CHAPTER 9 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

9.1 National Environmental Strategies

The existing national strategies and plans relating to the environment are shown in **Table-9.1.1**. These strategies/plans provide for sustainable development and do not preclude development that incorporates adequate consideration for sustainability of the environment. It also requires that environmental conservation shall be realized by the efforts made by all sectors.

Table-9.1.1 National Plans and Strategies Relating to the Environment

Name of Plan/Strategy	Responsible Authority	Issue Year
The Middle Path, National Environment Strategy for Bhutan	National Environmental Commission	1998
Bhutan 2020, A Vision for Peace, Prosperity and Happiness	Planning Commission	1999
Biodiversity Action Plan for Bhutan 2002	Ministry of Agriculture (MOA)	2003
Vision and Strategy for the Nature Conservation Division 2003	Department of Forestry Services, MOA	2003

Prepared by JICA Study Team

The descriptions of these national strategies and plans are as follows:

(1) The Middle Path, National Environment Strategy for Bhutan (1998)

The strategy outlines three main avenues of sustainable economic development: expanding hydropower, increasing agricultural self-sufficiency, and expanding the industrial base. Then it examines each avenue in detail, describing the enabling conditions for development and the implications of such development.

Regarding the expansion of hydropower, it is essential that the watersheds upon which hydropower projects depend are maintained. This will be possible if the government is able to limit forest incursions from a variety of socioeconomic development activities. To that end, the government has committed itself to maintaining national forest cover of at least 60%.

In addition, one of the more pressing reform needs is that the conservation of protected areas must not be left to the forestry sector alone. Other sectors benefiting from well preserved, up stream catchments should also contribute to the continued protection of watersheds, especially within the hydropower sector.

(2) Bhutan 2020, a Vision for Peace, Prosperity and Happiness (1999)

This document shows the procedure for development up to 2020 and describes the nation’s vision for 2020. It describes environmentally sustainable development as follows:

“In 2020, 60 percent of our nation will still be forested and we will be unique among the community of nations for the proportion of our territory that we have freely chosen to set aside and designate as national parks, nature reserves and other protected areas.

In our approach to environmental conservation, natural resources are not only seen as something to be preserved but also as a development asset that can, with care and wisdom, contribute to the process of sustainable social and economic development.”

(3) Biodiversity Action Plan for Bhutan 2002 (2003)

The following four components are linked to the analysis of the current situation by addressing threats and realizing opportunities. These four strategic components must be put into operation simultaneously.

- Management of Protected Areas, Buffer Zones and Biological Corridors
- Integrated Conservation Development Programs (ICDPs)
- Environmental Education
- Research, Survey and Monitoring.

To truly conserve a country's natural heritage, biodiversity conservation must function on a variety of scales and it must be integrated within the programs of all sectors.

(4) Vision and Strategy for the Nature Conservation Division 2003 (2003)

Conservation in the Bhutanese context does not exclude sustainable use of resources for development purposes. In particular, watersheds represent the most critical ecological functions for Bhutan. The watersheds have values for drinking water quality, hydropower, and irrigation potential.

While the main aim of protected area management is to conserve the ecosystem, the socio-economic development of the people can not be ignored. Conservation threats can best be tackled by addressing the underlying development pressures and constraints, and offering alternatives.

9.2 Environmental Legislation

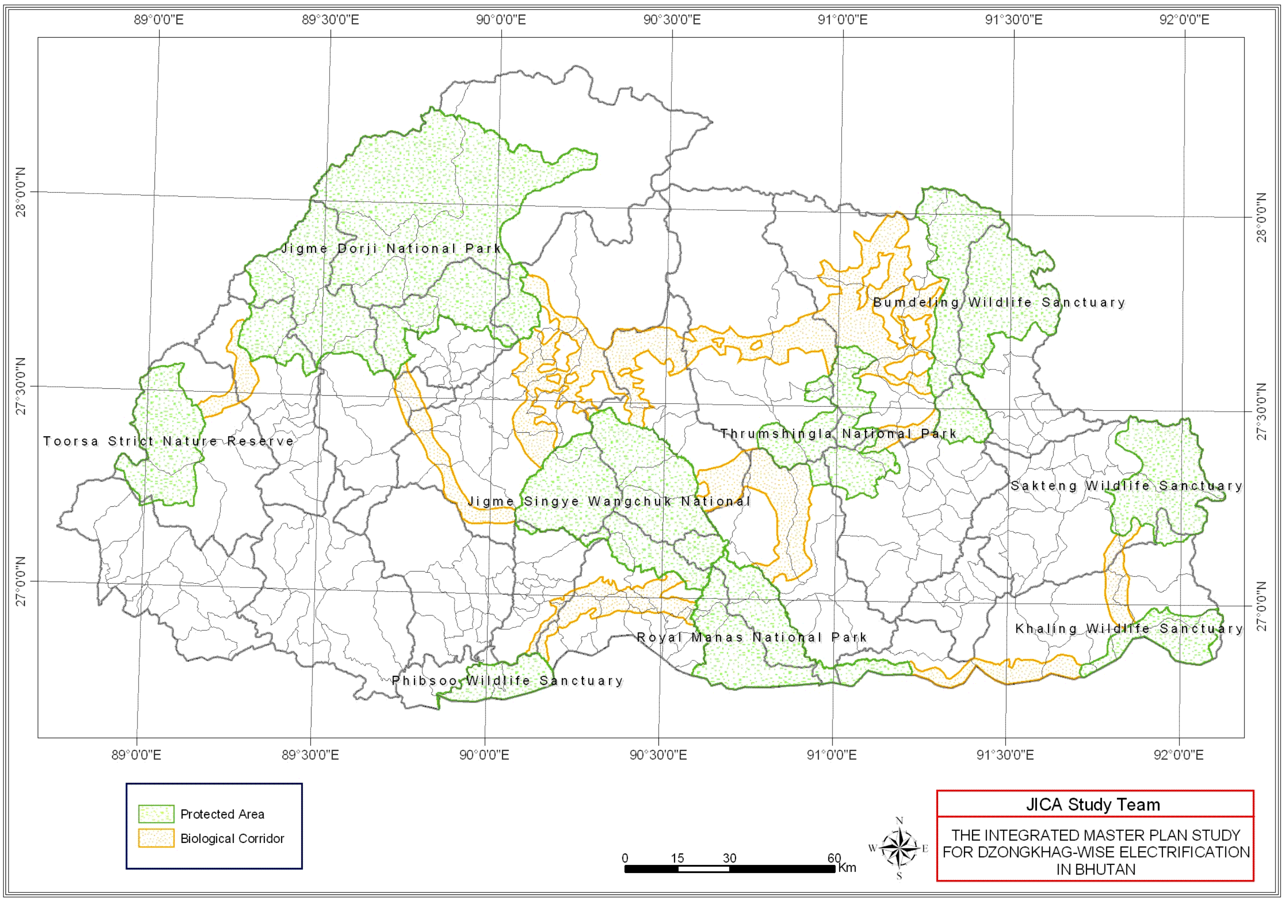
(1) Environmental Acts and Regulations

Acts and regulations relating to nature conservation are well addressed. It is believed that this situation is partly due to the fact that the country has a rich natural environment. On the other hand, regulations relating to public pollution have not been prepared in so much detail. **Table-9.2.1** shows the legislation pertaining to the environment in Bhutan.

Table-9.2.1 Environmental Legislation in Bhutan

Name of Act and Regulation	Responsible Organization	Issue Year
Forest Act 1969	Department of Forestry, Ministry of Agriculture (MOA)	1969
Bhutan Forest and Nature Conservation Act 1995	MOA	1995
Forest and Nature Conservation Rules of Bhutan	MOA	2000
Environmental Assessment (EA) Act 2000	National Environmental Commission (NEC)	2000
Regulation for the Environmental Clearance of Projects and Regulation in Strategic Environmental Assessment	NEC	2002
Electricity Act of Bhutan	Department of Energy, Ministry of Trade and Industry (MOTI)	2001
Land Act 1979	Ministry of Interior (MOI)	1979
Pesticides Act of Bhutan 2000	MOA	2000
Livestock Act of Bhutan 2000	MOA	2000
Biodiversity Act of Bhutan 2000	MOA	2000
Seed Act of Bhutan 2000	MOA	2000
Land Acquisition Act 1990	MOI	1990
Mines and Minerals Management Act 1995	MOTI	1995
Plant Quarantine Act of Bhutan	MOA	2000
Environmental Codes of Practice for Sewage and Sanitation Management in Urban Areas	NEC	2000
Environmental Codes of Practice for Hazardous Waste Management	NEC	2002

Prepared by JICA Study Team



Source: Department of Forest, MOA

Figure-9.2.1 Location of Protected Areas and Biological Corridors

(2) Nature Conservation and Forest Preservation

The "Forest and Nature Conservation Rules of Bhutan" are designed to preserve the nation's forests, which cover nearly 70 percent of the country. Four national parks, one natural reserve, and four wildlife sanctuaries have been declared as protected areas (PAs). Five of these nine areas already have a management plan. International donors such as UNDP/GEF and WWF assist with the management activities in PAs. Protected areas cover twenty six percent of the national land. In addition, a biological corridor was established to enable wild animals to move between PAs.

It is prescribed that the territory of protected areas be classified into the following 6 zones: (i) core zone, (ii) administrative zone, (iii) seasonal grazing zone, (iv) enclave zone, (v) buffer zone, and (vi) multiple-use zone. Every zone has roles and functions in PAs. The activities in each zone are controlled with consideration for these roles and functions. But definite zoning in PAs have not yet been decided.

The Department of Forestry, Ministry of Agriculture (MOA) continues to define forest management units (FMUs) in order to promote sustainable forest management. Fourteen FMUs are in operation and seven FMUs are planned for establishment. Each FMU has to prepare a forest management plan. There are seven other units for forest management called working schemes (WS).

(3) Environmental Impact Assessment

The "Environmental Assessment (EA) Act 2000" and the "Regulation for the Environmental Clearance of Projects and Regulation in Strategic Environmental Assessment" comprise legislation relating to environmental impact assessment in Bhutan. The regulations are based on the provisions of the EA Act 2000. Sectoral Guidelines were prepared with the assistance of the Asian Development Bank (ADB) in 1999. These guidelines were revised in 2003 to conform to the Regulation for the Environmental Clearance of Projects. The "Sectoral Guideline for Transmission Lines", originally prepared in 1999, was revised and renamed "Sectoral Guideline for Transmission and Distribution Lines" in the 2003 revision.

It is necessary to obtain environmental clearance prior to the implementation of projects. This applies both to entities that are required to obtain development consent from relevant authorities and also to those that are not required to do so. This is stipulated in the Environmental Assessment Act 2000.

The requirements for the implementation of development projects are explained in Section 9.4 below.

