的な考え方である。したがって、調査に当たっては計画を完成させると同時にその後の見直し作業が DOE だけで行えるように必要な技術移転を行っていくということも重要な視点である。

DOE がこのマスタープランに要望しているのは、グリッドプランについては各村落へ到る 11kV ラインのルート図までのレベルであり、配電線図は求められていない。低圧配電線については RE3 のように事業実施予算の中で作成されるべきものである。オフグリッドプランについても各村落単位で計画をつくるのが望ましいが、太陽光発電の場合には画一的なモデルが可能であるのに対し、マイクロ水力によるミニグリッドの場合には発電計画地点の個別評価から始めなければならず、限られた調査期間の中で取り上げられる地点は限定される。このような理由から、全ての村落について同じレベルでのオフグリッドプランとすることを目標とするのではなく、DOE がオフグリッドによる地方電化に逡巡している原因である sustainable な運営システムが確立されていないという点を取り上げ、この点について詳しく検討し、それに基づくいくつかの標準的なモデルを提案することが有効であろう。同時にオフグリッド対象地域の村落について社会経済データの収集を行い、各村落にどのモデルを当てはめていくかを判断できるようにしておくことが必要であろう。この点については次回 S/W 協議の際に十分議論し、意見の食い違いが生じないよう確認しておく必要がある。Sustainable なオフグリッドシステムが提案できればマイクロ水力の計画自体は DOE の技術者でも十分可能と考えられる。もちろん、調査期間中に図上検討や現地踏査によってオフグリッドを想定したマイクロ水力候補地点の発掘に努めることは重要である。なお、このモデルプランに基づくオフグリッドのパイロット事業についてはこの調査の中で行うことは求められておらず、調査後にブータン政府が別途計画することなる。

（２） 作業フロー

調査全体の作業フローについては別紙 Conceptual Diagram of RE Master Plan Study に示すとおりである。以下にその要点を示す。

ア. GIS マップ

この GIS マップにはこれまでに建設された送配電網、RE３によって計画策定された送配電網、全国の村落データなどが取り込まれていなければならない。これらのデータをデジタル化して GIS マップを作成する。

イ. グリッドプラン

グリッドプラン作成に当たって必要となるのは 2020 年までの電源開発計画、計画条件（需要想定、ロス率など）、コストデータ、経済性の判断基準などである。こういった作業はコンサルタ

ントだけで行うのではなく、DOE ほかの政策担当者と十分に意見調整を行う必要がある。グリッドプラン作成はこういったパラメータを前提にして、11kV までの中圧、高圧の送電網を計画する作業であり、適切なコンピュータモデルを使用して行う。さらに、将来においてこのグリッドプランの改定が必要になった場合に DOE の職員だけでその作業が行えるよう、モデルの操作方法については適切な OJT を行うことが必要である。

ウ. オフグリッドプラン

グリッドによる電化が技術的、経済的に無理と判断される地域は確実に存在するということはブータン政府も認めている。ただし、これまでオフグリッドに対して積極的ではなく、マイクロ水力によるミニグリッドの新規開発計画はドナー提案の４カ所(UNDP ３カ所、E7 1 カ所)のみであり、太陽光発電の普及については独自の開発プランは持っていないという状態である。このようにオフグリッドの地方電化については体制、ノウハウなどの面で今後大幅に強化する必要があり、これがこのマスタープラン調査の大きな目的となるであろう。対象地域でのニーズ、負担能力、維持管理手法、担当組織などを検討して持続可能なオフグリッド地方電化のモデルプランを提示し、それを政府や地元と議論しながらコンセンサス形成を行うことが求められる。

オフグリッドプランでは、標準的な戸数、地形、生活パターンのいくつかのモデル村落を対象に太陽光やマイクロ水力によって電化するためのモデルプランを作成し、同時に村落のデータベースをできる限り詳しく整備する。その上で各モデルプランをどの村落に導入していくかを想定する作業となる。この作業の過程では前述のように C/P 側のオフグリッドに関する知識経験が不足しているため技術移転に努め、彼らのキャパシティ ビルディングを図っていくという発想が必要である。さらに設備の維持管理手法やオフグリッド電力供給に関連した村落組織のあり方などについても現地調査を行いながら具体的に検討するという姿勢が必要となる。(Objectives の(5)及び(6)を参照)

DOE の意見としては、オフグリッドについてはマイクロ水力によるミニグリッドが最優先であり、次いで太陽光発電を想定している。風力発電についてはほとんど研究されていない。むしろ、雨期などに発生する大量の余剰（水力）電力を活用した水素エネルギーの利用（水素利用燃料電池）などについて研究したいという要望が示された。

（３）作業項目

第１段階及び第２段階で行う主な作業は以下の通りである。

Stage 1:

(1) GPS survey to create database on un-electrified villages;
(2) Socio-economic survey at candidate remote villages;
(3) GIS mapping of un-electrified villages and their relevant information;
(4) Analysis on “Energy Best Mix” and “Demand Side Management (DSM)”;
(5) Demand estimation and demand map creation;

(6) Off-grid model plan with micro hydro, solar, wind energy and new technology;
(7) Development of computer model for grid extension designing;
(8) Testing of computer model on model districts and on-the-job training:

Stage 2:

(1) High and mid voltage (11kV/33kV and above) grid extension plan for Districts (single line diagram);
(2) Identification of off-grid zones;
(3) Survey on potential off-grid hydropower sites;
(4) Introduction of rural organizations/industries for sustainable operation;
(5) Off-grid rural electrification plan for Districts;
(6) Operation & Maintenance guideline for on-grid and off-grid electrification;
(7) Comprehensive district wise RE plan targeting the year 2020:

特に第1段階での未電化村落のデータ収集作業については十分な計画と準備が必要である。未電化村落の所在がすべて把握されているわけではなく、DOEの発言では全国で約2,000カ所あるということである。この中には戸数が数軒であっても村という単位を構成している辺境の村もあり、現地踏査は徒歩で何日もかかる行程となる。また、南部の低地帯ではインドとの国境付近に外国人の立ち入りが許されない場所もある。このような事情から、未電化村落の位置や戸数といった基本的データを調査するためにはローカルコンサルタントを活用することが不可欠である。実際に各地を踏査する場合には6月から9月までの雨期を避けなければならず、村落数が多いため数ヶ月必要との意見も出された。現在実施中のRE3においても、ローカルコンサルタントが対象村落での住宅位置図の作成など細かい作業を請け負っている。ローカルコンサルタントの活用はこのマスタープラン調査の効率化と内容充実のために、是非とも検討されなければならない。この点について次回S/W協議の際にDOEの経験をもとに具体的な協議が行われることが必要である。

ローカルコンサルタントによる調査実施がアクセス等の問題から非常に困難な地域については、集落や耕作地の有無の判断について衛星写真の活用も検討されよう。例えば民間に販売されているSPOT衛星写真の解像度は10m、IKONOS衛星では解像度が1mとなり、農地や住宅の位置などについてはかなり正確に把握することができる。ただし、世界中のあらゆる場所について写真が撮影されているのではなく、需要が期待できないため未撮影のままの地域も多い。一例としてIKONOS衛星がブータンについて撮影済みの地域を別紙に示す。ただし、こういった衛星写真は新規撮影のリクエストを受け付けており、もちろん有料であるが地域を指定して新規撮影を依頼することも可能である。当然、広範囲の地域を対象とする場合には写真の枚数も増え、利用費用も大幅に増加する。IKONOSの写真は最小単位が11km四方の地域となっており、これを購入する場合の費用は約100万円である。

6.4 その他の事項

（1）調査開始前に必要となるデータ

作業フローに示したように、このマスタープラン調査ではGISマップ作成に前提となるデジタルの地形図が必要であり、さらに現在作業中であるRE-Ⅲと電源開発プランの見直し作業の成果が必要となる。RE-Ⅲについては2003年8月、また電源開発プランについては2003年5月が目標となっている。少なくともこの調査の開始時点で、この両作業の最終原稿案が提供されなければならない。この両作業の進捗具合については次回のS/W協議において再度議論することとなろう。

（2）カウンターパート

このマスタープラン調査の正式なカウンターパートは地方電化政策や計画を担当するDOEである。ただし、実際に事業を実施するのはBPCであるため、調査の実施に当たってはBPCを常に参加させておくことが必要である。

（3）今後の取り扱い

DOEとしては早期の調査開始を要望しているが、(1)に指摘した通り、事前に行われるべき作業の一部がまだ終了していないなどの理由から、調査開始時期については不透明な部分がある。DOEとしては当然のことながらM/M協議の際に、この調査が第9次期間中に行われるよう改めて要望した。

付　属　資　料

APPLICATION FOR THE TECHNICAL COOPERATION BY THE GOVERNMENT OF JAPAN

1. BACKGROUND INFORMATION

1.1 Project Title

Integrated Master Plan Study for Dzongkhag (District) Wise Electrification by Renewable Energy in Bhutan
- Challenge from Villages -

1.2 Location of the Object

The Whole of Bhutan - 20 Districts (Dzongkhag) -

1.3 Executing Agency

Department of Power
Ministry of Trade & Industry
Royal Government of Bhutan

1.4 Project Justification

(1) Background

Bhutan has 46,500 km^2 in land area and about 667 thousands in population. Land of the country rises from about 100 m in altitude in the Indian border area up to 7,500 m toward Tibetan Plateau. Most of the population is concentrated in the river villages. Mainly these are four river basins, namely Amo chu, Wang chu, Puna chu and Manas chu (Refer to Attachment-1).

Necessity of Rural Power Supply

Some 85 % of the population are living in rural area and almost all the people there have no access to electricity. At present the people receiving electricity supply is less than 30 % of the country population despite the large installed generating capacity of 357 MW. In the year 1999, 76 % of the total generation was exported to India and the remaining only 24 % was consumed in the country. Of course, the power exporting is important income source of the foreign currency. That income has much contributed to improving

Secondly, the Master Plan Study is necessary to establish integrated operation and maintenance system involving local people for sustainable rural power supply.

Participation of the local people and involving local people are essential for sustainable operation of rural power supply. Now the people receiving power in rural area cannot repair the simple fault, like just changing one fuse of the power supply facilities. Department of Power (DOP) staffs have to make a long trip to the local villages from Thimphu for 5 or 6 days just to change the broken fuse on call (e.g. for solar panels in remote areas). This is a big loss of DOP's resources. The remaining non-electrified areas are mostly very far from roadway. Under the present management system to the rural areas, achievement of sustainable rural power supply to the remaining non-electrified areas is desperate.

Lack of information and fundamental training to the local people and lack of self-reliance mind of local people leads to the above situation. For the sustainable power supply to the rural areas, it is important to set up the integrated operation and maintenance system including local people. The system should periodically provide fundamental training and information on operation and maintenance and Demand Side Management (DSM) to the local people, and more important, that should stimulate self-reliance mind of the local people.

The self-reliance mind is the most basic factor not only for sustainable power supply but also for widely social development in rural areas. In order to incubate and encourage the self-reliance mind of local people on the rural power supply, the following are recommendable: (i) involving local people from the planing stage, (ii) sharing responsibility on power supply between the local people and DOP, such as making fund by the village themselves for operation and maintenance, and (iii) introducing competitive system among villages.

The idea about the competitive system among villages is to prepare some evaluation system of the villages from the viewpoint of sustainability before introducing power supply facilities. Priority ranking of power supply to the villages is to be decided considering this evaluation result in addition to the economical point of view. By the system, the villages made much effort ready for operation and maintenance can mostly receive power earlier than the villages of less effort. The system will inevitably stimulate self-reliance mind of local people.

In order to establish the above mentioned integrated operation and maintenance system, technical assistance is required as the Master Plan Study.

Thirdly, the Master Plan Study is necessary to introduce the up-to-date, state-of-the-art technology.

The revolutionary changes are proceeding in the field of power at present. The price of solar and wind generating system have been drastically going down. Almost major auto-makers in the world announced that they would release fuel cell vehicles on commercial basis in the year 2004 or 2005. And there is a possibility to use the

(4) Project Priority in National Development Plan

The Master Plan Study is urgently needed to establish the appropriate strategy to achieve RGOB's long term target "electricity for all" by the year 2020. The Study is to be given high priority for realizing sustainable development of rural power supply by renewable energy resources for environmental conservation and for social and economic development.

1.5 Proposed Implementation Schedule

The period to establish the master plan is estimated at twenty-four (24) months (Refer to Attachment - 2).

1.6 Expected Funding Source

Technical assistance program by the Government of Japan.

1.7 Other Related Project

(1) ADB:
Power Distribution Master Plan Study for Rural Electrification by Grid Extension

(2) UNDP/GEF:
Bhutan Mini/Micro Hydropower Development Project

(3) JICA (under request)
- Feasibility Study for Small Hydropower Generation for Rural Development
- Review of Existing Micro Hydro Stations (13 Nos.) Implemented under 1st Phase and 2nd Phase Japanese Grant and Possible Up-gradation to meet New Electricity Demand
- Sustainable Rural Electrification through Extension of Grid to Villages

2. SCOPE OF THE STUDY

2.1 General

In accordance with the Objectives of the Study, the Study is broadly divided into three stages:

(2) Seminar at each targeted Dzongkhag;
- Distribution of questionnaires to local people to collect basic data for formulating operation and maintenance system, power supply system design, etc.
- Technology transfer

(3) Collection of questionnaires and their analysis;

(4) Preparation of demand map;

(5) Preparation of integrated operation and maintenance system;

(6) Preparation of ranking list of villages on operation and maintenance with evaluation method;

(7) Sample site reconnaissance to verify the study results;

(8) Grouping of demand and preparation of standard type power supply system;

(9) Preparation of potential map of solar and wind;

(10) GIS mapping of the system;

(11) Cost estimation and economic analysis on standard type power supply system and total plan;

(12) Formulation of appropriate development plan of rural power supply with priority ranking list and network diagram;

(13) Accepting voluntary activities for pilot plants, demonstration plants and /or actual plant installation and/or operation from private enterprises and any other government or multilateral organizations under the coordination of the Study to effectively use the information and formulate integrated master plan, if any.