9.3 Current Situation and Issues Relevant to Environmental Infomation

(1) Natural Environment

In national policies, conservation of biodiversity and sustainable development are regarded as being important. Accordingly, some effort has been made to prepare an inventory of the plant and animal species in Bhutan, as well as a plan for nature conservation.

The publications listed in **Table-9.3.1** include information on plant and animal species in Bhutan. It is also confirmed by other investigations of the flora and fauna that the country has a very rich biodiversity. However, the data acquired in various investigations that have been conducted are not available in a suitable form for use in the environmental assessment of development projects.

Table-9.3.1 Basic Information on Plant and Animal Species in Bhutan

Name of Publication	Organization	Issue Year
Forest and Nature Conservation Act 1995	Ministry of Agriculture	1995
1996 IUCN Red List of Threatened Animals.	IUCN- The World Conservation Union	1996
2000 IUCN Red List of Threatened Species	IUCN- The World Conservation Union	2000
Flora of Bhutan	Nature Conservation Division, Ministry of Agriculture	2002
Biodiversity Action Plan for Bhutan 2002	Ministry of Agriculture	2002

Prepared by JICA Study Team

The zoning definition for PAs management provides that the territory shall be classified into six (6) zones. However, as mentioned previously, this has not been clearly described even though the management plan for some of the PAs was established with support by international donor organizations. The policy for utilization of the PAs and restrictions on activities is therefore obscure at present. The territory of PAs includes areas in which people have resided for a long time. The activity of these people, which may potentially damage the natural condition of these areas, does not appear to be controlled, and apparently it will not formally be controlled for the time being.

On the other hand, while it is likely that degradation of ambient air, water, soil etc. is caused by urbanization and industrial development, finding a solution to these problems is not a high priority as the problems are not serious in Bhutan. Environmental standards and emission standards have not been established yet. Investigations and surveys of present pollution conditions are not conducted either.

Although soil erosion is regarded as a significant environmental issue in the country, no investigation of the current situation for increasing the nations understanding of the phenomenon has been carried out on the national scale.

It is therefore recommended that the institutional framework and human resources be enhanced in these fields to promote preservation of the living environment, as well as nature conservation.

(2) Social Environment

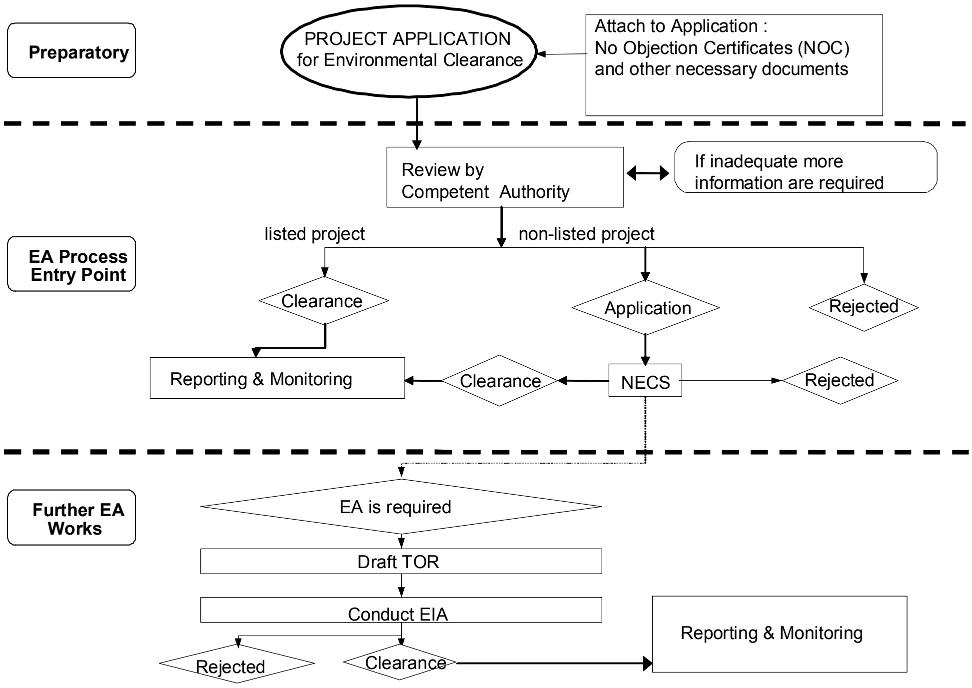
Statistics regarding indigenous people (IP) are not complete in Bhutan. However, it is known that some minor ethnic groups reside in the country. Consideration of IPs and minorities should be highlighted in considerations of the social environment. In Bhutan, there are more than five hundred religious facilities, including temples and monasteries. Although these facilities have been listed, their exact locations would need to be examined when considering the implementation of a project.

When an actual examination of the social environment is carried out in an environmental impact assessment (EIA), which may be required for obtaining environmental clearance, a special survey of the social environmental condition would need to be conducted for each individual project.

9.4 Environmental Laws and Procedures Relating to Rural Electrification

(1) Environmental Clearance

As described earlier, the EA Act 2000 requires proponents to obtain an environmental clearance from the National Environmental Commission Secretariat (NECS) prior to the project implementation. This prescription is applied to rural electrification projects as well. The procedure of application, as well as the issue of environmental clearance, is illustrated in **Figure-9.4.1** below.



Source: Sectoral Environmental Assessment Guideline, NEC

Figure-9.4.1 Environmental Assessment Procedure in Bhutan

The general procedure for obtaining an environmental clearance is expressed as follows:

a) The project proponents have to submit "Environmental Information" regarding the proposed project and an application for environmental clearance to both the relevant government authority and to NECS.

b) In case of a project that has a sectoral guideline, the environmental information will follow the requirements of that guideline. Distribution line projects in rural electrification plans have sectoral guidelines that were revised in 2003. Accordingly, environmental information regarding the rural electrification distribution line project should be prepared with consideration for the revised sectoral guideline.

c) The project proposal is officially announced after receiving approval from the relevant authority and the NECS. Conditions regarding the validity of the environmental clearance are also announced.

Then NECS conducts project screening based on the environmental information that is submitted by the proponent for the screening process. This results in the proposal being classified into one of three categories:

1) Issuance of environmental clearance: when NECS concludes that the project can satisfy the conditions defined in the Environmental Assessment Act and that negative environmental impacts will be mitigated and acceptable. Specifically, this means that the NECS has determined that the project is able to contribute to sustainable development of the Royal Government of Bhutan (RGoB).

2) An EIA is required for further examination of the environmental aspects because of

the concern that significant negative impacts may be caused by the project implementation.

3) Issuance of a blanket denial for the project.

When an EIA is required, the proponent has to prepare the terms of reference (TOR) for the EIA. After the TOR is approved by the NECS, the proponent prepares and publishes an Environmental Assessment Report. When the proponent completes the publication in accordance with the terms defined in the relevant regulation, the NECS issues an environmental clearance based on the report. So far, there has not been any case of an EIA being completed in accordance with the EA Act 2000 although only case that the environmental assessment for transmission lines just going into procedure is being done.

The Regulation for the Environmental Clearance of Projects prescribes that all environmental clearances have to show the conditions for environmental conservation to the proponents. These conditions will include mitigation measures, environmental monitoring, and so on.

According to NECS, an EIA may be required for rural electrification projects whose sites include a part of a PAs, however, this is not stipulated in any relevant legislation.

(2) Land Acquisition and Resettlement

The Land Act 1979 describes the procedure for land acquisition that is required when a project site includes registered private land. The rule for compensation for land acquisition of the registered private land is regulated by the Land Compensation Rate, which has been revised many times before the enactment of the Land Act. The latest revision was in 1996. The latest compensation rate for land acquisition is shown in **Table-9.4.1**.

Table-9.4.1 Land Acquisition Compensation Rate

Classification of Land	Compensation Rate
Rural Land Compensation Rate	
Chhuzhing	35,000 Nu./acre
Kamzhing	20,000 Nu./acre
Tseri/Pangzhing	5,000 Nu./acre
Urban Land Compensation Rate	
Thimphu town	
Commercial area	30 Nu./ft^2 (1,306,800 Nu./acre)
Residential area	20 Nu./ft^2 (Nu. 871,200 Nu./acre)
"A" Class Town	
Commercial area	20 Nu./ft^2 (871,200 Nu./acre)
Residential area	10 Nu./ft^2 (Nu. 435,600 Nu./acre)
"B" Class Town	
Commercial area	10 Nu./ft^2 (435,600 Nu./acre)
Residential area	5 Nu./ft^2 (217,800 Nu./acre)
"C" Class Town	
Commercial area	5 Nu./ft^2 (217,800 Nu./acre)
Residential area	2 Nu./ft^2 (87,120 Nu./acre)

Note: The classification of Town is defined in the Annex of the Source Document
Source: Land Compensation Rate 1996, Ministry of Home

The Land Compensation Rate 1996 document does not mention the procedure for determining the compensation for disruption to living and occupation affected by land acquisition. However, it does show that any house shall be paid for on the basis of a valuation carried out in each case by a qualified engineer, and that cash crop trees are compensated by compensation rates for fruit trees which are determined for various kinds and ages of trees. In addition, the document does not mention the rate that should be paid as compensation for resettlement that results from the project.

On the other hand, the Land Act says that "as far as possible the Government shall give substitute land instead of cash compensation while acquiring land."

(3) Deforestation and Usage of Protected Areas

The proponent of a project is required to apply in writing to MOA for approval prior to the clearance of Government Reserve Forest for governmental purposes such as road construction, irrigation channels, transmission lines for electricity, telephones etc. Government Reserve Forest excludes the defined community forests that are managed by communities in local districts and it also excludes the previously forested areas that have been declared as no longer being forests.

Most activities, including construction, taking wildlife of any kind, settlement and cultivation are prohibited within any Protected Area, except where a written permit or authorization is obtained.

Government institutions have to apply to MOA in writing, through the concerned Dzongkhag Administration, for the use of government land. The application, prepared on the specified form, shall show the name of project, name, length and width of the area that will be deforested, the name of the PAs, if applicable, and so on. MOA will either reject the application and inform the applicant through the Dzongkhag Administration or request an investigation team to inspect the affected site. The investigation team consists of Divisional Forest Officer (DFO), the NECS, Dzongkhag administrators, etc. In this case, the decision is based on the examination made by the investigation team.

9.5 Environmental and Social Considerations in Relevant to Preparation of the Master Plan for Rural Electrification

(1) Effort on Strategic Environmental Assessment

The "Regulation for the Environmental Clearance of Projects and Regulation in Strategic Environmental Assessment" was enacted according to the "Environmental Assessment Act 2000". Though the regulation says that, "the Secretariat (NECS) may issue further guidelines on strategic environmental assessment tools and procedures", none have been published yet. Currently, SEA is not mandatory for development plans, etc.

It is meaningful to make efforts to preserve the areas that are fragile in natural as well as social aspects. The efforts will be based on the proper examination and consideration of the environment in the master plan preparation phase of nation-wide rural electrification projects. Although SEA has not been conducted in Bhutan, the NECS, which is responsible for regulation of the environmental assessments in Bhutan, agreed to cooperate with the Study Team for application of SEA concepts, based on an understanding of the project's significance.

Nevertheless it has not been practical in Bhutan to approve the implementation of SEA officially. Therefore the environmental examination in the Study included SEA as a case study by basically following the SEA regulation in Bhutan. In the course of the examination, the Study Team regards SEA as "an environmental consideration in the master plan planning stage". Chapter 17 describes the implementation and results of the case study.

(2) Policy of Environmental and Social Consideration

In the study for the master plan, careful attention was paid to maintaining transparency for the environmental and social considerations in the planning phase, and also the decision-making process used in the nationwide project. Workshops were utilized for publicity of the master plan. In the course of doing this work, the concept of a Strategic Environment Assessment (SEA) and reduction of cumulative impacts were taken into account.

In addition, environmental aspects and items to be considered in the environmental consideration were decided considering not only Bhutanese legislation and JICA guidelines for environmental and social consideration but also the environmental guidelines of international donors such as World Bank, ADB, and JBIC.

It is probable that the following two issues are the most sensitive concerns that are due to the rural electrification project. This assessment is based on the analysis of the current environmental situation and the characteristics of the project.

(i) The first concern is the impact of deforestation.

(ii) The second concern is the impact on protected areas (PAs).

Accordingly, the following two policies are adopted as part of the environmental and social consideration of the project:

- Prioritization of the Protected Area and Biological Corridor in environmental considerations
- Consideration of cumulative impacts on the environment

The Department of Forestry, MOA has not shown definite areas to be prioritized in the protected areas. If this information was available, it would be useful for environmental analysis of the development project. Also there has not been any case required to conduct EIA following proclamation of the EA Act 2000, even where projects have been developed within protected areas.

9.6 Effort for Utilization of Clean Development Mechanism and Application to the Project Proposed in the Master Plan

(1) Efforts on the United Nations (UN) Framework Convention on Climate Change

The "First Greenhouse Gas Inventory" was published in September 2000. The NEC outlined Bhutan's contribution to green house gases (GHG) in the document and examined the impact of global warming on Bhutan.

The micro hydropower project in Chendebji village in Trongsa Dzongkhag, which is being promoted by 'e7', is being be considered as a clean development effort at a specific project level. The 'e7' group consists of 9 companies from the developed countries that attend the G7 meetings. This project is an application of a small scale Clean Development Mechanism (CDM) supported by the "e7 Fund for Sustainable Energy Development". The Kansai Electric Power Co., Inc. in Japan, which is one of the 'e7' member countries, plays a core role. Both the RGoB and the Government of Japan have approved the project as a CDM application. The project has been validated by DOE (Designated Operational Entity), and was registered by the Executive Board (EB) on May 23, 2005.

The Project Design Document (PDD) for the Chendebji project explains that the amount of GHG emissions would be reduced if hydropower was used for electricity generation instead of using fossil fuel combustion. For this project, the baseline is that the village would otherwise be electrified by a diesel power generator. The reasons for this baseline setting are as follows:

- The on-grid electrification of Chendebji village is not included in "9th FYP (2002 -

2007)" and RGoB is not planning to electrify the village with a small-scale hydro power project.

- In almost all of the villages in which small-scale hydro power stations have already been constructed, the construction has been supported by various kinds of official foreign assistance. These realities demonstrate that such projects would not be profitable or feasible in the Chendebji village. Therefore, the village would not be electrified without the assistance provided by the CDM project. Thus, electrification by diesel power generation, which is the method generally used for remote electrification projects, would otherwise be applied to Chendebji.

The possibility of electrification by extension of the power grid to the village is not mentioned clearly in the PDD. It is assumed that the authors regarded on-grid extension as difficult to realize in Chendebji since Chendebji is in a steep and remote district, and the PDD highlights the advantages of diesel power generation from the financial aspect and the ease of introduction.

(2) Possibility of Application of CDM for the Rural Electrification Project in the Master Plan

RGoB has been promoting hydropower utilization in its national policies. As the generated electricity is not distributed to the whole nation equally, RGoB intends to solve this issue by grid extension. Based on this scenario, it is not possible to apply CDM to such a large-scale project. The conceivable types of CDM application are those projects up to 15 MW output capacity that would produce a reduction in GHG emissions through the substitution of biomass for fossil fuel, and through the utilization of renewable energy.

As for small scale CDM project, there are preceding case as shown above. It is reasonable to assume as follows in considering the application of small scale CDM for the rural electrification project in Bhutan. It should be a "renewable energy project" "applied to small scale CDM", and "the baseline is to be set by introduction of electrification by means of fossil fuel i.e. a diesel power generation" like the Chendebji micro hydro power project. Small-scale CDM may be applicable to such projects proposed in the master plan if the project site is located in an area where it is very difficult for electrification by grid extension and that area can be regarded as an appropriate place for electrification by renewable energies.

The following matters should be kept in mind when planning a CDM application:

a) The definition of the renewable energy projects applicable to the small-scale CDM procedure is "renewable energy project activities with a maximum output capacity equivalent of up to 15 MW (or an appropriate equivalent)".

b) Public funding for CDM projects must not from the diversion of official development assistance for rural electrification.

The possibility of CDM application for the on-grid electrification projects in Bhutan is mentioned here because these projects could reduce CO_2 emissions due to combustion of kerosene, LNG, and firewood. It is probable for on-grid electrification to apply CDM, since people will use lesser amounts of combustion of energy sources and lighting sources such as kerosene for lamps after village electrification is achieved.

As for diesel power generation, areas in Kalikhola as well as in Panbang have been electrified by independent diesel power generation units. The diesel fuel being burnt in these units might be counted as the reduction of CO_2 in CDM.

In order for the application of CDM, the methodology of CDM has to be approved by EB, and the PDD has to be validated and registered. The PDD should logically explain the effect of the project in contributing to an additional reduction of GHG.

Making an application for a small scale CDM as a "Switching from fossil fuels project" could be considered if the project was designed around a scenario of replacing existing diesel generators with a renewable energy source generator. Under these conditions, the project should reduce anthropogenic emissions from sources and directly emit less than 15 kilotons of CO_2 equivalent annually.

Below are examples of scenarios for the applications of CDM to electrification by on-grid. When a CDM application is actually prepared, further study and examination would be required to obtain various base data required to introduce the project logically.

- The targeted area would be electrified by diesel power generation and not have on-grid electrification. In the case of electrification by on-grid as a CDM project, the assumed emission of CO_2 from diesel power generation must be reduced.
- Firewood would be consumed continuously and the consumption of firewood would increase, because of factors such as increasing population, without on-grid electrification. In the case of on-grid electrification as a CDM project, the assumed emission of CO_2 from firewood combustion in households could be reduced. (It is regarded that the reduction of CO_2 emission from increase of firewood consumption is countable in CDM in this baseline scenario. However, CO_2 emitted from the combustion of biomass, which includes firewood, cannot be counted in sustainable conditions.)

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

FINAL REPORT

PART-B

PLANNING METHODOLOGY AND ANALYSIS

CHAPTER 10 TECHNICAL STANDARDS FOR POWER FACILITIES

10.1 Present State of Technical Standards for Power Facilities

10.1.1 Present State

National or institutional technical standards for the power sector have not been issued yet in Bhutan. Only the following are noted in Power Data issued by DOE:

(a) Allowable maximum voltage variation of transmission lines and distribution lines should be within ±5%.

(b) Allowable maximum frequency variation should be within ±3%.

Most of the existing power facilities were supplied by India, and the Bhutan power grids are interconnected with the Indian grid. Bhutan refers to the technical standards issued by Central Electricity Authority (CEA) of India, accordingly.

Project planning and feasibility study level design of power projects in Bhutan have been performed on the basis of the national standards of the consultants' country in charge of the project or International Electro-technical Committee (IEC) standards, but taking into account climatic conditions in Bhutan.

PSMP recommends that the system reliability rules specified in the present or future Indian regulations be applied to Bhutan's projects for energy export to India. It also suggests that from the aspect of the present scale of domestic power system and the economic aspect, it is not necessary to apply the system contingency criterion of N-1 for the power system in Bhutan. The N-1 contingency criterion is that the outage of a single system component element (generator, transformer or transmission circuit) does not lead to cascading outages due to overloads or instability. Application of this criterion will be carefully studied and discussed with DOE by Study Team.

Application of the N-1 criterion to the HV power networks should be determined in careful consideration of impacts by an outage in Bhutan's network to stability of the power system for export to India.

10.1.2 Trend to Legislating Technical Standards

A consultant team was dispatched to Bhutan in April 2004 under ADB's TA program for preparing technical standards for the power sector. The program is scheduled to complete by September 2005. The Bhutan's counterpart is the Bhutan Electricity Authority (BEA) under the DOE.

Scope of work of the TA program is mainly preparation of the following draft regulations/codes, including review of the present organization for legislating the technical regulations and/or codes for the Bhutan's power sector and assistance in institutional capacity building for BEA.

(a) Regulations for monitoring of the structures in power plants

(b) Regulation for minimum safety requirements for O&M of the hydropower stations

(c) Safety codes for electric power industry

(d) Regulations for safety in the electric power industry

Besides the ADB TA, BEA has assistance of NORAD in tariff structuring.

10.2 State of Technical Standards for Distribution facilities

10.2.1 Technical and Planning Standard

There are no unified electrical standards in Bhutan, and existing facilities were constructed in accordance with the individual standards of each project at present. There are only small differences among standards ADB/RE-1, RE-2, RE-3 and the DOP Standard (basic standards, guidelines and cost estimation for infrastructure construction pertaining to power sub-transmission and distribution) that were drawn up in 1998 and that are used for small-scale projects. The overview of each standard is described in **Table-10.2.1**. Together with the BPC, the ADB consultants hired through the BEA Technical Assistance are also developing construction and design standards for the BPC.