Stage 3: Basic Design Level Study Stage

According to the result of the study, basic design level of the study will be carried out to all the villages that have to be electrified by year 2020.

2.2 Work Schedule

The proposed work is to be completed within the period of twenty-four (24) months.

2.6 Other Relevant Information and Request

(1) Not only the need of electricity supply but also the need of water supply is extremely high in rural areas. Then, only in the case that the local request is much strong and also renewable energy can be effectively utilized for water supply, the water supply system could be included in the Study.

(2) Energy demand-supply basic forecast for each district for 2020 (firewood, LPG, kerosene, petrol/diesel) will be included in the study.

(3) One package of the development project in the priority list will be mostly small. Therefore, in addition to the Government own budget, the option of finance sources will increase; for example, Japanese grass root grant, NGO/NPO's assistance and any other small voluntary assistance will become acceptable to execute the one package of the project.

3. GLOBAL ISSUES

3.1 Environmental Components

The Study envisages formulating a rural power supply development plan by renewable energy resources for the sustainable growth of the country. Environmental aspects are to be carefully managed to increase its positive effects.

The greenhouse effect of the Earth is not encouraged through the development of renewable energy, which is one of the Global Issues suffered by CO_2 and Nox gas emission.

3.2 Environmental Impacts Forecast

The project implementation will lower the gap of living standard level between urban and rural, then contribute the mitigation of people's concentration to urban areas. No deforestation is required for the execution of the project. Since the power supply to households reduces the consumption of fuel woods, the Project will contribute forest conservation.

3.3 Women as Main Beneficiaries

The electrification of households will reduce daily hard burden of women like fuel wood collection and long time domestic work in dark and unhygienic kitchen. The Project will create job opportunities for both male and female, and further increase production in

4.2 Undertakings of the Government

In order to facilitate a smooth and efficient conduct of the Study, the RGOB shall take necessary measures:

(1) to secure the safety of the Study Team.

(2) to permit the members of the Study Team to enter, leave and sojourn in the country in connection with their assignment therein, and exempt them from alien registration requirement and consular fees.

(3) to exempt the Study Team from taxes, duties and any other charges on equipment, machinery and other materials brought into and out of the country for the conduct of the Study.

(4) to exempt the Study Team from income taxes and charges of any kind imposed on or in connection with any emoluments or allowances paid to the members of the Study Team for their services in connection with the implementation of the Study.

(5) to provide appropriate office and office equipment including copy and facsimile machines required for the Study Team procured for the project.

(6) to provide necessary facilities to the Study Team for remittance as well as utilization of the funds introduced in the country from Japan in connection with the implementation of the Study.

(7) to secure permission or entry into private properties for the conduct of the Study.

(8) to secure permission for the Study to take all data, documents and necessary materials related to the Study to Japan.

(9) to provide medical services as needed. Its expenses will be chargeable to the members of the Study Team.

(10) to provide Dzongkha - English interpreters.

Attachment - 1: Location Map
Attachment - 2: Proposed Work Schedule of the Master Plan Study
Attachment - 3: Organization Chart of Royal Government of Bhutan
Attachment - 4: Organization Chart of Department of Power

7. DEPARTMENT OF POWER

Situational Analysis

Assessment of the Current Situation in the Sector

Adequate energy input is essential for all socio-economic development activities. While the primary energy need of most of the Bhutanese population is being met from bio-mass, modern forms of commercial energy such as electricity and fossil fuels (petrol, diesel, kerosene, liquefied petroleum gas) are also increasingly used and in demand. Most of the electricity in Bhutan is generated from local hydropower plants. Today about 75% of the electricity generation is exported.

Hydroelectric Power

Bhutan is endowed by nature with a large hydropower potential. The hydroelectric potential is estimated to be over 30,000 MW and by the end of the 8th Five Year Plan period, we would have only about 1.42% of that potential harnessed.

During the 8th Five Year Plan, the Sector has started contributing about 45% of the Royal Government revenue earnings as against 25% during the 7th Five Year Plan period. The sector is thus being recognized as the core economic sector and being considered as the backbone of the Bhutanese economy. The annual domestic electricity consumption has been growing at an average rate of 9.53% over the last five years. Bhutan's demand has increased to over 90 MW and 532 Million Units (MU) per annum in the year 2000 from 70 MW, 338 MU per annum in the year 1995. The hydroelectric generation capacity, transmission and distribution networks have also increased catering to more than 35,000 electricity consumers. The commissioning of 60 MW Kurichu Hydroelectric Project, Basochu Upper stage of 24 MW and Kellungchu Micro hydel of 200 kW along with the development of Eastern Transmission grid during the 8th Five Year Plan augmented the overall power supply infrastructures capacity of the Kingdom. Rural Electrification has been an important aspect of hydropower development in the country. More than 30% of Bhutanese households/gungs have access to electricity. During the 8th Five Year Plan, 84.2 MW hydropower installed capacity has been added to the existing power system.

Bio-mass Energy

Biomass consisting of mainly the fuel wood/firewood caters to the primary energy demand of the population, more than 70% of which live in rural areas. Firewood is used for cooking, heating as well as for lighting in some areas. It is estimated that Bhutan has one of the highest per capita consumption of firewood in the world. Efforts are being made to reduce the demand and sustain the supply-demand growth rate by providing alternatives such as electricity through an extensive rural electrification programme. Sustainable supply and efficient utilization of this renewable bio-energy resource will be alternative strategy in future.

Fossil Fuels

Most of the fossil fuels (petroleum products) used in the Kingdom are imported. The demand has been increasing at an alarming rate especially in the Transport sector. As per record during the year 1999-2000, 26,844 kilo-litres of diesel, 6520 kilo-litres of petrol, 15,000 litres of kerosene, 3,000 tons of liquefied petroleum gas (LPG) and 890 kilo-litres of aviation turbine fuel (ATF) were imported. Kerosene is used mostly for lighting purposes in the non-electrified areas.

Assessment of the Situation at the end of the 8th Plan

Objectives and Strategies of 8FYP

- Implement construction, selectively, of power projects for which detailed project reports have been completed;
- Enhance revenue collection by efficient operation of the existing hydropower stations and its distribution system;
- Encourage the use of energy resources like hydropower, which are renewable, environmentally clean and sustainable;
- Extend rural electrification;
- Liaise with other Government agencies to ensure the protection of existing and future hydropower catchment areas; and
- Develop policy guidelines and power tariffs conducive to the promotion of bilateral and multilateral cooperation in hydropower development.

Review of the 8FYP – Achievements

While most of the major programmes were centrally executed, power distribution programme such as the rural electrification was implemented at the Dzongkhag level with close coordination and cooperation of the Dzongkhag authorities by the Dzongkhag based Electricity Supply Sections of the Department of Power. The beneficiaries/communities were closely involved at the geog and village level during the rural electrification. Lately, electrical contractors in the private sector are also engaged in the implementation of RE project works. Map 1 shows the existing infrastructures at the end of 8FYP.

Power Generation Programme

Major Projects for implementation during the 8FYP such as the Kurichu, Basochu and Tala Hydroelectric Projects were reflected outside the Plan budget outlay. Kurichu project of 60 MW, 400 Million Units (MU) energy generation capacity, construction of which started during the 7th Five Year Plan is completed during the 8FYP and has started supplying electricity to six Dzongkhags in Eastern Bhutan and two Dzongkhags in Southern-Central Bhutan. Surplus energy (about 90%) from Kurichu is being exported to the North-Eastern grid of India through the existing 132 kV Gelephu-Salakati power line as Dungsam Cement project load did not come up during the plan period. Implementation of Kurichu Project has facilitated other economic development activities in the Eastern and South-central region. Basochu Upper Stage of 24 MW, 106 MU energy generation capacities is also completed and has augmented the generation

supply capacity in Western Bhutan as well as increased the reliability of grid power supply in the capital. The construction of Tala Hydroelectric Project of 1020 MW started during the 8FYP and more than 50% of this Project works have now been completed. Physical construction of Basochu Lower Stage of 38.6 MW capacity has just been started. Tala and Basochu Lower Stage will be completed during the 9FYP.

Rongchu micro hydel of 200 kW capacity built across Rongchu stream in Kellungchu valley of Lhuentse Dzongkhag has been completed. This pilot project has been built under the Joint Implementation Testing Programme, funded by the Environment Ministry of Netherlands and the Royal Government of Bhutan to test the possibility of sequestration of green house gases. This is the first project planned, designed and built entirely by the Bhutanese engineers and local contractors without any external technical assistance. The project is supplying power to about 200 households in Gangjur geog, villages in and around Kellungchu valley and power supply line from this project is also being extended to Dungkhar in the North. In addition to the commissioning of the above-mentioned new Projects, the existing mini hydels such as the Thimphu Mini hydel (360 kW), Gangjur (120 kW), Chumey (1500 kW), Gidakom (1250 kW), Wangdi (300 kW) and Chenari (750 kW) have been rehabilitated. Construction of Yonglachu/Khoma Small hydel (1 MW) in Lhuntse and Panbang (200 kW) and upgradadtion of Tintibi Mini hydel in Zhemgang could not be carried out, as the sites were found techno-economically not feasible for development after the pre-construction study. Grid power supply extension from the eastern grid fed by Kurichu was found more feasible for these places. The 8FYP budget outlay for these two projects have been therefore re-appropriated to construct Mongar-Lhuentse grid supply line in Lhuentse and for setting up of a 40 kW diesel generator at Panbang and grid extension works at Tintibi, Zhemgang. Besides, standby/captive diesel generators of 3.570 MW total installed capacities were added in the system in various Dzongkhag headquarters to improve the reliability of electric supply and for emergency need.

Therefore, an additional hydropower power installation of 84.2 MW and 506 Million Units annual generation capacity have been achieved causing a development impact of about 24% increase in hydro installed capacity during the Plan period. Total installed capacity of the Power system at the end of the 8th Five Year Plan period is 444 MW including the diesel generating capacity. Annual average energy generation capacity has also been enhanced to 2326 MU from 1838 MU at the end of 7th Five Year Plan period.

Power Transmission Grid Programme

Under this programme funded by the Government of India, Eastern Transmission grid to evacuate and distribute Kurichu power has been constructed. Grid power line of 132 kV and 69 km length has been extended from Kurichu to Nanglam (initially built for Dungsam Cement Project power supply) via Nangkor in Pemagatshel under the scope of Kurichu project. Similarly, 132 kV line of 10 km length has been extended from Gyelposhing (Kurichu) to Killikhar(Mongar) and 30 km long line from Killikhar to Kanglung (Trashigang). Grid supply line of 132 kV 24 km length is also extended from Nangkhor(Pemagatshel) to Deothang for supply of power to Samdrupjongkhar. Transmission line of 132 kV 129 km long is also extended from Nanglam via Tintibi, Zhemgang to Gelephu, Sarpang for export of surplus power generated by the Kurichu Project and also to increase the reliability of power supply to the proposed Dungsam project in Nanglam. A total distance of 262 km long 132 kV grid network

has been completed during the 8th Five Year plan with 6 major transmission substations for distribution of electricity to the various load centres at Mongar, Trashigang, Samdrupjongkhar, Zhemgang and Sarpang Dzongkhags. The 48 km long transmission line to Lhuentse and substation at Tangmachu will be completed in the beginning of 9th Five Year Plan.

In Western Bhutan, 23 km long 66 kV transmission line from Lobessa to Basochu Upper Stage has been completed. Works have started for the construction of 220 kV Semtokha-Basochu Lower Stage power plant. Similarly works for construction of 400 kV lines to export Tala power as well as the 400/220 kV, 200 MVA Interconnecting substation between Chukha and Tala grid supply at Malbasse, Pasakha have started which will be completed in the 9th Five Year Plan. Survey works for drawing grid power supply lines to Tsirang and Dagana have also begun.

Under the improvement and upgradation of Transmission System, Gedu substation has been upgraded to 26 MVA, 66/33/11 kV voltage level for supply of construction power to Tala Project and works are on to upgrade Singhegaon 220/66 kV substation by additional 50 MVA, Phuentsholing 66/33 kv sub station by 10 MVA and Penden 66/33 kv sub station by 5 MVA.