Table-10.2.1 Comparison of Standards for Distribution Facility in Bhutan (1/2)

		ADB/RE-1 Standard (WORLEY: New Zealand)	ADB/RE-2 Standard (TATA: India)	ADB/RE-3 Standard (SMEC: Australia)	DOP Standard
Medium Voltage		33 kV, 11 kV, 6.6 kV	33 kV, 11 kV	33 kV, 11 kV, 6.6 kV	33 kV, 11 kV
Pole	Common	Steel Pole (Galvanized)	Steel Pole (Painting)	Steel Pole (Painting)	Steel Pole *Indian Standard Product
	MV	10 m (2.0 kN, 4.5 kN) 11 m (3.5 kN, 5.0 kN) *10 m (2.0 kN) is used only for straight line.	10 m (2.00 kN): 33 kV 9 m (1.93 kN) :11 kV	10 m (2.00 kN): 33 kV 9 m (1.93 kN): 11 kV	33 kV: 10 m or more 11 kV: 9 m or more
	LV	8 m (1.4 kN, 3.5 kN)	8.5 m (1.93 kN)	7.5 m	8.5 m
Transformer		Oil Immersed (Capacity) 3P: 100, 63, 25 kVA	Oil Immersed (Capacity) 3P: 160, 100, 63, 25, 16 kVA *160 kVA is used only for 33 kV.	Oil Immersed (Capacity) 3P: 500, 315, 250, 160, 125, 63, 25, 16 kVA *25 kVA and 16 kVA are used only for 11 kV. 1P: 10 kVA(6.6 kV)	Oil Immersed (Capacity) 3P: 500, 315, 250, 160, 125, 63, 25, 16 kVA
Electric Wire	MV	ACSR (Wolf, Dog)	33 kV: ACSR (Wolf, Dog, Rabbit) 11 kV: ACSR (Dog, Rabbit) * Wolf and Dog are used for trunk line, and Rabbit is used for branch line.	33 kV: ACSR (Wolf, Dog, Rabbit) 11 kV: ACSR (Dog, Rabbit) * Wolf and Dog are used for trunk line, and Rabbit is used for branch line.	33 kV: ACSR (Wolf, Dog, Rabbit) 11 kV: ACSR (Dog, Rabbit) * Wolf and Dog are used for trunk line, and Rabbit is used for branch line.
	LV	ABC (50 mm^2)	ABC (50 mm^2) XLPE (4cores, 2cores)	ABC (50 mm^2)	Urban: ACSR (Dog) Rural: ACSR (Rabbit)

Prepared by JICA Study Team

Table-10.2.1 Comparison of Standards for Distribution Facility in Bhutan (2/2)

		ADB/RE-1 Standard (WORLEY: New Zealand)	ADB/RE-2 Standard (TATA: India)	ADB/RE-3 Standard (SMEC: Australia)	DOP Standard
Max Span (m)	MV	Not decided	(33 kV / 11 kV) Wolf: 60 / - Dog: 60 / 60 Rabbit: 60 / 60	(33 kV / 11 kV) Wolf: 55 / - Dog: 60 / 65 Rabbit: 65 / 65	(33 kV / 11 kV) Wolf: 55 / - Dog: 60 / 65 Rabbit: 65 / 65
	LV	Not decided	50 m (ABC)	40 m (7.5 m Pole)	45 m
Installation Method of Transformer		On pole	On pole *The position of transformers shall be 2.5 m or more.	On pole: 160 kVA or less On ground: 250 kVA or more	On pole: 160 kVA or less On ground: 250 kVA or more
Clearance of lines (m)	Line to Ground	(33 kV / 11 kV / LV) Across road, Along road: 6.5 / 6.5 / 5.5 Others: / 5.5 / 5.0	(33 kV / 11 kV / LV) Across road: 6.1 / 6.1 / 5.8 Others: 5.8 / 5.8 / 4.0	(33 kV / 11 kV / LV) Across road, Along road: 6.1 / 6.1 / 5.5 Others: 5.8 / 5.8 / 4.5	(33 kV / 11 kV / LV) Everywhere: 6.5 / 5.5 / 5.0
	Line to Line	(33 kV / 11 kV / LV) Lateral: 0.9 / 0.7 / - Vertical: 1.0 / 0.6 / -	(33 kV / 11 kV / LV) Lateral: 0.9 / 0.7 / - Vertical: 1.0 / 0.6 / -	(33 kV / 11 kV / LV) Lateral: 0.9 / 0.7 / - Vertical: 1.0 / 0.6 / 0.3	(33 kV / 11 kV / LV) Lateral: 0.9 / 0.7 / - Vertical: 1.0 / 0.6 / -
	Line to Building	Not decided	(33 kV / 11 kV / LV) Lateral: 1.8 / 1.2 / - Vertical: 3.7 / 3.7 / -	Not decided	Not decided
	Line to Line (Different voltage)	33 kV/11 kV: 1.2 33 kV/LV: 1.5 11 kV/LV: 1.2 MV/Communication Line: 1.8 LV/Communication Line: 0.6	33 kV/11 kV: 1.2 33 kV/LV: 1.5 11 kV/LV: 1.2 MV/Communication Line: 1.8	Not decided	33 kV/11 kV: 1.2 33 kV/LV: 1.5 11 kV/LV: 1.2 MV/Communication Line: 1.8

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10.2.2 Construction Standard

DOE and BPC have no construction standards, and a construction standard is made up in every project. As a result, there are many points of similarity. Here, the main part of the specification which was applied in ADB/RE-2 is described.

(1) Selection of Routes

The proposed ro

ute is to be the shortest and practical, and installed along the roadways so as to be accessible to the site easily for maintenance and in the case of accidents. The areas listed below are to be avoided as far as possible.

a) Steep hills and valleys

b) Urban development areas

c) Areas remote from the roadways

d) Areas where abrupt changes are likely to occur

e) Roadways, rivers and drainage ditches which are hard to cross

f) Near the airport

g) Areas which are likely to suffer from natural disasters

(2) Locations of Distribution Lines

The distribution lines are to be located away from steep hills, valleys, lakes, forests and rivers. Make sure that the lines keep a proper distance from the dangers and do not cross the schoolyards and cemetaries. Also, the distribution lines are to be away from the storage buildings for explosives.

(3) The Trimming Widths for Obstacle Trees

The trimming widths for obstacle trees are based on the voltage and the importance of the line. The widths can not be restricted, yet the widths shown below have to be followed as much as possible.

Voltage		Required Width for Trimming
(a)	240 V to 415 V	Instructed by the local staff
(b)	11 kV	4.6 m on both sides from the center of the lines and the main obstacle trees which fall into the lines
(c)	11/33 kV (Trunk Lines)	6.1 m on both sides from the center of the lines and the main obstacle trees which fall into the lines

(4) Erection of Support

After the final survey of the line and after marking of the pole locations with pegs, excavation work has to be commenced. Excavation at present in Bhutan is generally done by pick axes, crow bars and shovels, although sometimes earth augers can be used. The depth of the foundation to be excavated for poles shall be 1.6 m for 8.5 meter (LV) poles and 9.0 meter (11 kV) poles and 1.9 m for 10 meter (33 kV) poles.

The earth resistance should be as low as possible and should not exceed 10 ohms.

(5) Anchoring and Providing Guys for Supports

One or more guys will have to be provided for all supports where there is unbalanced strain acting on the support which may result in tilting/uprooting or breaking of the supports at the following places (a) Angle locations (b) Dead end locations (c) Tee-Off points (d) Steep gradient locations to avoid uplift on the poles.

(6) Stringing of Line Conductors

The erection of overhead line conductors is a very important phase in construction. The erection of conductors can be sub-divided into three separate parts as follow

(a) Transport of conductors to work site.

(b) Stringing of conductors.

(c) Tensioning and sagging of conductors

The conductor drum shall be transported to the tension point without injuring the conductor. The drum should be so supported that it can be rotated freely. While stringing, care should be taken to see that the conductor does not rub against any metallic fitting of the pole or on the bad/rocky ground. Wooden trussels should be used for this purpose to support the conductor. The conductor should be passed over the poles on wooden or smooth metallic snatch pulley blocks provided with low friction bearings.

On the completion of the stringing of the conductor, tensioning operations will commence. Temporary guys will have to be provided for both the anchoring supports in the section where the stringing has to be done.

The conductor should then sag in accordance with the sag-temperature chart for the particular conductor and span. The sag should then be adjusted in the middle span of the section.

(7) Earthing of Distribution Lines

(a) Metal support – All metallic supports shall be earthed.

(b) Steel poles – The metal cross-arm and the insulator pins shall be bonded together and earthed along with pole at every pole for HT lines and at every 5th pole for LT lines.

All special structures on which switchers, transformers, fuses etc. are mounted should be earthed.

Earthing practices to be followed during construction is indicated in the construction/sketch. The earth resistance should be as low as possible and should not exceed 10 ohms.

(8) Installation of Transformer

The main points to be borne in mind while selecting sites for distribution sub-station are as follows:

(a) It should be as near the load-center as feasible.

(b) It should be far away from obstructions to permit easy and safe approach of MV overhead distribution line.

(c) It should be easily accessible by road as far as possible to facilitate transport of equipment.

(d) It should be easily approachable and visible from a distance to prevent pilferage by miscreants.

The distribution sub-station and earthling of the equipment and structure shall conform to the relevant construction drawings/sketches.

10.2.3 Maintenance Standard

In BPC, maintenance and inspection are performed based on the "Maintenance Schedule for Distribution Systems", which is the guideline for maintenance works. The guideline shows, in detail, the maintenance and inspection items for facilities such as the distribution transformers, the overhead and underground medium voltage distribution lines, the low voltage distribution lines and the service wires, and recording forms. Incidentally, though the periods for each maintenance and inspection work are also outlined in the guideline, the works should actually be performed following the instruction of a manager. Maintenance records are kept but there is no definite safekeeping deadline for them.

The maintenance is divided into scheduled maintenance and special maintenance, the latter of which will be performed in case of necessity.

Scheduled Maintenance

1) Inspection

2) Preventive Maintenance

3) Overhauls

Special Maintenance

1) Special Inspections

2) Night Inspections

3) Emergency Inspections

4) Follow-up Inspections

5) Check Inspections

The typical items of maintenance and inspection for each facility are described in **Table-10.2.2**.

Table-10.2.2 Items of Maintenance and Inspection in BPC

Facility	Items of Maintenance and Inspection
Distribution Transformers	Supports, Connection, Oil, Bushings, Lightning arrestors, Switches, Earthing, Voltage etc.
Overhead MV Distribution Lines	Supports, Stays, Cross arms, Insulators, Conductors, Jumpers, Tree trimming etc.
Underground MV Distribution Lines	Cables, Fuses, Earthing, Circuit breakers etc.
LV Distribution Lines	Poles, Conductors, Tree trimming etc.
Service Wires	Service wires, Service lead ins, Meter boards etc.

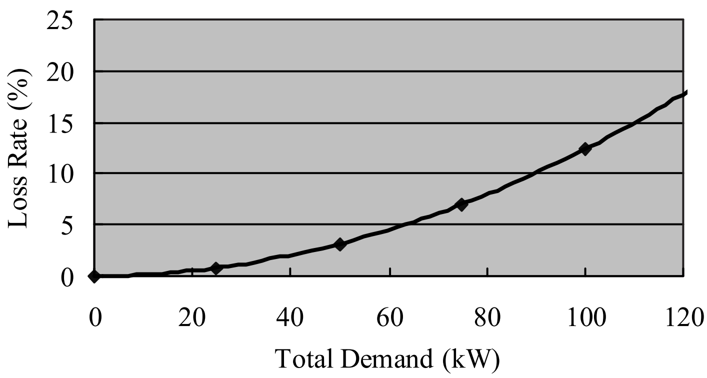
Source: BPC

10.3 The Problems from Previous RE Projects

(1) Use of Large Capacity Transformers

In previous RE projects, the design of most distribution networks was composed of one large capacity transformer at the center of a load and long low voltage lines. For example, in ADB/RE-3, the capacity of most designed transformers is 63 kVA. Therefore, transformer work depends on manpower in the mountainous areas, providing difficulties because the 63 kVA transformer (33 kV, 3 phase) is heavy, with a weight of 700 kg. Moreover, in the districts where the density of loads is small, it is not economical because the cost of low voltage lines is great and the low voltage line generates considerable energy loss. Especially in Bhutan, since the medium voltage lines and the low voltages line are installed individually on different poles, the expansion of low voltage lines lead, not only to the increase of low voltage conductors, but also to an increase of poles. Therefore, the appropriate arrangement of distribution substations is important.

In this master plan project, the capacity of transformers in the mountainous areas where vehicles cannnot access shall be standardised to be 25 kVA or less. Incidentally, as the minimum capacity of transformers that are now procured in Bhutan are 63 kVA for 33 kV and 25 kVA for 11 kV, the availability of smaller capacity transformers is being investigated. According to surveys regarding the availability of suitable transformers, it may be possible to procure up to 25 kVA for 33 kV, 16 kVA for 3 phases of 11 kV and 10 kVA for a single phase of 11 kV. **Figure-10.3.1** illustrates a relationship between the demand supplied by one distribution transformer with 100% of operation and the energy loss generated by the LV line in Bhutan. The graph shows that the installation of two or more 25 kVA transformers is more profitable in terms of avoiding energy loss compared to the typical design of one large capacity transformer of 63 kVA or more.



Note: Loss rate is calculated on the basis that the average demand per household is 1.1 kW, the span between 2 customers is 130 m and the LV line is a 50 mm^2 ABC.

Prepared by JICA Study Team

Figure-10.3.1 Relationship between demand and LV line loss

(2) Decision on Standardised Span

In former rural electrification (RE) projects, the standardised span was decided based on the length of pole and the permissible clearance between a distribution line and the ground. The standardised span, being useful for the flatlands, has no significance for mountainous areas, especially when a line is installed over a valley. Moreover, even though it is possible to install poles further apart to produce longer spans over a valley, the poles were installed in regular intervals, equivalent to the standardised span, which occasionally caused some problems.

For this reason, in Bhutan, deciding a standardised span is not as effective as deriving the span on an individual case basis, considering some important factors such as the length and strength of a pole, and the sag of a line.

Furthermore, it is important to improve the understanding of the relationship between the sag and the span rather than to choose a standardised span.

(3) Low Utilization Rate of Distribution Transformers

The capacity of distribution transformers installed in previous RE projects is relatively excessive compared to the actual demand. Since an excessive capacity transformer leads not only to surplus investment but also to the increase of no-load loss that is generated constantly independent of the load, the economic loss by installing such a transformer is very large. In this master plan project, the proper selection of transformer capacity must be performed based on an accurate demand forecast.

(4) Difference of Distribution Line Length Between Plan and Actual Work

In the former RE projects, the route design of distribution lines was often decided without considering the geographical features of the sites. Therefore, there were some cases where the designed distribution line route bypassed valleys, cliff lines, etc with a straight line. In these cases, the actual construction had to go by a roundabout route to avoid these difficult geographical features and the cost greatly exceeded the budget. In this masterplan, the difference between the budget and the actual cost will be reduced owing to the use of GIS that makes it possible to choose the most realistic distribution line route considering the geographical features.

(5) Extention of Distribution Lines from Smaller Capacity Lines

Normally, the installed conductor capacity is decreased towards the end of a line. However, in some existing lines, there are a few sections where a thicker (higher capacity) conductor has been connected after a thinner (smaller capacity) conductor. This situation may cause an over-current in the thinner conductor. It is necessary to replace the existing conductors with conductors of adequate capacity.

10.4 Request from Bhutan the Results of its Study on Technical Standards

(1) Poles

1) Fabricated Steel Pole

Though the total weight of a fabricated steel pole is heavier than the steel pole now in use, the workability of the fabricated steel pole is superior and more suitable in cases where a longer pole is necessary, because the fabricated steel pole is composed of 4-5 parts and the weight of one part is about 50 kg, lighter than one part of the steel pole. Incidentally, since the price of the fabricated steel pole is higher by 50 to 100%, and the diameter of the pole at the ground level is thicker compared to the steel pole, places where the fabricated steel pole could be used are limited.

2) Wood Pole

The wood pole is popular for rural electrification on the grounds that 1) it is easy to obtain locally, 2) it is lighter compared with a concrete pole and 3) it is easy to climb on. Treated wood poles or kiln-dried (KD) wood poles are generally used. The price of an imported wood pole of 9 to 11 m in length is estimated at approximately US$100-200. If shorter poles, such as 8 m poles are made in Bhutan, the price may be cheaper.

The wood pole has disadvantages in that 1) it is difficult to estimate the strength of a pole because its strength depends on individual material and 2) the strength of wood pole is reduced with the rot. Therefore, a wood pole should be used only for supporting low voltage ABC cables in consideration of safety. When a treated wood pole is used, attention should be paid to environmental protection against soil contamination from chemicals applied to the pole.

(2) Conductors

a) Bared Conductor

Now, ACSR (Aluminum Conductor Steel-Reinforced) is used in Bhutan. Since a cost comparison of ACSR and AAC (All-Aluminum Conductor) was studied in past RE projects, Study Team studied their feasibility. AAC is not only cheaper but also lighter than ACSR, which is an important advantage in Bhutan where construction works rely on human power. On the other hand, the use of AAC in Bhutan has the following disadvantages:

1) Compared to ACSR, AAC is not as strong and therefore is not suitable for a long span line.
2) The use of AAC with ACSR is not suitable from an operation and Maintenance (O&M) standpoint. It is desirable that existing ACSR is changed into AAC as often as conductor replacement is warranted. In this case, the following extra works may be needed to ensure an appropriate clearance of a line from the ground.
    a) Installation of another pole between 2 poles
    b) Change of an existing pole to a longer pole
3) Covered conductors, to be used in environmentally protected areas, need a suitable strength for the load considering the cover. For this reason, ACSR or AAAC (All-Aluminum Alloy Conductor), of which strength is almost the same as ACSR, is suitable for the covered conductor. The use of different strength conductors together is not desirable from an O&M point of view.

According to a cost estimation, based on the general conditions in Bhutan, the cost benefit of using AAC is approximately 1 or 2%, considering the increase in the cost of poles due to a rise in the total number of poles required and the use of longer poles.

Based on these studies, Study Team arrive at our conclusion that ACSR should be used as standard specification. However, on the detail design level, a trial use of AAC may be considered in particular areas where it is extremely difficult to transport materials or equipment.

b) Covered Conductor

In Bhutan, medium voltage lines are often installed in mountainous areas. However, since it has recently become difficult to gain permission for tree trimming for right of way, the use of covered conductors, to reduce the total amount of tree trimming and to reduce earth fault caused by the contact of grown trees with lines, is studied. The procurement cost of a covered conductor, with AAAC or ACSR with XLPE (Cross-linked Polyethylene) cover, will be roughly 120% of bared conductor of ACSR.

The covered conductor is to be used in environmentally protected areas where an approval for tree trimming may not be easily attained. By the use of covered conductors, the requested tree trimming areas would be expected to be reduced from approximately 6 m from the center of a pole to a width of approximately 2 m from the center of a pole. In order to minimize a tree trimming area, the arrangement of conductors should be changed from a horizontal arrangement and a triangle arrangement to a vertical arrangement.

(3) Transformers

Since the problem of transporting transformers in mountainous areas needs to be solved, it is appropriate to study the use of the smaller capacity (lighter) transformers. Furthermore, the adoption of single-phase transformers may lead to cost reductions. For this reason, the use of a single-phase transformer and a mold transformer was considered.

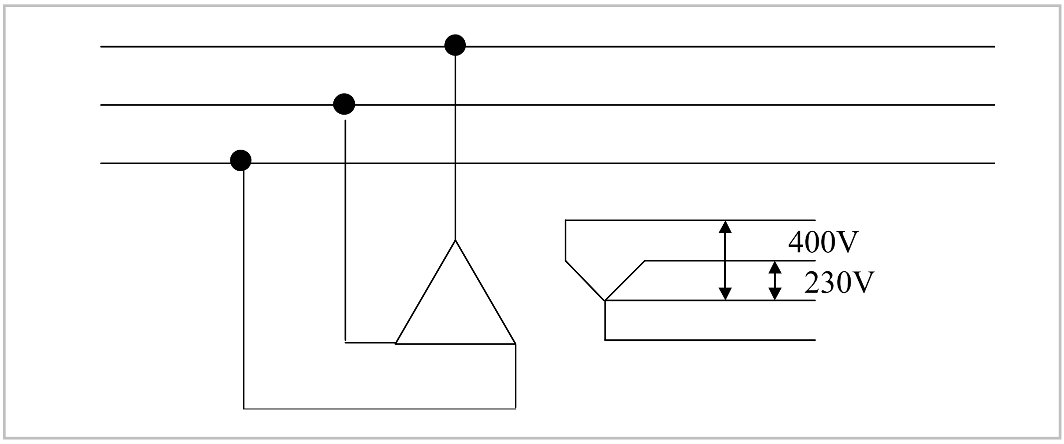
a) Single-phase Transformers

Although three-phase transformers are used routinely in rural areas of Bhutan, for villages in this RE project where three-phase demand is not anticipated in the future, single-phase transformers will be used. The use of a single-phase transformer may have advantages as it is possible to get a smaller capacity transformer of lighter weight.

The price and the weight of a transformer is almost the same between the single-phase and three-phase, if the capacity is the same. However, the total cost of distribution facilities will be reduced because the single-phase system needs only two conductors. Incidentally, when three-phase demand occurs in the future, it is possible to provide support by installing one more conductor and changing the transformer (exchanging a single-phase transformer with a three-phase transformer, or installing two more single-phase transformers and connecting three single-phase transformers to get three-phase).