Power Distribution Programme

Under the Power Distribution programme, 6211 additional consumers (till June 2001) have been added to the system. Extensive rural electrification works have been carried out in about 183 villages in the Dzongkhags of Ha, Samdrupjongkhar, Trashigang, Trashiyangtse, Chukha, Thimphu, Punakha, Wangdue, Paro and Lhuentse and 80% of the works have also been completed for further rural electrification of additional 6028 households in various Dzongkhags under Rural Electrification ADB Phase II Loan Project. Works have also started to electrify additional 388 households in Dungkhar, Chungkha and Zhemgang under the Sustainable Development project funding from the Netherlands. Khuruthang Township was electrified and substantial works on improvement and upgradation of existing electric services in Thimphu and Paro have begun. About 286 km length of 33 and 11 kV overhead lines and 504 km long low voltage overhead lines (400/230 Volts) have been added to the Distribution network during the first three years of the 8FYP period. The feasibility study conducted during the 8FYP rural electrification survey found the capacity coupling system was not feasible for rural electrification in Kengkhar village, Mongar. The commissioning of the Kurichu Hydro Power Project has increased the power sector activities in Eastern Bhutan. To meet the increased workload on account of extensive rural electrification programme, the Department of Power has established independent Electricity Supply Offices at Lhuentse, Mongar, Pemagatshel and Trashiyangtse in 2001. Earlier the electric services in these Dzongkhags were looked after from Trashigang. For the first time, grid electricity was made available to Yangtse Dzongkhag during the 8th Five Year Plan.

Alternate Energy Programme

For institutional lighting of lhakhangs, goenpas, chamkhangs, monastic schools/shedras, BHUs, Boarding schools, community schools and rural households, 180 sets of photovoltaic panels were installed in Chukha, Paro, Haa, Thimphu, Punakha, Pemagatshel, Yangtse, Bumthang, Samdrupjongkhar, Wangdue, Lhuntse, Trongsa and Mongar from the 7FYP spill-over stock. In

Gasa, additional 115 sets were installed for rural electrification by the Dzongkhag Administration under donor assistance. National Strategy for Improved Stoves and Alternate Energy Technologies/Sources was also formulated. The Department of Forestry Services implemented Electric Stoves in Royal Bhutan Police complex as a pilot demonstration project for replacement/reduction of firewood use by other alternate energy sources. 1350 solar electrification sets have been procured during the end of the 8th Five Year Plan period and their installations have started in various Dzonkhags for institutional lighting purpose.

Hydrometeorological Networking and Feasibility Studies

Collection of hydrometeorological data for hydropower planning continued during the 8FYP. These data were collected from 21 river gauging stations and 84 meteorological stations and are archived for future reference and record. During the 8FYP, feasibility studies of Mangdechu Hydroelectric Project of 360 MW across Mangdechu in Trongsa Dzongkhag and Punatsangchu Hydroelectric Project of 870 MW across Punatsangchu in Wangduephodrang Dzongkhag were conducted. These two projects have been found techno-economically feasible and are planned for execution during the next Five Year Plan periods. Gathana micro hydel in Gasa Dzongkhag was investigated and found not suitable for electric supply to Gasa for techno-economic reason. Under GEF/UNDP funded project "Study to remove barriers to micro hydel development in the Kingdom", four feasible micro hydel sites have been identified at Sengor (Mongar), Sakten (Trashigang), Tang (Bumthang) and Gasa.

Institutional Capacity Building and Technical Assistance programme.

Asian Development Bank provided the technical assistance for the development of legal and institutional framework of the Power Sector major scope of which included the development of Electricity Act, institutional framework of the Power sector as well as the Corporatisation plan of the Utility functions of the present Department of Power. Based on these studies and plans developed under the various technical assistance, it is proposed to segregate and unbundle the present functions of the Department of Power into three functions and organizations set-sup namely: 1) Bhutan Electricity Authority (regulatory functions), 2) Bhutan Power Corporation (to take care of the Electric Utility functions) and Department of Power/Energy (for the planning and policy functions and coordination). The study has also proposed that all the Generating companies/corporations such as the Chukha, Kurichu, Basochu and Tala shall be under a major holding company.

Tariff studies have suggested that the future power sales tariff shall be based on capacity, voltage level as well as energy consumption pattern for the industrial, commercial and bulk consumers. The lifeline tariff rates based on various levels of consumption (slab system) is proposed for domestic consumers (both rural and urban). The long range marginal costs of supply are reflected and cost-recovery system devised accordingly, and subsidy if any shall be as per this transparent tariff system.

The study for the preparation of water resources management plan and Hydro Power Master Plan update funded by the Norwegian Government has been just launched which will be completed in the 9th Five Year Plan.

Operations and Maintenance Programme:

Under this programme, operations and maintenance of the existing power supply infrastructures were carried out including the capital cost involved in the purchase of power from Chukha Hydropower Corporation and import from India.

Review of 8FYP Expenditure on Capital and Recurrent costs

Expenditure	1997-98	1998-99	1999-2000	2000-01*	2001-02*	Total 8FYP
Capital	111.885	731.455	573.784	893.289	998.964	3309.377
Recurrent	161.262	289.543	286.171	285.334	319.710	1342.020
Total	**273.147**	**1020.997**	**859.956**	**1178.623**	**1318.674**	**4651.397**
Progressive	273.147	1294.144	2154.10	3332.723	4651.397	

* Expenditure estimate for the year 2000-01 based on sanctioned budget, 2001-02 based on estimate submitted

The above progressive expenditure includes Basochu Upper Stage cost of Nu 1435 million (which was outside the Plan Budget outlay). Therefore, net plan budget expenditure by the end of 8FYP is estimated to be over 3,216.397 million which is 95% of the 8FYP total sectoral budget outlay of Nu 3374 million on planned activities. This indicates sectoral achievement of over 90% of the 8FYP target.

NINTH PLAN

Vision:

To be the lead player in South Asia in the development of Hydroelectric power in terms of technology and sustainability and to achieve the goals as set out in the Vision 2020 document.

Mission

To provide adequate, safe and reliable electricity through improvement and expansion of transmission and distribution network including sustainable development of environment-friendly hydroelectric projects and enable the sector to continue to be the backbone of the Bhutanese economy.

Goals/Objectives:

- To fulfill the electrical energy demand of the domestic consumers;
- To foster sustainable and environment-friendly development of hydroelectric power generation;
- To accelerate the pace of development of hydroelectric power for export to generate revenue and thereby enhance the contribution of the electricity sector to the GDP;
- To improve the quality of life and alleviate poverty especially in the rural areas by providing electricity as stimulant for socio-economic development;

- To achieve the automation in the generation, transmission and distribution of electricity and to increase efficiency and reliability in the operations and management of the system;
- To strengthen the institutional and professional capacity of the implementing agencies and their staff; and
- To create the enabling environment including the policy and legal framework for the development and utilization of the hydroelectric sector including private sector participation.

Strategies:

1.1 Adopt Programme approach in formulation of Plans for sectoral development and rolling plan for the fund-flow and its utilization;

1.2 Integrated approach and coordination with other Sectors in planning infrastructure development, principles of cost sharing (counterpart funding for local costs), sustainable development and environment-friendly implementation methodologies.

2.1 Develop Integrated Rural Electrification Plans and Programmes including the Dzongkhag-wise RE Master Plan for 100% electrification by 2020 and Five Year RE Plan including techno-economic feasibility study for phased development and electrification;

2.2 Dzongkhag based Electricity Supply Sections will be involved for the identification and cost-effective investment decisions and rural electrification in consultation with DYT and GYT. Techno-economic feasibility study on proposal submitted by the Dzongkhag for final selection/ identification of villages/households to be conducted by the Sector i.e. Sector will determine the techno-economic cost-effectiveness in consultation with the funding agency and Dzongkhag before the implementation.

2.3 Construction of small/mini hydroelectric Projects for supply of electricity to isolated and remote areas.

2.4 Undertake most construction activities through private sector contracts including the Rural Electrification works.

3.1 Improvement and Up gradation of existing electricity supply infrastructures and facilities both in urban and rural areas to cater to the increased load demand and to improve reliability, safety and overall system efficiency through change management

4.1 Feasibility studies for investment in Hydro power projects for sustainable development and cost-effective investment of resources including scheduling of development. These will include preparation of Energy Master Plan, Water Resources Development Policy, Water Act and Hydropower Master Plan Inventory Update, Feasibility studies of about 2,000 MW Hydro Power Project(s) for investment in the subsequent Five Year Plans as per vision 2020; feasibility and project preparatory technical assistance works etc.

4.2 Project promotion, fund mobilization and Power purchase agreements arrangement and including assistance in construction mobilization of already studied hydroelectric Projects for onward development;

4.3 Development of transmission grids to interconnect regions to ensure reliability of power supply within the Kingdom as well as for export.

4.4 Proper operation, maintenance and management of existing power infrastructures and available resources for provision of quality services to the consumers including power trading/business through re-structured Generation, Transmission and Distribution Corporations and Electricity Authority.

4.5 Creation of Central/Independent Load Dispatch centre for optimum operations and management of resources through proper coordination and scheduling.

5.1 Promotion of hydroelectricity as a commodity for sale locally and for export based on market conditions and development of suitable tariff system thereof;

5.2 Study of market opportunities and strengthening of marketing capability and establishment of infra structural facilities and mechanisms for export;

5.3 Improve upon domestic revenue collection through demand side management techniques and improved technology for reduction of losses.

6.1 Adopt state of the art technology (for leap-frog catch) so that electricity generation and transmission becomes efficient and reliable (minimize man-made errors, do not re-invent the wheel)

6.2 Promote automation in the hydroelectric generation, transmission and distribution for efficient and reliable services (use of SCADA, benefit of value addition in fibre optic communication etc).

7.1 Human Resources Development through Skills and Training Development programme and projects, strengthening of HRD Unit etc.

7.2 Formulation and establishment of Hydropower Policy Guidelines including creation of transparent regulatory framework to encourage growth of the Hydro power sector and for possible participation of Independent Power producers and Operators (private sector participation).

NINTH PLAN PROGRAMMES

Exchange rate: 1US$ = Nu 50

Seven broad thematic programmes mainly for the power infrastructures and institutional capacity building are outlined for the 9FYP. The hydropower investment (implementation of major projects as industries for revenue generation) is considered outside the plan. Skills Development and Training Programmes related to Power Sector are included in the National Human Resources Development programme being formulated by the Royal Civil Service Commission.

Total Budget and Manpower Requirement of the Department of Power (Nu in Millions)

	2002-03 (5%)	2003-04 (15%)	2004-05 (25%)	2005-06 (35%)	2006-07 (20%)	Total (100%)
Infrastructure works	199.75	599.25	998.75	1398.25	799.000	3995.000
Technical Assistance	25.25	75.75	126.25	176.75	101	505.00
Total Capital Budget	225.000	675.000	1125.000	1575.000	900.000	4500.000
Project-tied recurrent	-	-	-	-	-	-
Regular- current *	52.307	57.538	63.291	69.621	76.583	319.339
Total Recurrent #	123.255	267.599	412.480	557.954	356.661	1717.949
TOTAL	348.255	942.599	1537.480	2132.954	1256.661	6217.949
Total Additional Manpower @	411	892	1375	1860	1189	1860 (max)
T.A. (man-months)	40	121	202	283	162	808 mm

* = Recurrent cost for the Department of Power, Bhutan Electricity Authority excluding the Bhutan Power Corporation. # Total estimate of recurrent cost and manpower includes for all the three organisations

7.1 Power Generation Programme (Nu 180 million)

In-country electricity consumption growth rate has been 9.53% per annum over the last five years. Growth rate of 7-15% (average of 12%) is forecasted over the 9FYP period. To cope with this growth rate, generation supply capacity of 10 MW firm power per annum has to be added in the local supply system to cope with the demand in line with the Sustainable development strategy. That means, a power generation plant of at least 75 MW peaking capacity has to be added in the system to meet the internal incremental demand within the next five years. So the investment plan in power generation/supply infrastructure has to be made to cover the cost of building additional 50 MW firm power plant during the 9FYP. A share of this power generation infrastructure development budget can be invested as Govt. Equity input in Mangdechu and/or Punatsangchu Projects (about 10% of the total project cost) and a small portion (about 2%) kept for construction of 3 isolated micro/mini hydel plants in remote areas during the 9FYP. Feasibility studies of Gasa (150 kW), Sengor (50 kW), Tang (400 kW) and Sakten (200 kW) Micro Hydel sites have been conducted during the 8th Five Year Plan for rural electrification of about 642 remote rural households. Major Power Project costs of Mangdechu and Punatsangchu will be reflected outside the 9FYP as part of the economic development programme. This equity budget provision can be invested initially to build up the basic infrastructures such as the approach/access roads, bridges as well as construction power required for the implementation of these incoming mega projects.

Power Generation Program, Activities and Budget outlay

Sl. No.	Sub-Programs/ Activities	Physical Target (Output)	Budget Outlay (Nu million)	Remarks
1.	Micro Hydel Projects	Sengor (50 kW), Sakten (200 kW) and Tang (400 kW)	180 million	USD 3.606 million worth
	Total	**650 kW– 3hydels**	**180 million**	

7.2 Power Transmission Grid Programme (Nu 1,910 million)

To evacuate the power generated by the Chukha, Kurichu, Basochu and Tala projects and to extend the grid supply to meet the bulk power demand of Dzongkhags and major industries as well as to increase the reliability of supply, it is necessary to extend the power transmission grid network.

Based on the projected demand forecast, it is proposed to build the Tintibi-Trongsa/Bumthang Transmission grid, Basochu-Tsirang/Dagana-Gelephu transmission network as well as extend transmission line and substations to the Industrial estates being proposed by the Department of Industries during the 9FYP. As part of the mega Projects under construction, Basochu-Semtokha line and associated transmission substation and Malbasse 400/220 kV substation and associated Tala power lines will also be built. It is estimated to invest Nu 1910 million worth in this programme.

It is also proposed to extend grid power supply to Gasa dzongkhag (Nu 36.667 million) and other important Dungkhag headquarters like Bhangtar and Lhamoizingkha (Nu 63.333 million) based on the prioritized proposals submitted by the Dzongkhags.

After the commissioning of Tala system and its integration with Chukha system, Basochu system and integration of Kurichu with the Western grid in the country; the system will grow complex and will require proper coordination and scheduling of events for optimum generation, transmission and utilization of energy.

Therefore, it is proposed to create National Load Dispatch Center at Gedu or any suitable location for the economic load dispatch and coordination of power generation and transmission activities (availability, load forecast, frequency control) among the generating companies (Tala, Chukha, Basochu, Kurichu), Bhutan Power Corporation (for in-country transmission and distribution) and the Eastern Regional Electricity Board (EREB, Calcutta) and may be the Northern Grid of India too.

This establishment will consist mainly of dedicated real time data communication network laid in fibre-optic cables including the SCADA, Information Receipt & Processing Center manned by few dedicated engineers to coordinate the whole power system. This establishment may be

under the Druk Hydro Power Corporation in the beginning and later on, Bhutan Power Trading Corporation once it is formed can take over the function. The suitable budget provision has been made accordingly.

Power Transmission Programme, Activities and Budget outlay

Sl. No.	Sub-Programs/ Activities	Physical Target (Output)	Budget Outlay (Nu million)	Remarks
1.	Tintibi-Trongsa/ Bumthang line and substations	132/33 kV line and substations	578 million	An additional budget of Nu 200 million for construction power supply to Mangdechu Project required.
2.	Basochu-Tsirang/Dagana-Gelephu line and substations	220/132/66/33 kV lines and substations	1132 million	Can serve as grid link between Kurichu & Basochu for reliability of supply.
3.	Grid power supply extension to Gasa Dz. HQ, Bhangtar & Lamoizingkha Dungkhag HQs	Grid Power supply to Gasa and other areas	100 million	Grid supply cost to Gasa estimated at Nu 36.667 million
4.	National Load Dispatch Center	At Gedu	100 million	Economic load dispatch and coordination among Generation, Transmission & Distribution operators
5.	Project tied lines and substations	i) Semtokha-Rurichu system ii) 200 MVA, Malbase substations iii) 400 kV lines of Tala	N.A.	Budget built in the Major Hydropower Projects
	Total		**1,910 million**	

7.3 Power Distribution Programme (Nu 1,800 million)

During the 9FYP, the utility functions shall be segregated from the regular functions of the Department of Power. The electricity supply and sales functions shall be corporatised and handled by a separate autonomous corporate agency to be named as "Bhutan Power Corporation" (BPC), responsible for the micro/mini hydel generation, transmission and distribution of electricity and for electricity business in the Kingdom. This corporate body shall be incorporated under the Company's Act and the Electricity Act of Bhutan. This corporation shall buy electricity from the generating companies such as the Chukha, Basochu and Kurichu besides self-generation from isolated mini/micro hydels for distribution and sales to the consumers. Bhutan Electricity Authority will be created under the Electricity Act 2001 and will

be the Regulating Agency of the Royal Government who shall ensure that electricity business is carried out in the Kingdom in a safe and sustainable manner. The Power Distribution programme during the 9FYP shall mainly consist of following programme activities: -

i) Rural Electrification
ii) Urban Electricity Extension Services in Phuntsholing

The plan fund and budget shall be made available by the Government to enable the Bhutan Power Corporation to carry out the above activities besides the regular functions of electricity supply and sales to the existing consumers.

To achieve the mission target, keeping in view the vision 2020 for 100% electrification, it is planned to electrify 15,000 households in 20 dzongkhags through extensive rural electrification (RE) programme estimated at a cost of Nu 1500 million by either grid extension or through isolated micro hydel development. Besides, there will be sub-transmission and distribution activity namely urban electricity extension services to extend and upgrade existing electric power supply infrastructures in Phuentsholing, where the urgent need is felt. The existing power supply infrastrcures of Phuentsholing built since 1965 needs rehabilitation. A tentative budget of Nu 300 million (US$ 6 million) is proposed under this scheme. Operations and maintenance division, in consultation with the concerned electricity supply section will prepare the detailed programme for implementation.

In order to be able to achieve the RE targets, it will be absolutely necessary to contract out the construction of the rural electrification. While about 30% could be undertaken by the BPC, the balance 70% will need to be contracted to private parties. This will allow simultaneous execution of the works and will also enable acceleration of the RE program. This will mean deviating from the conventional method where the Department of Power and the communities only are involved in the RE works. This new approach being proposed will also help the private sector to grow and increase employment opportunities.

The two programmes namely the Power Transmission and Power Distribution will both be implemented by the BPC. The Royal Government will provide the total budget outlay for these two programmes as a capital investment to BPC on work-order basis for implementation.

The programme activities and budget outlays are shown in the table below:

Power Distribution Programme, Activities and Budget outlay

Sl. No.	Sub-Programs/ Activities	Physical Target (Output)	Budget Outlay (Nu million)	Remarks
1.	Rural Electrification in 20 Dzongkhags	15,000 Gungs	1,500 million	Dzongkhag-wise break up shown in Table 3.3.1
2.	Urban Service Extensions & Upgradation	Phuntsholing and other places	300 million	As per priority to be identified.
3.	Compensation against tariff subsidy	3959 MU @ Nu 0.4594 /kWh average	*	Separate budget to be kept in the a/c of BPC.
	Total		**1,800 million**	

Equitable distribution of Dzongkhag-wise households (about 20 to 25% of the total households depending upon the implementing capacity) planned for RE are as follows:

Rural Electrification Programme, Physical Target and Budget Outlay

Sl. No.	Name of Dzongkhag	Physical Target Output	Budget Outlay (Nu million)	Remarks
1.	Bumthang	337	33.7 million	
2.	Chhukha	896	89.6 million	
3.	Dagana	672	67.2 million	Villages identified by the Dzongkhag
4.	Gasa	110	11 million	
5.	Ha	281	28.1 million	
6.	Lhuentse	628	62.8 million	
7.	Mongar	1091	109.1 million	
8.	Paro	702	70.2 million	
9.	Pemagatshel	980	98 million	
10.	Punakha	519	51.9 million	
11.	Samdrupjongkhar	1012	101.2 million	
12.	Samtse	1250	125 million	
13.	Sarpang	935	93.5 million	
14.	Thimphu	646	64.6 million	
15.	Trashiyangtse	812	81.2 million	
16.	Trashigang	1728	172.8 million	
17.	Trongsa	367	36.7 million	
18.	Tsirang	687	68.7 million	
19.	Wangdiphodrang	831	83.1 million	
20.	Zhemgang	516	51.6 million	
Total	**20 Dzongkhags**	**15,000 gungs**	**1500 million**	

A budget of Nu 1500 million (US$ 30 million at the rate of US$ 2000 or Nu one lakh per household) is proposed for the RE programme. Detailed household and village site survey in each proposed geog will be done in consultation with the Dzongkhag for implementation of the programme. Donar/Lending agencies may ask for further techno-economic and social study of the scheme before the sanction and approval of the fund for rural electrification. This extensive programme will require active participation of the end-users as well as the implementing agencies. Since the plan is very ambitious, private sector participation shall be necessary to augment the existing institutional capacity of the implementing agency(s).

7.4 Institutional Capacity Building Programme (Nu 375 million)

The present functions of the Department of Power will be unbundled and Bhutan Electricity Authority (Regulatory body for enforcing rules & regulations), Bhutan Power Corporation (a corporate body for electricity supply and sales) and the Department of Energy/Power (Energy Planning and Policy functions) shall be created in the 9FYP. A new Ministry for Energy and Water Resources is also expected to be formed. Corporatisation plan for the Bhutan Power Corporation (BPC) is ready and this corporation will start functioning from July 2002.

Under this programme, various other techno-economic feasibility studies, water and energy resource plans and including power master plan update (NORAD), RE- Master Plan, policy guidelines, electricity rules, regulations, technical standards and codes shall be developed. It is proposed to carry out feasibility study of two/three major hydropower projects (Diglai Project across Bumthangchu in Zhemgang, Rothpashong/Kholongchu in the East, and/or the Punatsangchu Phase II) during the 9FYP. A budget of Nu 375 million is proposed under this programme. This programme is aimed at institutional capacity building of the Sector in technical, financial, and legal as well as managerial aspects of the Sector.

Institutional Capacity Building Programme, Activities and Budget outlay

Sl. No.	Sub-Programs/ Activities	Physical Target (Output)	Budget Outlay (Nu million)	Remarks
1.	Water Resources Management Plan and Hydro power Master Plan update	i) Master Plan Reports ii)Hydrometeorological Equipment	112.5 million	Fund secured and Project starting in 8FYP.
2.	RE-Master Plan study and investment studies	1) 20 Dzongkhags' RE Master Plan & Investment study reports	100 million	ADB PPTA for US 0.70 million during 2002 for loan investment study.
3.	Feasibility studies of 2,000 MW Hydropower Project sites	1) Lower Bumthangchu (Diglai), 2) Kholongchu	150 million	Sites to be finalised in consultation !

		3)Punatsangchu Stage II		
4.	Development of Guidelines, Regulations, Standards & labels	Lot	12.5 million	
	Total		**375 million**	

7.5 Alternate Energy Programme (Nu 200 million)

An integrated approach in planning of available energy resources for their optimum and sustainable development and utilization based on short term, medium term and long term supply-demand forecast is necessary as Energy is an important input for the economic development of the country. Only the electricity sector is given importance today, because of its obvious impact in the economy. However, import of fossil fuel and its dependence to sustain the transport sector is an issue to look into, including the sustainable yield of biomass to meet the primary energy need of the rural population. The affect of global warming due to release of greenhouse gases from burning of these fossil fuels and biomass are issues of concern. Efficiency improvement in its utilization is a step to start with. Energy technology and processes, including the efficient standards have to be chosen based on these concerns and considerations.

Under this programme, bio-mass, solar and any other alternative energy programme and projects including the improvement in management and technology and energy efficiency sub-programmes shall be carried out. An integrated Energy Master Plan is expected to be developed under this programme. Solar water heaters, solar dryers, solar lighting, improved efficient biomass stoves and alternatives will be demonstrated. Private sector shall be encouraged to participate in enhancing the efficiency improvement programme. Consumers and traders awareness campaign can be launched to promote clean energy and utilization of efficient energy technologies and cost savings. Studies can be carried out to find out possibilities of replacement of polluting (global warming) energy by renewable, clean, environment-friendly and energy & converting technologies and some pilot projects can be launched. For example, pilot project to demonstrate the electric bus or fuel cell technology can be introduced in & around the capital and Phuntsholing to study the possibility of reducing fossil fuel consumption and its substitution.

Alternate Energy Programme, Activities and Budget outlay

Sl. No.	Sub-Programs/ Activities	Physical Target (Output)	Budget Outlay (Nu million)	Remarks
1.	Integrated Energy Master Plan	1) Reports	100 million	Energy Balance Table
2.	Solar Energy Projects	i) Solar Water Heaters, Dryers ii) Photo-voltaics	75 million	On the Principles of cost sharing!
3.	Bio-mass Energy Projects	i) Efficient Stoves ii) Room Heaters iii) Energy Plantation & Catchment protection	12.5 million	i) Principles of cost sharing and end-user participation! ii) Technology transfer and adoption
4.	Energy Conservation & Efficiency Projects	i)Awareness campaign ii) Standards & labels iii) Pilot Project on CFL lighting etc.	12.5 million	Consumers & Traders education!
	Total *		**200 million**	

Besides the above mentioned Projects, if additional funding can be secured through grant assistance from multilateral/bilateral donor agencies for investment in infrastructures development projects to support renewable and environment-friendly energy technologies for rural development and to promote socio-economic development activities, such Projects will be welcome and will be included as additional under the Alternate Energy Programme during the 9FYP. Therefore, the limited budget provision (*) is subject to revision depending upon the availability of fund during implementation. The feasibility study and specific project documents will support for such an extension.

7.6 Private Sector Participatory Programme in the development of Hydro Power Sector – Nu 35 million

To increase the implementation capacity in the development of Hydropower sector during the various stages of implementation from planning, design, construction and operations and maintenance, private sector participation is felt necessary, as the existing institutional capacity of the Department of Power and its Associates is limited.

To enhance the institutional capacity of the private sector for various development activities, a separate programme is therefore planned during the 9FYP.

In the past, private sectors have been involved mainly in the supplies of electrical construction materials (trading) and transport of goods. Lately, construction contracts are being awarded for the building of Power Projects' infrastructures such as buildings, roads, and water supply and very recently works have been awarded for the construction of power plants (civil works in Basochu and Kellungchu Hydel). Till date, the Department of Power staffs have done most of

the power distribution works such as Rural Electrification. In the 9th Five Year plan, the implementation capacity has to be doubled to achieve the planned target of electrifying 15,000 households in 5 years. In this case, private construction companies have to be employed to get the plan works done in time. Therefore Power sector would like to seriously encourage the real participation of the private sector during the 9FYP by creating enabling environments.