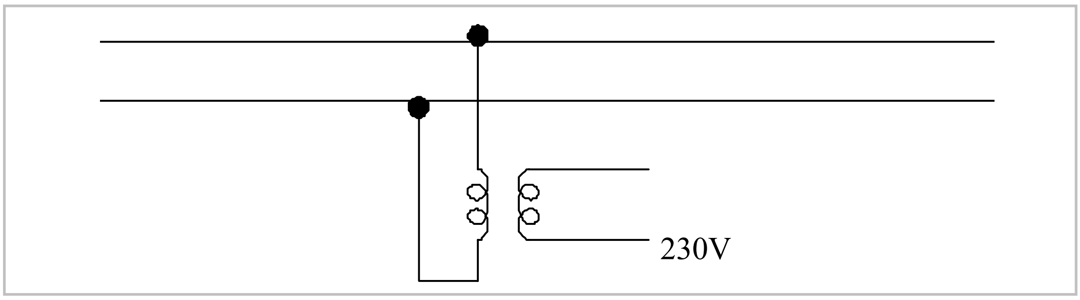
When power is supplied by single-phase, it is necessary to consider the following facts:

- The current per individual conductor of single-phase is greater than that of three-phase for the same demand and for this reason the voltage drop of single-phase lines is also greater.
- The single-phase line may cause an imbalance in the current of each conductor at a trunk line.



Prepared by JICA Study Team

Figure-10.4.1 Three-phase System



Prepared by JICA Study Team

Figure-10.4.2 Single-phase System

b) Single Wire Earth Return System

The Single Wire Earth Return System (SWER) is regarded as an effective single-phase technique for rural electrification. SWER, using the ground instead of one conductor, has the following advantages:

- The conductor cost is reduced because the system needs only one conductor

- The system makes it possible to make the span longer because there is no possibility of conductor twining.

Therefore, in some countries, SWER is adopted as the electrification method for long lines with small demand to reduce cost. However, since SWER needs an isolating transformer, if the length of medium voltage line is short, a financial advantage cannot be guaranteed. Generally, when the total length of SWER is less than 8 km, it is unlikely that the use of SWER will generate a cost benefit. Moreover, the risk that the distribution transformer for SWER may become sunk cost should be considered, because it is difficult to divert it to other sites when three-phase systems are needed. Incidentally, since the current runs through the ground in SWER, safety for citizens and the affects on communication lines should be considered. According to the New Zealand regulation "New Zealand Electrical Code of Practice for Single Wire Earth Return Systems: NZECP 41: 1993", regulations regarding earthing arrangements and load current are provided as follows;

- The grounding shall not be greater than 5 ohms.
- The maximum permissible load current shall be 8 amperes.

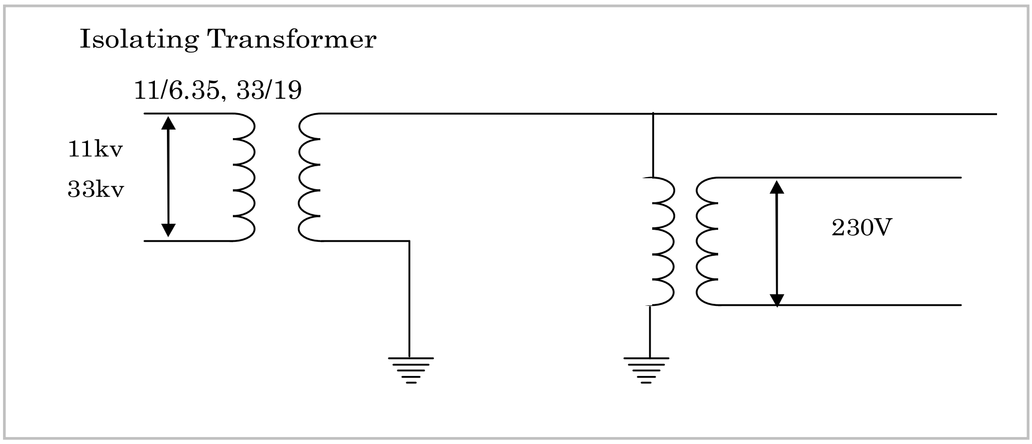


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Figure-10.4.3 SWER System

c) Mold Transformer

Mold transformers, which do not need insulation oil, are used effectively in the buildings where noncombustibility is required. However, since the epoxy resin that is used as insulation material is easily affected by ultraviolet rays, it is necessary to consider using a box to cover it so it is not affected when used in the open air. Furthermore, though the weight of the mold transformer is roughly the same or greater compared to a regular oil immersed transformer, the price is more than double. Therefore, there is little advantage in using it, except for special purposes in Bhutan.

In other countries, there are examples of using a small capacity (about 1 kVA) mold transformer for a small village, though it is difficult to procure this particular capacity of oil immersed transformer.

(4) Insulators

Insulators are classified by their material into porcelain insulators, glass insulators and polymer insulators. The porcelain insulator is currently used in Bhutan. The Study Team summarized the characteristics of 3 types insulators such as performance, workability and economy and studied their feasibility.

a) Porcelain insulator

Porcelain insulator is the most popular and reliable insulator. It is composed of such crystal phases as quartz, alumina and mullite with strong bonding of molecules. It is not so fragile that a small crack will lead to it being easily crushed. On the other hand, it is difficult to identify the damage from the external appearance and it often takes considerable time for an investigation in a case of line trouble.

b) Glass insulator

Glass insulator is made of soda-lime glass composed of SiO_2, Na_2O and CaO mainly. Glass, a fragile material generally, is not a mechanically-strong material. Glass used for an insulator is toughened by heating and rapidly cooling its surface. When the stress balance between surface and internal parts of glass is lost, shattering, a phenomenon when glass is broken to pieces and scattered, is caused. Though a glass insulator that causes scattering in the case of a problem can be detected easily from the ground during a patrol, the number of problems may be increased because of its lack of mechanical strength compared with porcelain insulator. Security against scattering of glass fragments is also very important. The price and weight are almost the same as porcelain insulator.

c) Polymer insulator

The price is approximately 2.5 times and the weight is approximately one-seventh that of the porcelain insulator. Polymer insulator is stronger against the impact of a thrown stone.

Considering the advantages and disadvantages in each type of insulator, it is desirable that a porcelain insulator is used as the standard specification, and that a glass insulator and a polymer insulator are used in mountainous areas. The glass insulator is used where extensive time is spent on investigating any problems and the polymer insulator is employed where the priority is workability.

(5) Voltage Regulators

Voltage drop often becomes a problem when long distance medium voltage lines are installed. In this case, the adoption of a voltage regulator is one effective solution to ease the voltage drop. Since the voltage regulator of is 3,000-5,000 kVA capacity is heavy, it should be installed along a road.

(6) Coupling transformer

In rural areas, there are some villages where demand is very low and the capacity of transformer to match the demand may be less than 25 kVA. In the case of 33 kV, it is very difficult to procure a transformer whose capacity is less than 25 kVA and too many 25 kVA transformers will be designed without regard to demand. The problems raised by this situation are as follows;

1) Increases in material cost

2) Increase of no-load loss generated by transformer

3) Decline in workability

In order to avoid these problems, the use of a coupling transformer that converts voltage from 33 kV to 11 kV is effective. Since the cost of a coupling transformer with the capacity of 300 to 500 kVA will be approximately US$30,000 to US$40,000, the adoption of a coupling transformer will be limited to areas where the cost reduction by using smaller transformers is almost same as the cost of a coupling transformer.

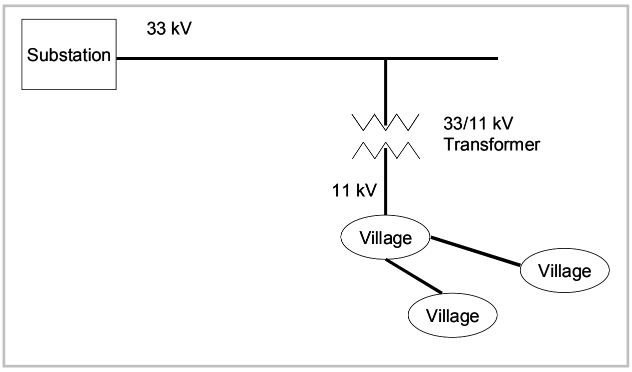

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Figure-10.4.4 Coupling Transformer

10.5 The Technical and Design Standards for the Master Plan

Study Team studied the technical and design standards taking the following 3 factors into consideration, then decided on suitable standards for Bhutan.

(1) Safety and Reliability

Since distribution facilities such as poles and lines are installed exposed to wind and rain and next to habitation, standards should be studied considering the safety and the reliability of these facilities.

(2) Workability

In Bhutan, of which features are mountainous, transportation of materials and equipment relies upon human power. Therefore, the weight of materials and equipment affects the workability of construction, making this an important decision for the standards.

(3) Economy (Life cycle costs)

Though initial costs tend to be given priority in cases of rural electrification because of financial problems, life cycle costs including O&M costs and energy losses are also very important for sustainable operation.

Design parameters for technical evaluations such as pole strength calculation were decided considering the natural conditions in Bhutan as follows:

Atmosheric Temperature	Maximum	40 ℃
	Minimum	-10 ℃
Wind Velocity		27 m/s

In present standards, icing of 10 mm thickness on a conductor is assumed to calculate a wind load for a line. Considering the prevailing natural conditions, icing should be assumed in the areas of more than 3,000 m height. Not assuming icing, such facilities as poles and conductors produce a margin in their strength, and this can lead to cost reduction.

10.5.1 Planning Standards

(1) Voltage

The nominal medium voltage shall be 33 kV and 11 kV. 6.6 kV shall be adopted only where a medium voltage line is extended from an existing 6.6 kV line. In the future, existing 6.6 kV lines should be replaced by 33 kV or 11 kV step by step. The nominal low voltage shall be 230/400 V and the voltage at the connecting point between BPC and a customer shall be from -10% to +10% of the nominal voltage. The medium voltage line is designed so that the voltage at the end of the line will be between approximately -5% to +5% of the nominal voltage.

(2) Network System

The network system of medium voltage lines for rural electrification is radial. In rural ares, extension with single-phase lines should be adopted positively in case three-phase demand is not expected, except for trunk line.

(3) Clearance

The minimum permissible clearance of lines is discribed in **Table-10.5.1**.

Table-10.5.1 Required Ground Clearance (m)

	33 kV	11 kV	LV (ABC)
Across Roads	6.1	6.1	5.5
Others	5.8	5.8	4.5

Prepared by JICA Study Team

Table-10.5.2 Required Clearance between Adjacent Lines (m)

33 kV and 11 kV	1.2
33 kV and LV	1.5
11 kV and LV	1.2
MV and Communication Lines	1.8
LV and Communication Lines	0.6

Prepared by JICA Study Team

10.5.2 Technical Standards for Main Distribution Facilities

Distibution facilities shall conform with international standards such as IEC, BS or ANSI. In order to minimize the variety of facilities, the following specifications are standardised.