A study will also be carried out under the technical assistance financing from ADB to identify possible areas for private sector participation, to formulate the framework of guidelines/rules and regulations for their participation including the terms of reference for private sector engagement. Conceptually, it is felt that the Private sector can actively involve in the following activities of the Power sector during the 9FYP:

i) Rural Electrification works (execution);

ii) Possibility of Central Maintenance Section, Begana and its small transformer-manufacturing unit to be privatised;

iii) Participation in Hydro power plant development (Build Own & Operate BOO scheme, Build, Own, Operate & Transfer Scheme (BOOT) etc. as an Independent Power Producers (IPPs);

iv) Study the possibility of Power Distribution Services for community operations (eg City Corporation to look after all utility services in town) and private sector participation in billing and collection depending upon the feasibility.

v) Entrepreneurial skills development and Training of community electrician, wireman and lineman for self-employment in the electrified areas for internal wiring, repair and line construction/maintenance contracts.

Therefore, following program activities and budget outlays are tentatively proposed to be carried out:

Private Sector Participation Programme, Activities and Budget outlay

Sl. No.	Sub-Programmes/ Activities	Physical Target (Output)	Budget Outlay (Nu million)	Remarks
1.	Study of Private sector participation in hydropower development (IPPs)	Policy framework, guidelines, identification of barriers and areas of opportunities	20 million	ADB TA
2.	Feasibility study for community and Private sector participation in Electricity Supply Services (Business)	i) Identify possible areas for community participation, private sector involvement in Electricity supply Services and draw out strategies and plans. (ii) Privatization of Begana facilities; (iii) RE Contracts management and TOR	10 million	
3.	Skills and Training of Private Electrician/ Wireman/Lineman	Lot	5 million	ADB TA
	Total		**35 million**	

Major Economic Development Projects & Programme (Outside the Plan).

Tala Hydroelectric Project of 1020 MW capacity, construction of which started during 8th Five Year Plan will be completed and commissioned in the 9th FYP. Most of the electro-mechanical plant and equipment will be installed during the second half of the 9th FYP. The Project is anticipated to be commissioned in the year 2004/05. When this Project is commissioned, it is expected to generate above 4924 million units of energy per annum. The completion cost of the Project is expected to be around Nu 43 billion. The Project is being financed by the Government of India at 60% grant and 40% loan at 9% interest rate, payable in 12 years.

Basochu Lower Stage (Baso-Ruri scheme) of 40 MW installed capacity estimated at the present capital cost of 553 million ATS (Nu 1659 million) is expected to start in the beginning of the year 2002 and complete in the year 2004. It will generate 186 million Units per annum when completed and augment the generation supply in the Western system. Project cost worth 430 million ATS is financed by the Government of Austria at 2.786% interest rate payable in 20 years (5 years grace and 15 years repayment) for the construction of Power plant. Remaining 123 million ATS is required for financing the construction of 35 km 220 kV line between Rurichu and Semtokha and 70 MVA, 11/220 kV switchyards at Rurichu including the construction power.

It is planned to invest in the construction of Mangdechu Hydroelectric Project of 360/600 MW capacity in Trongsa dzongkhag and Punatsangchu project of 870/1000 MW in

Wangduephodrang preliminarily as the major economic development activities for export of electricity, during the 9th FYP. As part of an equity investment on the principles of cost and risk sharing, it is planned to invest atleast 10% of the Project cost from the Royal Government's side as equity input mainly for the pre-construction activities such as on the project access roads, construction power and other basic project infrastructures to start with. These two mega projects can be completed in the 10th Five Year Plan period if implementation begins during the 9FYP.

It is anticipated that expenditures of atleast 60% of the project cost is expected to be spent during the 9FYP for Mangdechu Project and 40% for Punatsangchu. 50% and 30% external financing in the form of grant and loan are required for investment in Mangdechu and Punatsangchu respectively during the 9FYP.

Major Economic Development Programme, Activities and Budget outlay

Sl. No.	Sub-Programs/ Activities	Physical Target (Output)	Budget Outlay (Nu)	Remarks
1.	Tala Hydroelectric Project	1020 MW	25,800 million	60% expenses during the 9th FYP.
2.	Basochu Lower Stage	40 MW	1,659 million*	Construction just started in 2002.
3.	Mangdechu	360 MW (60% complete)	10,467 million #	Nu 1,744.5 million RGOB equity
4.	Punatsangchu	870 MW (40% complete)	16,260 million #	Nu 4,065 million from RGOB equity
	Total		**54,186 million**	

* Nu 369 million equity investment of the RGOB for line and substation construction and Nu 1290 million loan from Austrian Government

50% and 30% of the Mangdechu and Punatsangchu costs expected from external financing sources respectively. Physical targets of 60% and 40 % can be achieved only if the fund is mobilized in time. 10% RGOB equity investment is anticipated as shown in the remarks column.

Financial and Manpower Requirements (excluding Major Projects)

Financial Requirement

A sum of Nu 6, 217.949 million of budget (excluding major projects' cost) is required for the implementation of 9FYP Power sector programmes. The capital budget outlay is estimated at Nu 4,500 million of which the technical assistance component is estimated at Nu 505 million. The regular recurrent cost for the running and maintenance of the system is estimated at Nu 1717.949 million for the whole 9FYP period. The regular current budget is to support the system establishment cost, which includes pay and allowances of regular staff, hiring of buildings, utility charges and others.

Manpower Requirements

Presently the Department of Power's regular staff strength for planning, operations and management of the system is 850 in number. After the Corporatisation only about 170 staff (20% of the present strength) will remain in the Department. Additional manpower (@) will be required to implement the plans and programmes during the 9FYP. The projections are shown in the statement above accordingly. The average cost of establishment (including manpower, social cost, overhead charges) is works out to Nu 0.300 million per regular employee. Based on this estimate, the above manpower requirement has been derived upon.

Technical Assistance:

Technical assistance (TA) worth Nu 505 million is required for the institutional capacity building, formulation of Master Plans, feasibility studies of major programmes and projects. The consultant services required for complex engineering design and engineering works supervision are built in the infrastructure works. All programmes will require technical assistance and experts' services from outside especially when the programme involves new technology, process and their adoption in the country for the first time. About 20% of the technical assistance can be provided by the local consultants. A sum worth Nu 161.5 million of technical assistance is already secured for the Water Resources & Hydro Master Plan update from NORAD and RE Loan Project preparatory assistance and for formulation of guidelines for private sector participation in Hydropower sector from the ADB.

The total cost of foreign/international service (technical assistance) is estimated at Nu 0.625 million per man-month and the domestic consultant/service at one-fourth the international cost. The man-months requirement forecasted accordingly is for international consultants. 50% of the man-months for the technical assistance services can be availed locally. The budget outlay for the professional services requirement under Infrastructures development is charged to the works and not shown above.

Financing Mechanism

A portion of power generation programme is proposed to be financed through internal revenue savings (20% as the self-financing ratio) as equity investment of the Royal Government while micro hydels development and technical assistance projects are proposed for grant assistance financing from donors. Transmission programme is proposed for financing through grant from the donors like the Government of India and internal financing (project tied). Distribution programme especially the rural electrification is proposed for financing from internal savings; grant assistance from donors (India, Netherlands, Austria) and very soft loan from the ADB under rural poverty reduction programme. Most of the technical assistance programmes are proposed to be funded by the Donors (especially Feasibility studies, Master Plans etc) and from project-tied major infrastructure projects' fund for technical design and supervision.

Implementation Strategy

Most of the plan works such as the power transmission and rural electrification shall be done by the Bhutan Power Corporation (present Department of Power with Electricity Supply functions) on work order basis through its various Electricity Supply sections based in each Dzongkhag. Contractors (private sector) and the beneficiaries will augment the institutional implementation capacity. Autonomous bodies such as the Authorities created for the purpose shall implement the major hydropower projects. The planning, feasibility study types of programmes shall be implemented by the Departments under the Ministry of Energy and Water Resources. Dzongkhags and other relevant Sectors shall be consulted while framing the detailed implementation plans, studies as well as the strategies. Environment clearance and any other sectoral/stake-holder clearance will be sought before the programme activity is initiated in the field. Cost-sharing principle shall be encouraged including the community labour contribution and commitment especially in rural electrification programme from the future sustainability point of view. Private sector participation especially during the construction phase is necessary to augment the institutional implementation capacity of the Govt. owned implementing agencies.

The success will depend upon the fund mobilization ability for the financing of the various programmes to start with. Unless the fund is secured and mobilized, implementation strategy in the field will not work. Rolling plan concept has to be adopted to avoid the spillover and therefore broad programming concept is being adopted during the 9FYP. Constant monitoring and evaluation should form part of the programme management strategy.

Monitoring and Evaluation Mechanism

For quality control as well as for the smooth management of the Program/projects, monitoring and evaluation must be made an integral part of the program. Unless constraints, problems and delays are reported in a timely manner through the regular monitoring and evaluation mechanisms, the delays in all program activities are bound to occur. The Department of Power and Bhutan Electricity Authority on behalf of the Royal Government will do most of the monitoring, where donor financing is provided, the donors will also be involved in monitoring and evaluation mechanism. Prior to implementation of the Projects, programme activities charts will be worked showing various schedules of the activities and identifying physical and financial milestones. These programme charts will be used for strict monitoring and evaluation. Each Project shall have its own monthly progress review meeting where progress of activities will be reported and programme progress will be reported in a quarterly manner to the Higher Authorities and the Monitoring Agencies. Map 2 shows the location of the proposed significant Projects and Programmes of 9FYP.

RE-MASTER PLAN Concept

Presentation to JICA Mission

by

DOE

Objectives

- Vision: Electricity for all by 2020 ! (atleast electric light for all by 2020) – policy objective
- Poverty alleviation through extensive RE program for providing access to renewable energy (electricity) for stimulating socio-economic development activities (rural development !)
- Reduce green house gas emissions from rural areas (kerosene and firewood use) by substituting with clean energy !

Strategies

- 1) By hydroelectric power grid extension
- 2) isolated off-grid mini/micro hydels
- 3) Solar electrification/Photovoltaic
- 4) Bio-mass conversion/gasification
- 5) Fuel cell technologies (as energy carrier to substitute kerosene, firewood - Hydrogen as fuel input)

Physical targets

- Estimated rural households in the year 2000-01: **65,567 HH**
- Electrified till 2000 –01: 12,938 HH (i.e. 20% RE ratio)
- Villages – 646 nos
- Additional during the 8th plan (+ 6028 HH under RE-II ADB) by 2002-03 : 18,966 HH (about 27% of total).
- 9th Plan RE target (June 2007): + 15000 HH , total = 33,966 HH (about 44 %)
- RE_Master Plan target estimate: remaining 46,742 HH from June 2007 + % HH growth rate.

RE_MASTER PLAN TARGET

- 10th Plan (2007-2012): +20,000 HH (62%)
- 11th Plan Target (2012-2017): + 25,000 HH (83%)
- 12th Plan part (2017-2020): + 20,000 HH (100%)

(Estimated rural HH by 2020 ~ **100,000 HH** after considering rural-urban drift, family fragmentation and reduced population growth rate !)

BUDGET FOR IMPLEMENTATION OF RE-MASTER PLAN

- 1) 20,000 HH (2007-12) - US$ 46 million
- 2) 25,000 HH(2012-17) - US$ 66 million
- 3) 20,000 HH(2017-2020) – US$ 56 million

Total fund (present value) – US 130 million @ US 2000 per HH and RE rate of 5000 HH per annum equivalent to commitment of 10% net revenue earnings from hydroelectric export plough-back for the cause of RE !

RE-Master Plan Outputs

- Dzongkhag-wise and Year-wise RE Plan with techno-financial parameters
- To be updated/revised every 5 year Plan period to incorporate additional/refined data inputs/requirements/implementation schedules etc (Dynamic Plan)
- Training of Bhutanese counterparts for update/revision of cost and technology to make the plan .

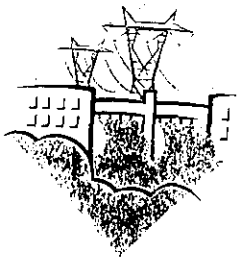
Discussion: RE-Master Plan study components

- Baseline information & mapping (socio-economic, techno-economic environments, other infrastructures) through extensive surveys !
- Demand Analysis
- Supply Analysis (Technology, Options)
- Infrastructures Development Plan, Dzongkhag-wise project & budget formulation (ranking list of villages and 13 years schedule !)
- Funding/financing mechanism/strategies

End of the Presentation

- Questions and Answers(Q&A) on 9FYP
- Q& A on RE-Master Plan study
- Any other questions
- Further Discussions !!!!!!!!!!

THANK YOU !



Power Sector Presentation to JICA Mission

by

Department of Energy

Ministry of Trade & Industry

Country's Baseline

- Land Area – 38,394 km^2 (as per 9th Plan)
- Altitude – 100 metres to 7,000 metres above sea level
- Forest cover – 72%
- Rainfall – 500 mm to 5000 mm (North to South
- Main rivers (North-South) – Amochu, Wangchu, Sankosh, Manas
- Specific discharge – 5 (minimum) to 50 litres/sec/km^2 (annual average).

Country's socio-economic data

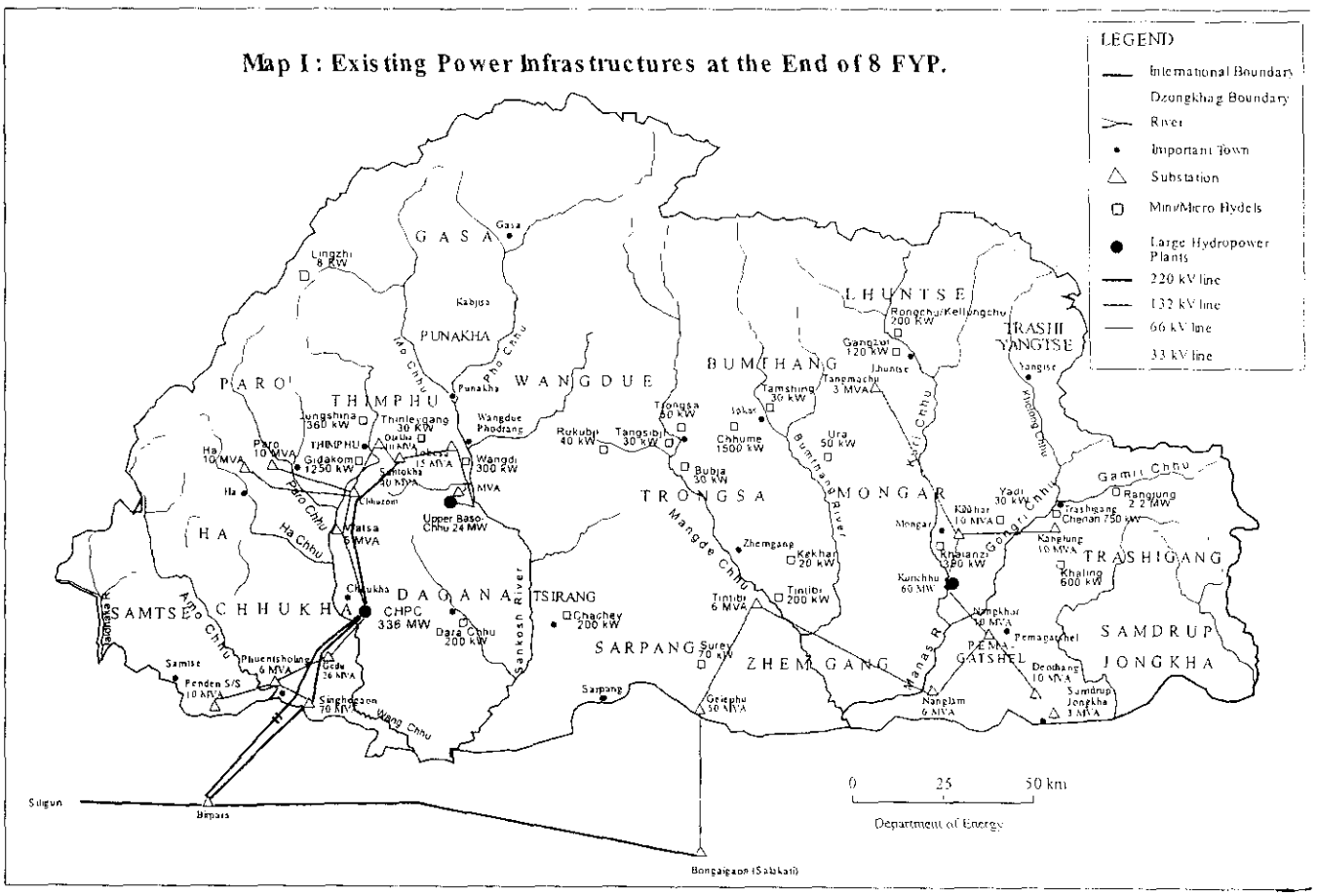
- Dzongkhags (districts) – 20
- Geogs (blocks) - 201
- Population – 658,000 in 2000
- Rural population – 79%
- Rural Households (estimate)- 65,567 gungs
- GDP growth (during 8th Plan) – 6.5%
- Annual GDP per capita – US$ 758
- Annual per capita electricity consumption ~ 740 kWh

Energy Sources

- Primary energy – Bio-mass (1.2 million m^3 per annum consumption, 1.9 m^3 per capita) for lighting, cooking and heating
- Import of Kerosene, Diesel, Petrol, LPG, Aviation Turbine Fuel etc on the increase !
- Hydroelectric installed capacity – 428 MW, 2385 GWh (105 MW, 530 GWh internal consumption)
- Solar PV installed – 74 kW
- Diesel Power installed capacity – 17 MW
- Total Electric Power installed capacity ~ 445 MW.

Status of Hydro Power Development

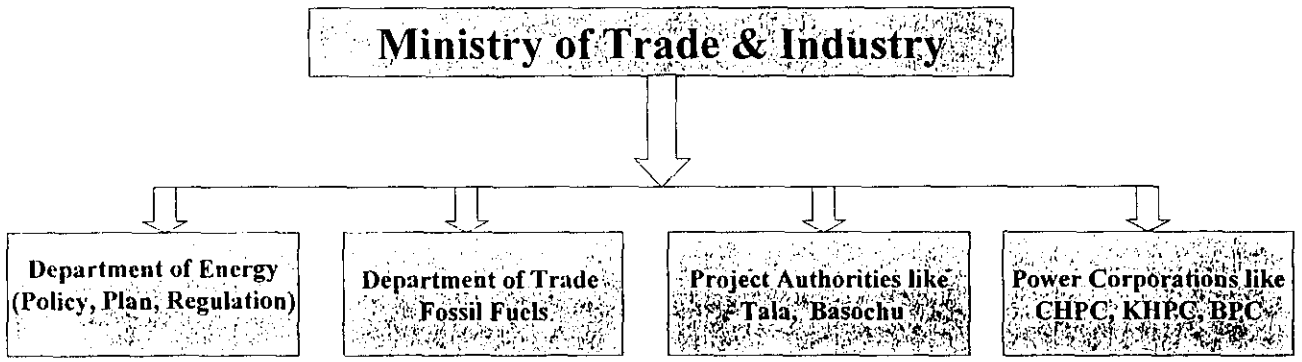
- Total Potential – 30,000 MW (120 TWh)
- Commercially viable (25 sites) ~ 16,000 MW
- Developed so far – 428 MW (1.42%), 23 nos of 8.6 MW installed capacity Mini/Micro Hydels (8 kW-2200 kW) and 3 nos of 420 MW installed capacity large plants plants (24-336 MW)
- Under construction – 1020 MW Tala and 40 MW Basochu Lower Stage



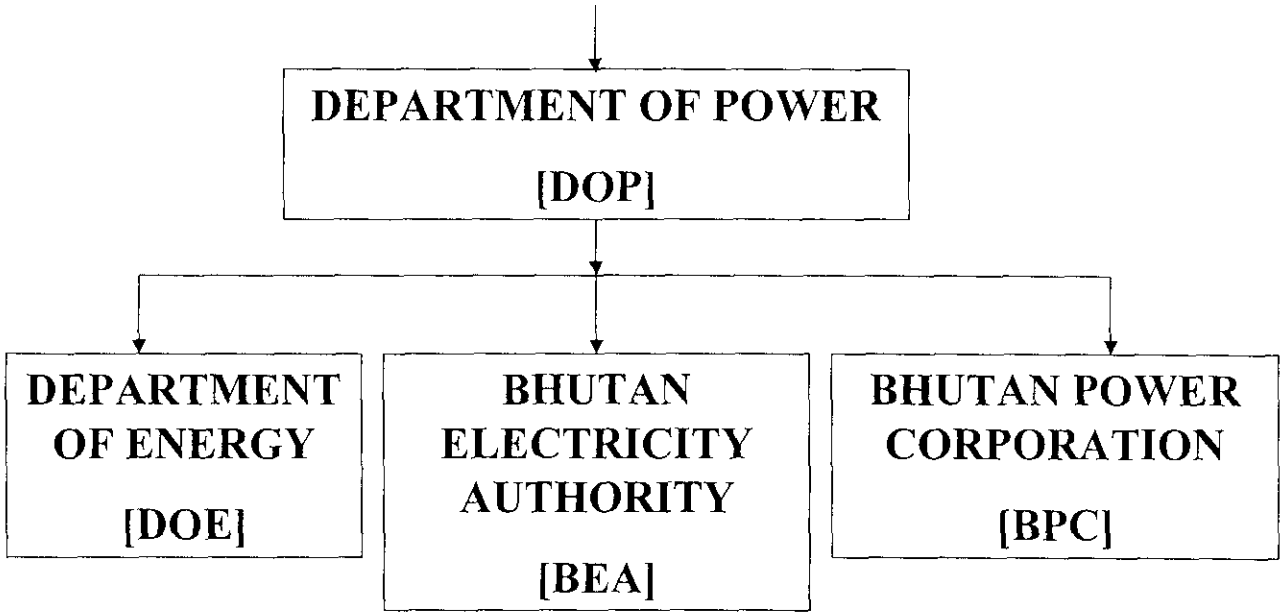
Institutional Set-Up

- Under Ministry of Trade & Industry
  - Electricity Policy, Planning, Regulations & Utility functions (Generation, transmission & Distribution)
  - Import of Fossil Fuels
- Under Ministry of Agriculture
  - Fire-wood, food and animals

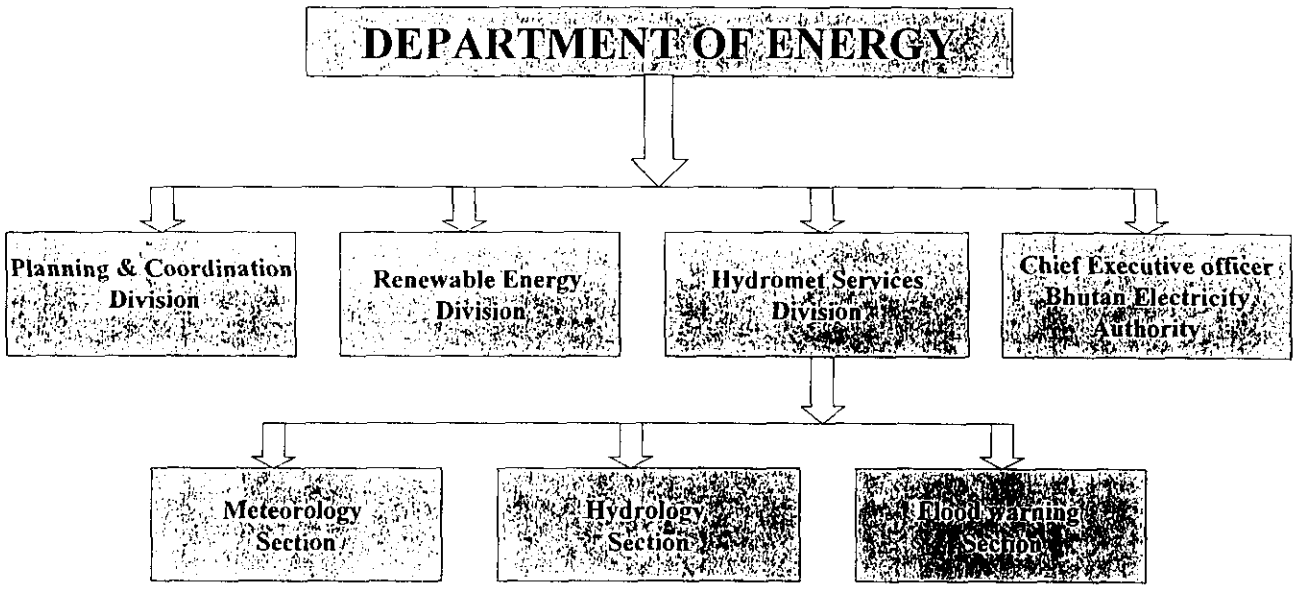
Organization Setup since July 2002



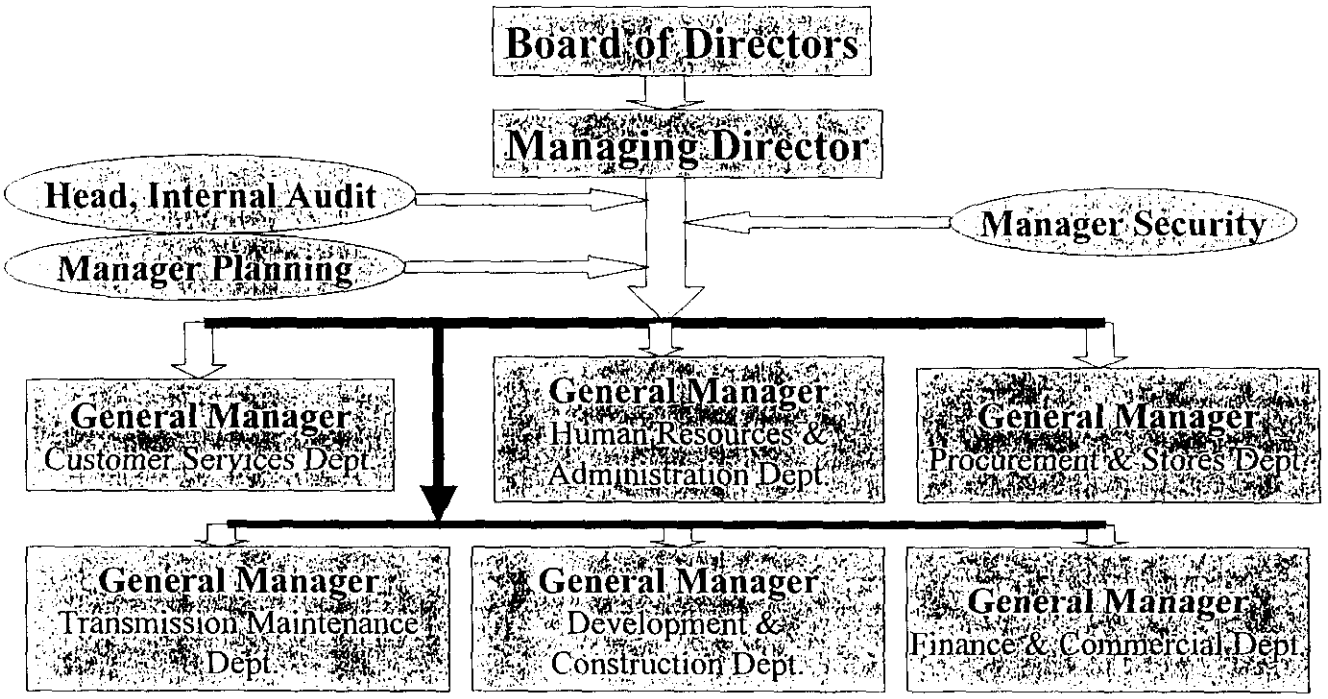
Power Department (Restructured plan)