(1) Transformers

The transformers that for use in the distribution substations are described in **Table-10.5.3**.

Table-10.5.3 Capacity of Transformer

		Capacity (kVA)
33 kV	Three-phase	25, 63, 125, 160, 250, 500
	Single-phase	25
11 kV	Three-phase	16, 25, 63, 125, 160, 250, 500
	Single-phase	10, 25

Prepared by JICA Study Team

(2) Conductors

The medium voltage conductors are ACSR and size is described in **Table-10.5.4**.

Table-10.5.4 Specification of Conductor

	Wolf	Dog	Rabbit
Nominal diameter (mm)	18.1	14.2	10.1
Weight (kg/m)	0.7256	0.3943	0.2139
Maximum current (A)	398	300	193

Prepared by JICA Study Team

Covered AAAC will be used in mountainous area in order to avoid earth faults.

Table-10.5.5 Specification of Covered Conductor

	AAAC 150	AAAC 95	AAAC 50
Nominal diameter (mm)	18.9	116.1	12.7
Weight (kg/m)	0.510	0.350	0.200
Maximum current (A)	485	370	245

Prepared by JICA Study Team

ABC (Aerial Bundled Cable) is used for low voltage lines because the lines are often installed in relatively low positions or close to buildings.

(3) Poles

The standardised pole is the steel pole with painting now in use. The fabricated steel pole may be used in mountainous areas.

The wooden pole is used only for supporting the low voltage ABC lines.

The minimum length of the pole is 10 m for 33 kV, 9 m for 11 kV and 7.5 m for LV basically.

The typical specifications of steel poles are shown in **Table-10.5.6.** However other specifications can be adopted as long as they have enough strength against the assumed load.

Table-10.5.6 Specification of Steel Pole

Length (m)	Strength (kN)
10	2.00
9	1.93
8.5	1.93

Prepared by JICA Study Team

10.5.3 Design Policy

(1) Distribution Substations

The capacity of a distribution substation shall be decided to meet the demabd of each village. Though the phase of a transformer shall be generally 3 phase, single phase may be adopted for the transformer with the capacity is no more than 25 kVA if three phase demand will not be assumed.

The distribution substation should be installed near the center of the load of a village and near a road. If the substation is located in a place that has no accessible roads, the maximum capacity of a transformer is 25 kVA, considering ease of handling. The maximum capacity of a transformer that is installed near a road shall normally be 125 kVA, for the reduction of low voltage line cost and energy loss.

The transformers of is 250 kVA capacity or less are installed on poles, and those with more than 250 kVA are installed on the ground with fences.

(2) Distribution Line Routes

The distribution lines are installed along roads, in consideration of ease of handling and ease of maintenance. When the lines are installed in mountainous areas, the route should be designed to avoid large differences in elevation and undulating terrain as much as possible. The maximum inclination of a line is roughly 30 degrees.

(3) Conductors

The size of a conductor is chosen considering the load current and voltage drop. Basically, Wolf is used for the trunk lines and Rabbit is used for the branch lines. The target voltage at the end of a line is from -5% to +5% of the nominal voltage.

(4) Poles

The double pole (H type pole) is used for the following situations, considering the wind load and the vertical load:

- On poles on which the distribution substation or the switch is installed
- On tapping poles, angle poles, or long span poles
- When the line is installed across a river or on a steep slope

In order to keep a proper clearance from the ground, the necessary length of pole and span should be considered.

(5) Switches

Switches are installed at suitable places in order to minimize the fault area. The general installation place is as follows;

- Approxmately every 10 km on trunk lines
- The tapping point from which a long branch line is extended

(6) Others

On 11 kV lines, for which the voltage drop will be too great, the voltage regulator will be installed at an appropreate position to compensate voltage. The standard capacity of the voltage regulators are 1,000 kVA, 2,000 kVA and 3,000 kVA.

In addition to the above, comments shown in **Appendix-B-II** on the technical standards for distribution utility designing have been submitted by DOE/BPC during the preparation of the progress report.

CHAPTER 11 OFF-GRID ELECTRIFICATION PLANNING

11.1 Renewable Energy Potential

11.1.1 Meteorological and Hydrological Data

(1) Meteorological Data

In Bhutan, the Hydromet Services Division of DOE is responsible for all hydrological and meteorological observations and data management, nation wide. There are 84 meteorological stations in total throughout Bhutan, 12 agro-meteorological stations (Class A), and 64 climatological stations (Class C), which are all managed by DOE. Manual observations are generally made twice a day (at 9:00 am and 2:00 pm) at these stations. In addition, there are five (5) Special Stations, installed mainly for management of communications facilities, and four (4) automatic observing stations for monitoring snow accumulation. **Table-11.1.1** below shows the parameters measured at each observation station. A location map of the stations is shown in **Figure-11.1.1** below.

Table-11.1.1 Observation Items

Type of Station	Number of Observing Stations	Observation Parameters
Class A Stations (manual observation)	12	1. Rainfall 2. Min./ Max. Temperature 3. Wind Speed and Direction 4. Sunshine hours 5. (Humidity) 6. (Evaporation) 7. (Solar Radiation) 8. (Soil Temperature)
Class C Stations (manual)	64	1. Rainfall 2. Min./ Max. Temperature 3. Humidity
Special Station (automatic)	5	1. Rainfall 2. Others
Snow Gauge Station (automatic)	4	1. Snow Depth

Prepared by JICA Study Team (Based on discussions with Hydromet Services Division / DOE)

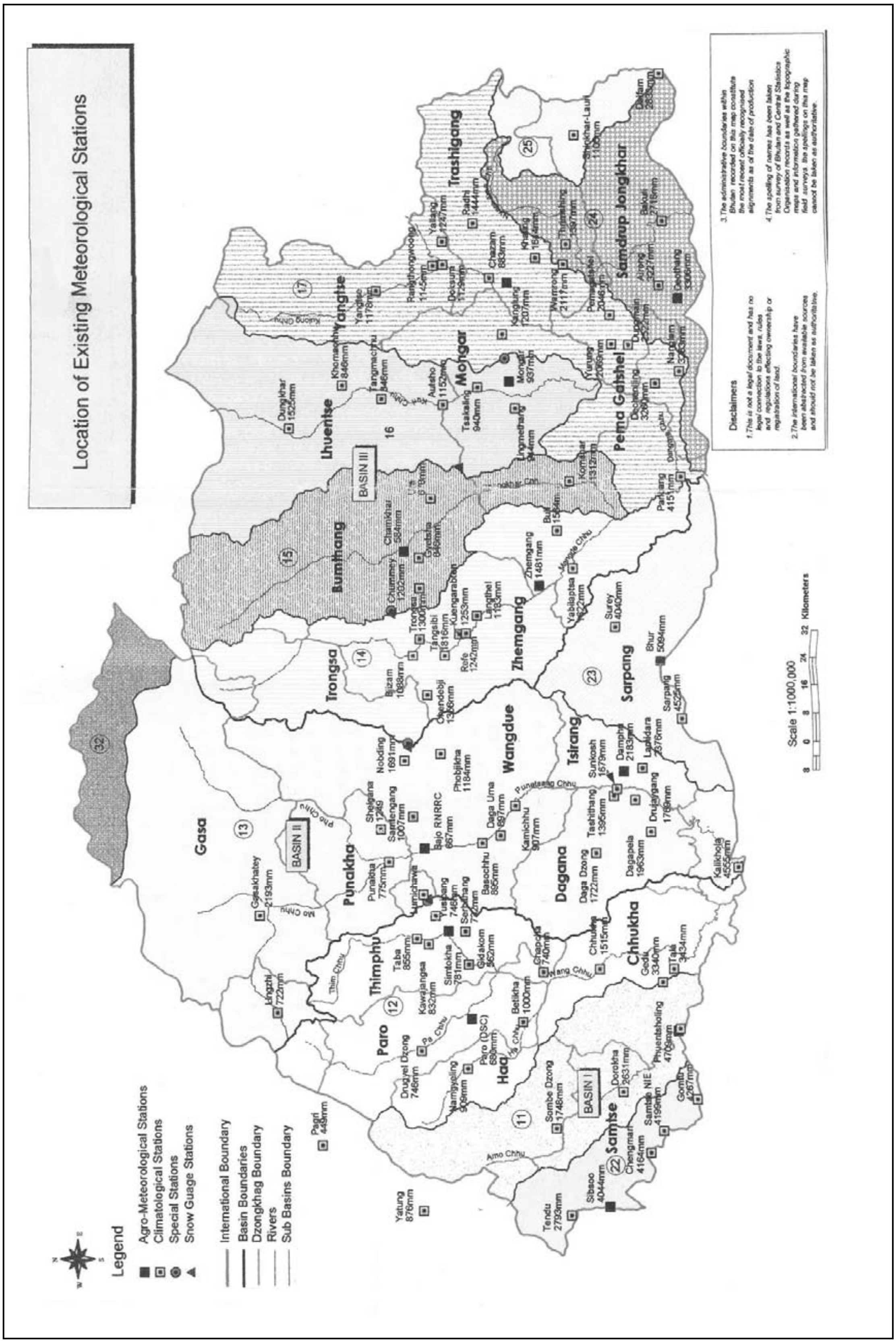
Of the stations listed above, 15 have had automatic observational equipment with data loggers installed by the Norwegian Agency for Development Cooperation (NORAD) for monitoring rainfall and solar radiation since the early 1990s. However, they were used for only 2-4 years and are no longer serviceable due to mechanical failure, etc.

Other than those facilities, there is a military-owned meteorological station inside the airport in Paro, and automatic meteorological observational equipment was installed by Nagoya University (Japan) and the Geological Survey of Bhutan, Ministry of Trade and Industry in 1999.