Organogram (DoE) w.e.f. 1 July 2002



Organogram (BPC) w.e.f. 1 July 2002



Functions of DoE

- ✓ Formulation of Macro-Level National Plans, Policies, Programmes & Projects and coordination of energy sector activities.
- ✓ Provide technical advice/support to RGoB on energy issues
- ✓ Monitoring & Evaluation of programmes and projects
- ✓ Techno-economic and budgetary clearance of energy projects

Situation Forecast - 9FYP

- Average 15 MW incremental demand p.a. forecasted
- 75 MW supply capacity addition in 9FYP period for sustainable supply
- 7- 15 % electricity growth rate forecasted !
- Anticipated 12% average electricity growth rate over the 9FYP period !
- 9FYP Revenue contribution – Nu 15 billion (about 60% of total national revenue by 2007)

Vision

- To be the Lead Player in South Asia in the Development of Hydroelectric Power in terms of Technology and Sustainability and make the Sector the engine of socio-economic growth in the Kingdom

Mission

- To provide adequate, safe and reliable electricity supply through sustainable and environment-friendly development of hydroelectric power both for domestic and export markets!

Goals and Objectives :-

- 1) To fulfill the electricity demand of domestic consumers;
- 2) To foster sustainable and environment-friendly development of hydroelectric energy resources;
- 3) To accelerate the pace of hydroelectric power development to generate revenue through export and thereby enhance the contribution of the Sector to the growth of GDP;

Goals and Objectives (Cont.):-

- 4) Provision of access to electricity as stimulant for socio-economic development to improve the quality of life especially in the rural areas;
- 5) To automate the generation, transmission and distribution of electricity to the extent possible to enhance the efficiency and reliability in the operations and management of the system;

Goals and objectives (Cont.):-

- 6) To strengthen the institutional and professional capacity of the sector including reforms;
- 7) To create enabling environment for private sector participation.

Strategies:-

- 1.1) Adopt programme approach in formulation of plans for sectoral development and rolling plan for the fund-flow and its utilization;
- 1.2) Integrated approach and coordination with other sectors in planning infrastructures development, principles of cost sharing, adopt sustainable development and environment-friendly implementation methodologies and options;
- 2.1) Develop Rural Electrification Master Plan for 100% electrification by 2020 and Five Year Plans for implementation based on techno-economics and phased development schedule;
- 2.2) Involve Dzongkhag based Electricity Supply Sections for identification and cost-effective investment decisions in consultation with DYT and GYT;
- 2.3) Implement Small/Mini Hydels & Solar electrification projects for remote and off-grid areas;
- 2.4) Undertake most construction activities through private sector contracts including RE works;

Strategies (cont.):-

- 3.0) Upgrade and extend existing electricity supply services and infrastructures to meet the increased demand and to improve upon reliability, safety and overall system efficiency in urban and electrified areas;
- 4.1) Conduct feasibility studies of potential hydropower projects for future investment decisions including scheduling of their development on least cost- maximum benefit criteria. Other studies will include preparation of Integrated Energy & Water Plans, update of Hydro Power Master Plan and potential sites' inventory update and other studies for policy and investment decisions;
- 4.2) Project promotion, fund mobilization and development of long term memorandum of understanding including power purchase agreements etc.;

Strategies (cont.):-

- 4.3) Development of National Transmission grid for the reliability of electric supply as well as National Load Dispatch Center for optimum load dispatch, scheduling and coordination among the parties;
- 4.4) Development of proper codes of practices, standards, rules, regulations, tariffs for systematic operations, management and utilization of resources for delivery of efficient services at the lowest possible cost to the consumers;
- 4.5) Re-structuring of the Sector for un-bundling of policy, regulations, operations, trading and other functions (Creation of Bhutan Power Corporation, Bhutan Electricity Authority, Generating Corporations, etc.);

Strategies (cont.):-

- 5.0) Promotion of hydroelectric energy as a tradable commodity, study of market opportunities and development of suitable tariff system thereof;
- 6.0) Adopt state of the art technology and automation so that electricity generation and transmission becomes efficient and reliable (supervisory control & data acquisition (SCADA), fibre optic communication - value addition to electric service & minimize man-made errors);
- 7.0) Human Resources Development through Skills Development & Training programme for strengthening the sectoral institutional capacity;

Strategies (cont.):-

- 8) Study and creation of framework and guidelines for active private sector participation in Hydropower development;
- 9) Alternate energy programme to promote energy conservation, catchment and environment protection, efficiency improvement in the bio-mass, fossil fuel & solar energies and technologies to sustain the primary energy needs of the people.

9FYP Infrastructure & Institutional Development Programme (A)

- 1) Generation (Micro) – Nu180 million
- 2) Transmission – Nu 1910 million
- 3) Distribution – Nu 1800 million
- 4) Capacity Building – Nu 375 million
- 5) Alternate Energy – Nu 200 million
- 7) Private Sector Development – Nu 35 million
- 9FYP Plan capital budget outlay- Nu 4500 million
- 9FYP Recurrent budget outlay – Nu 1717.949 million
- TOTAL 9FYP PLAN BUDGET = Nu. 6217.949 million

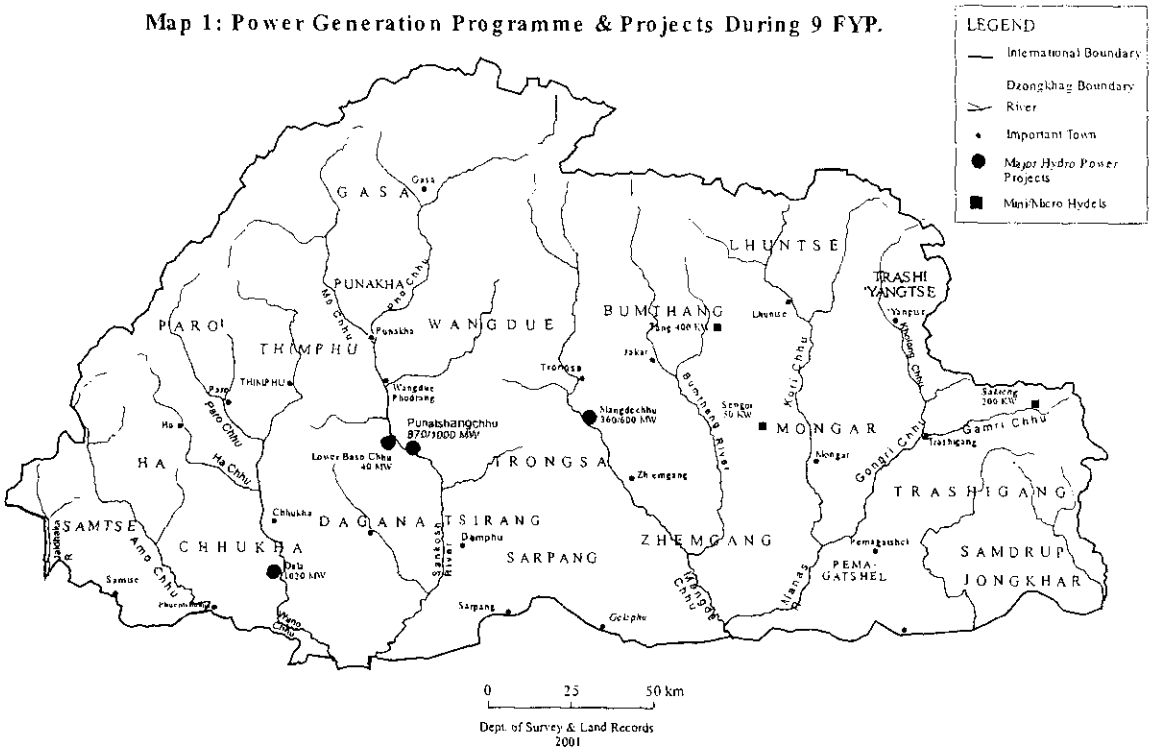
Hydro Power Industry Investment Programme (B)

- 7) **Major Projects (Outside the Plan)**
- 7.1) Tala Hydroelectric Project (1020 MW) = Nu 25,800 million (60 % of the Completion cost) during 9FYP.
- 7.2) Basochu Stage II Project (40 MW) = 553 million ATS = Nu 1,659 million (Nu 369 million equity investment from RGoB)
- 7.3) Mangdechu Hydroelectric Project (360 MW) = 60 % of US$ 348.9 million = Nu 10,467 million
- 7.4) Punatsangchu Hydroelectric Project (870 MW) = 40% of US$ 812.9 million = Nu 16,260 million
- TOTAL INDUSTRIAL INVESTMENT IN HYDRO POWER DEVELOPMENT = Nu 54,186 million (outside)

1) POWER GENERATION PROGRAMME

Sl #	Projects	Physical Target	Budget Outlay (Nu million)	Remarks
1	Micro Hydel Projects	1) Tang - 400 kW 2) Sengor - 50 kW 3) Sakten - 200 kW	180 million	GEF/JICA funding
	TOTAL	**650 kW**	**180**	

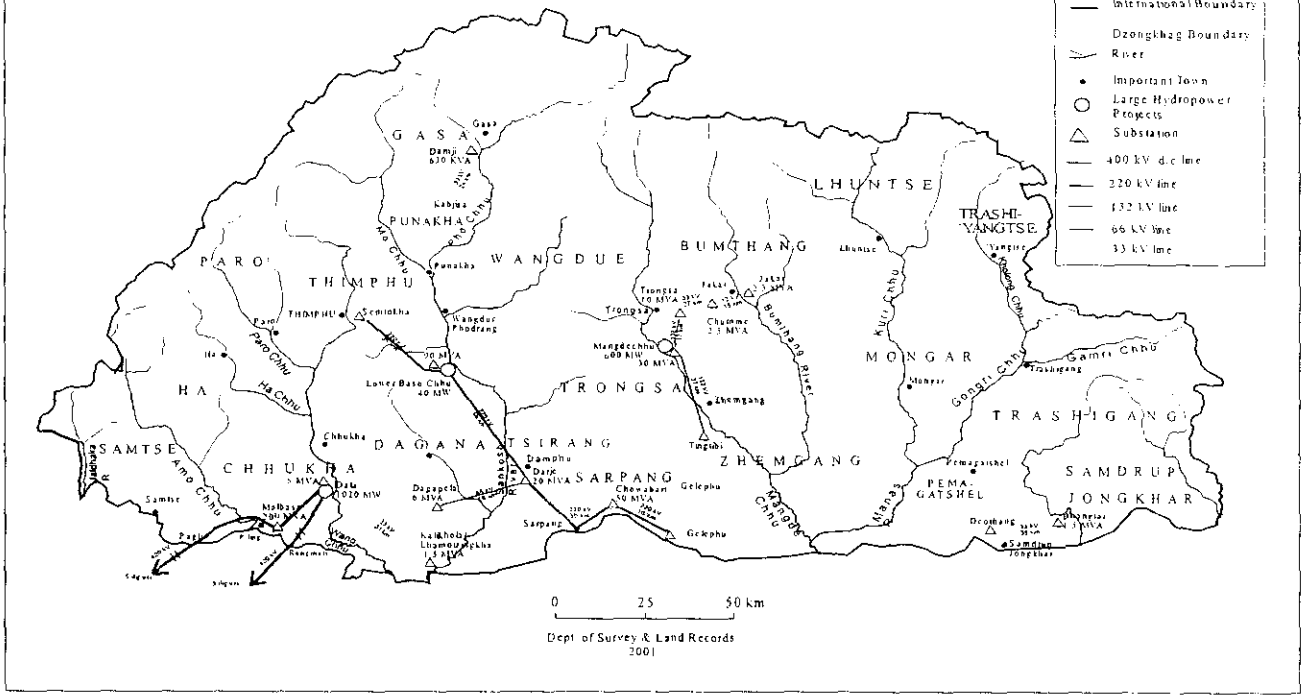
Map 1: Power Generation Programme & Projects During 9 FYP.



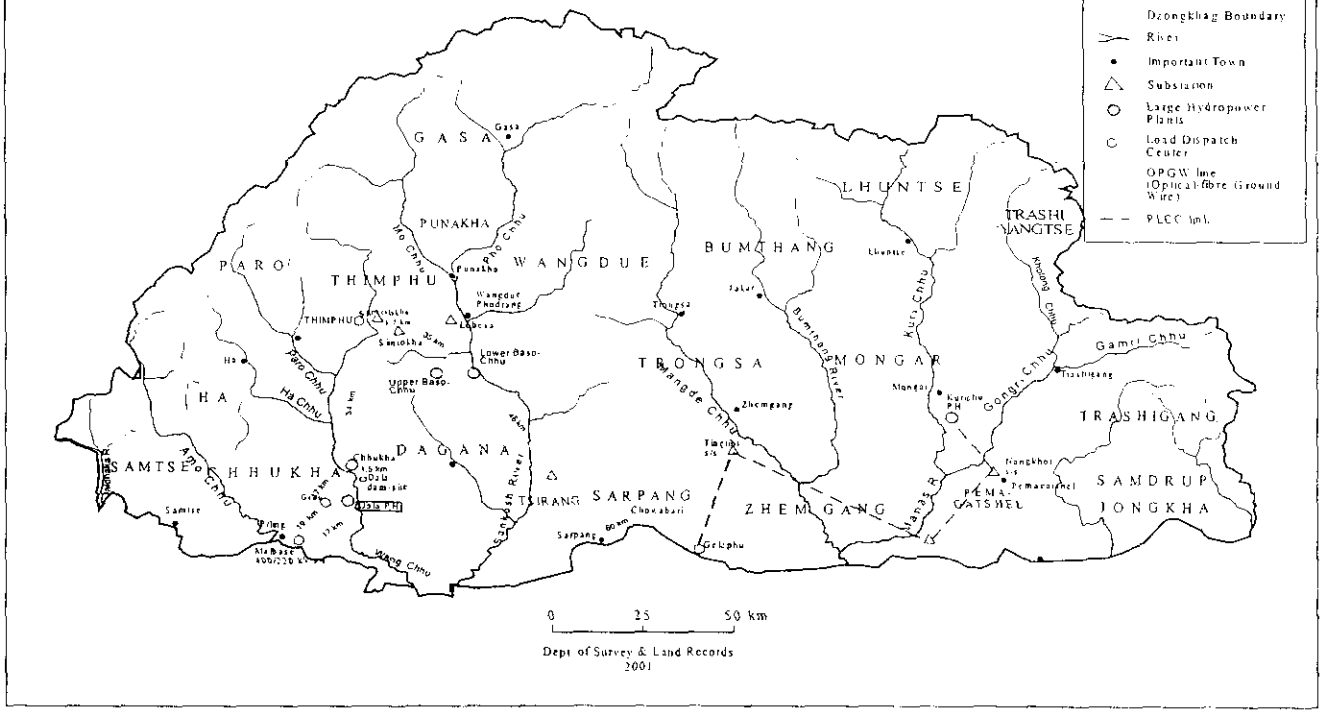
2) POWER TRANSMISSION GRID PROGRAMME

Sl #	Projects	Physical Target	Budget Outlay (Nu million)	Remarks
1	Tintibi-Trongsa/Bumthang line and Substations	132/33 kV lines and Substations	578	Can also provide power during construction of Mangdechu Project
2	Gelephu-Tsirsang-Dagana-Wangdue lines and Substations	220/132/66/33 kV lines and Substations	1132	Can serve as grid link between Western and Eastern system
3	Grid Power extension to Gasa, Bhangtar & Lhamoizingkha	33/11 kv lines and bulk substations	100	Grid supply priority as per Dzongkhag's proposal
4	National Load dispatch center	Thimphu	100	Economic load dispatch and co-ordination.
5	Project tied lines and Substations	(i) Semtokha – Rurichu system (ii) 200 MVA Malbase Substation *(iii) 400 kV lines of Tala*	NA	Budget built in the Major Hydro power projects
	TOTAL		*1910 million*	

Map 2A : Power Transmission Programme & Projects During 9 FYP.



Map 2B : Proposed National Load Dispatch Network During 9FYP.



3) POWER DISTRIBUTION PROGRAMME

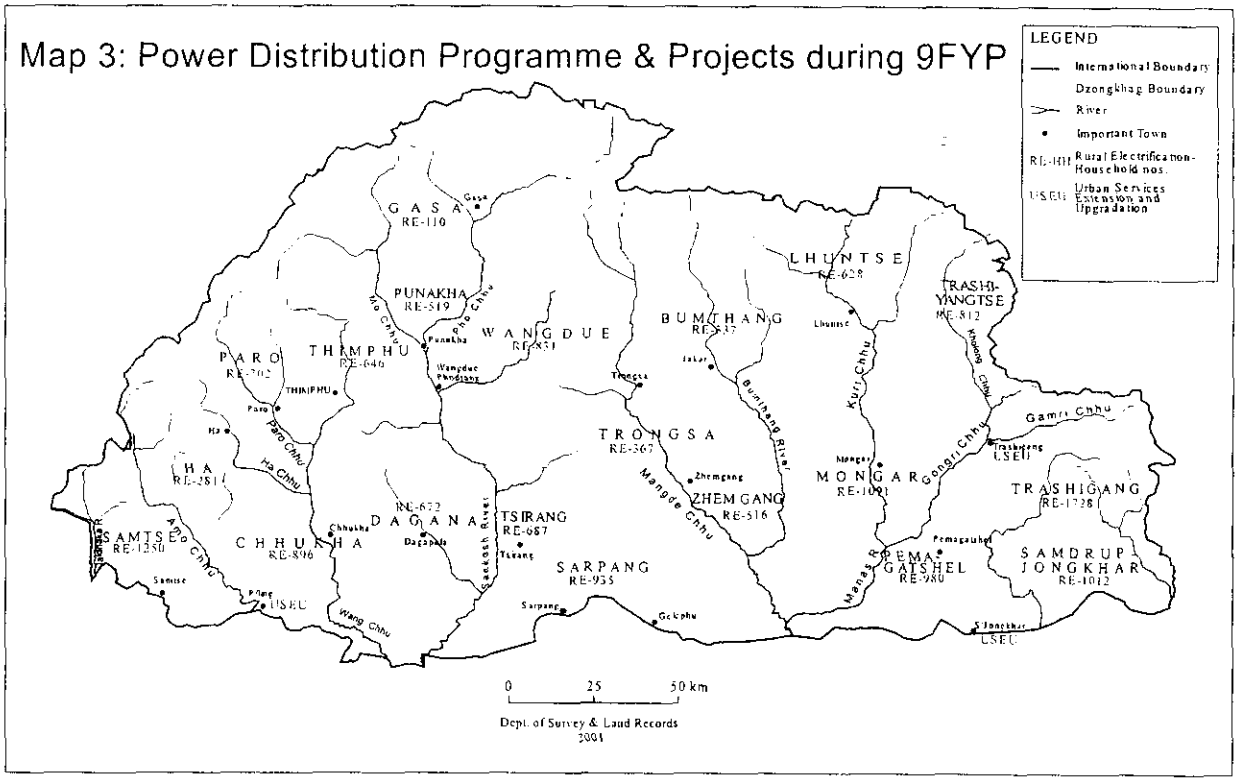
Sl #	Projects	Physical Target	Budget Outlay (Nu million)	Remarks
1	Rural electrification in 20 Dzongkhags	15,000 gungs	1,500	Details in next table
2	Urban service extension and upgradation	Phuentsholing and other urban areas	300	P/ling system on priority..
	TOTAL		**1800**	

3-a) RURAL ELECTRIFICATION PROGRAMME

Sl #	Dzongkhag	Physical Target (gungs)	Budget Outlay (million Nu.)	Remarks
1	Bumthang	337	33.700	
2	Chukha	896	89.600	
3	Dagana	672	67.200	Villages identified by the Dzongkhag
4	Gasa	110	11.000	
5	Haa	281	28.100	
6	Lhuentse	628	62.800	
7	Mongar	1091	109.100	
8	Paro	702	70.200	
9	Pemagatshel	980	98.000	
10	Punakha	519	51.900	

3-b) RURAL ELECTRIFICATION PROGRAMME (CONT.)

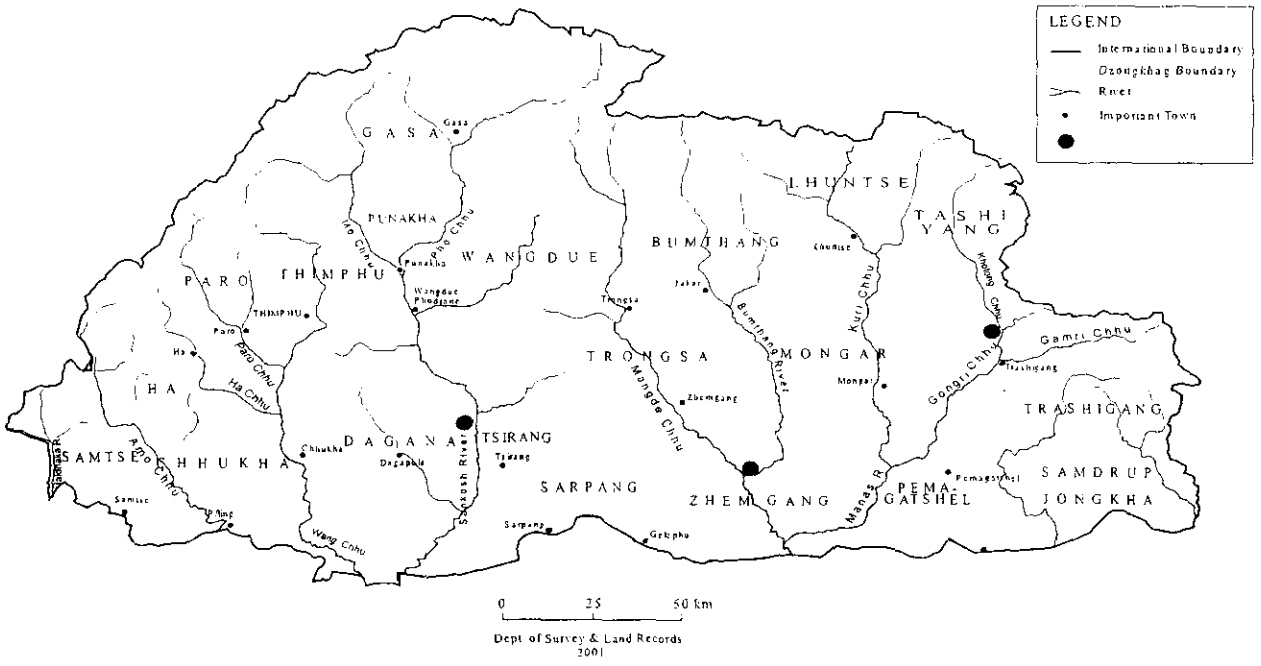
Sl #	Dzongkhag	Physical Target (gungs)	Budget Outlay (million Nu.)	Remarks
11	Samdrup Jongkhar	1012	101.200	
12	Samtse	1250	125.000	
13	Sarpang	935	93.500	
14	Thimphu	646	64.600	
15	Trashi Yangtse	812	81.200	
16	Trashigang	1728	172.800	
17	Trongsa	367	36.700	
18	Tsirang	687	68.700	
19	Wangdue	831	83.100	
20	Zhemgang	516	51.600	
	TOTAL	**15,000**	**1,500.000**	



4) CAPACITY BUILDING PROGRAMME

Sl #	Sub-Programmes/Activities	Physical Target	Budget Outlay (Nu million)	Remarks
1	Water resource management plan and Hydro Power Master plan update	(i)Master plan reports (ii)Hydromet. equipment	112.5	Fund secured from NORAD and project started in 8 FYP.
2	Rural electrification Master Plan study and investment studies	20 Dzongkhags' RE master plan and investment study reports	*100*	ADB PPTA for US$ *0.700 million secured* for 9FYP RE study
3	*Feasibility studies of 2,000 MW* hydro power project sites	(i)Lower Bumthangchu (Diglai) (ii)Kholongchu (iii)Punatsangchu II	150	*Proposed to GoI for* funding of the DPR.
4	Development of guidelines, regulations, standards and labels	*Lot*	*12.5*	*ADB TA*
	TOTAL		375	

Map 4 : Feasibility Studies of Large Hydro Power Project Sites During 9FYP.



5) ALTERNATE ENERGY PROGRAMME

Sl #	Projects	Physical Target	Budget Outlay (Nu million)	Remarks
1	Integrated Energy Master Plan	Reports	100	i) Baseline information ii) Supply-Demand analysis iii) Strategies iv) Development Plans & Programmes
2	Solar Energy Projects	(i)Solar water heaters, dryers (ii)Photovoltaics	75	On the principle of cost sharing
3	Bio-mass Energy Projects	(i)Efficient stoves (ii) Room heaters (iii) Energy plantation and catchment protection	12.5	(i)Principle of cost sharing and end user participation (ii)Technology transfer and adoption
4	Energy Conservation and efficiency Projects	(i) Awareness campaign (ii) Standards and labels *(iii) Pilot project on* CFL lighting iv) Others	12.5	Consumers and traders education
	TOTAL		200	

6) PRIVATE SECTOR PARTICIPATION PROGRAMME

Sl #	Projects	Physical Target	Budget Outlay (Nu million)	Remarks
1	Private sector participation in hydro power development	Policy framework, guidelines, identification of barriers and areas of opportunities	20	ADB TA
2	Skills and training of Private lineman/wiremen/electrician	Lot	5	RGOB funding
3	Feasibility study for private sector participation in Electricity Supply services (Business)	Identify possible areas for private sector involvement in Electricity Supply Services and draw out strategies and plans (Begana transformer factory, RE contracts management & ToR, etc.)	10	
	TOTAL		35