(2) Hydrological Data

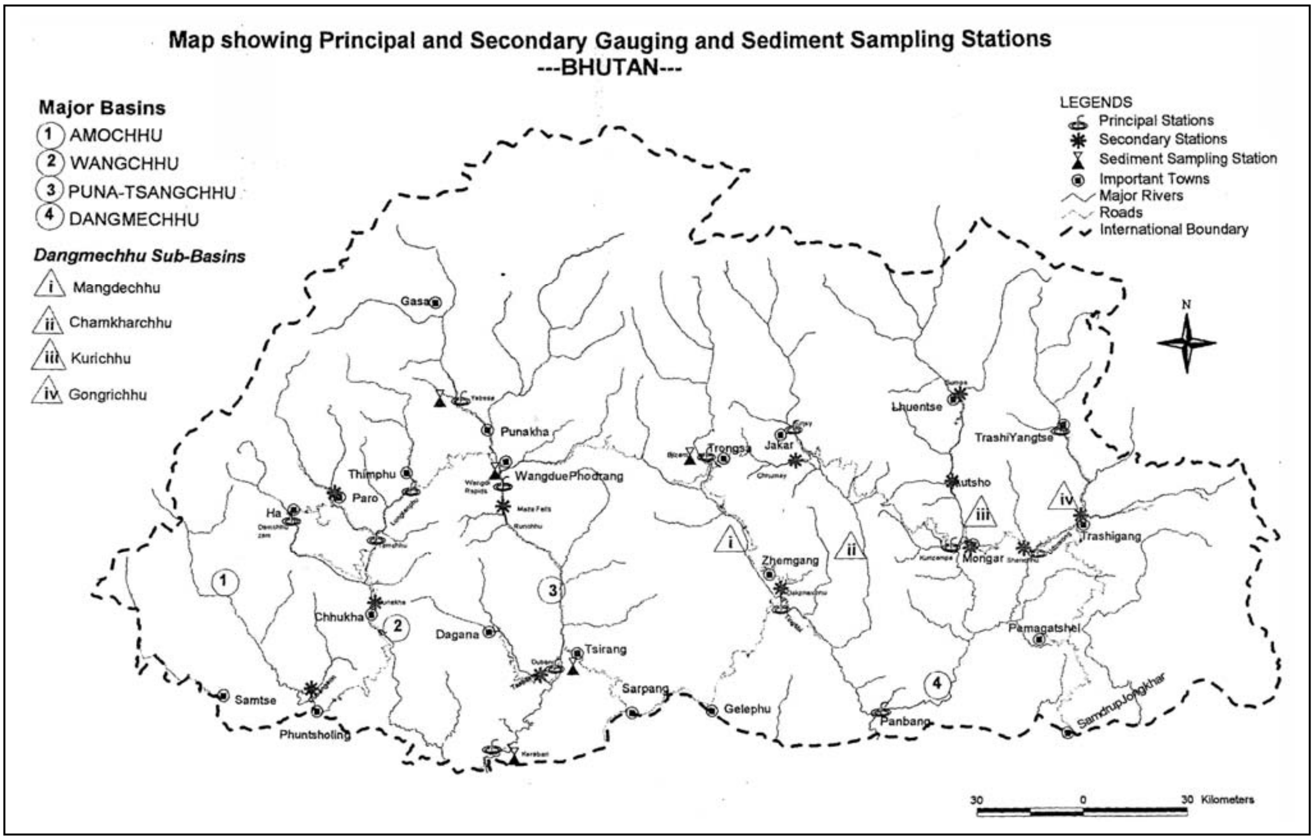
As for hydrological stations, there are 16 primary gauging stations installed in the main river system and 8 secondary gauging stations, in which observations of water level, discharge, and sediment/suspended load sampling have been made since 1987. **Figure-11.1.2** below shows the location of these hydrological stations.

Also in DOE, dry season discharge has been observed one or two times a year during the dry-season, December to April, since 1992 at 72 stations on the middle and small sized rivers (Lean Season Stations).



Source: DOE

Figure-11.1.1 Location Map of Meteorological Stations



Source: DOE

Figure-11.1.2 Location Map of Hydrological Stations

11.1.2 Micro Hydropower Potential

A nation-wide study to quantify the potential for small/micro-hydropower[1] generation has not been conducted up until now. However, as mentioned above, the Hydromet Services Division of DOE has measured the dry season discharge at least once a year since 1992 at 72 stations on the medium and small scale rivers. In addition, DOE staff will sometimes conduct field investigations of stream discharge rates, even in the hinterland. Unfortunately there are not any comprehensive study reports on these field investigations. However, DOE staff know well the potential sites for micro/small-hydropower in the conutry. Based on their knowledge and experience, DOP (current DOE) selected 31 candidate potential sites for micro/small-hydropower development in 1999 (see **Chapter 5**, **Figure-5.4.1** and **Table-5.4.1** above).

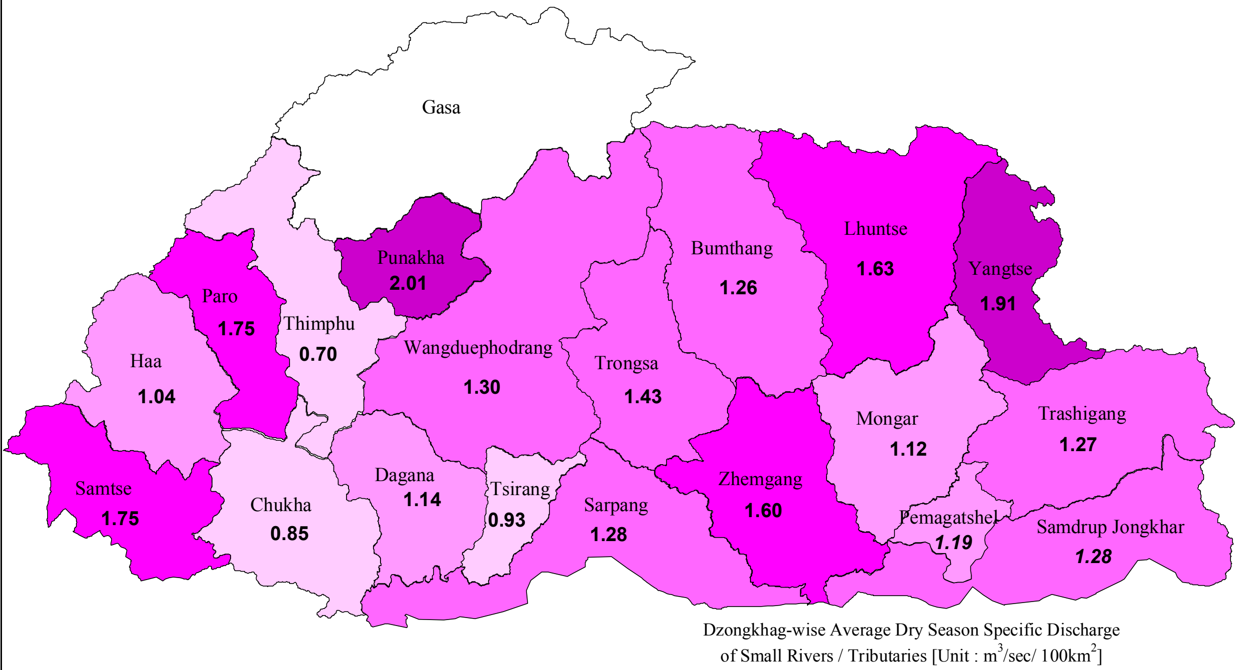
The obsevation records of the lean season discharge at 72 stations on small-scale rivers by the Hydromet Services Division of DOE is shown in **Appendix C-II**. **Figure-11.1.3** below shows the Dzongkhag-wise mean specific dry season discharge (m^3/sec/100 km^2) of small rivers that was estimated by using observed lean season dischage data at the 72 DOE gauging stations. According to **Figure-11.1.3**, the eastern region of Bhutan is generally expected to have a large potential for micro/small-hydropower due to adequate dry season discharge rates. This is especially so in the north-eastern region, such as Lhuntse and

[1] Relative Hydropower Generator Sizes: Large: approx. >5 MW, Small: 1-5 MW, Mini: 100 kW-1 MW, Micro: 10 kW-100 kW, and Pico: < 2 kW

Yangtse Dzongkhags, and for Punakha Dzongkhag in the central region. In contrast, the western region, such as Thimphu and Chukha Dzongkhags, show a low specific dry season discharge compared with other regions.

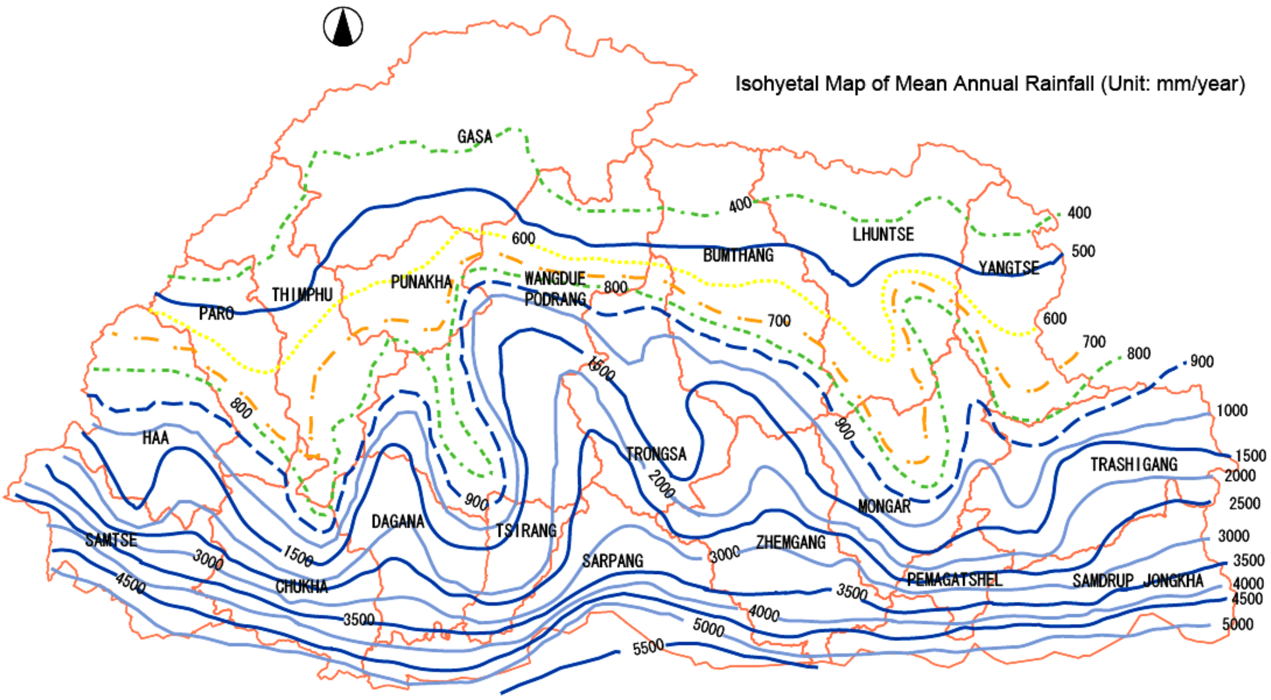
In Bhutan, the isohyet map of mean annual rainfall is not published officially. However, an isohyet map of mean annual rainfall is included in the feasibility study for the Chendebji micro-hydropower CDM project, as shown in **Figure-11.1.4** below. In **Figure-11.1.4**, the southern part of Bhutan, close to the border with India (such as Samtse, Chukha, Zhemgang, Pemagatshel, and Samdrup Jongkhar Dzongkhags), is world famous as a large rainfall area, especially near the border of the Assam region in India. Here, the rainfall reaches almost 4,000 mm/year. In the middle latitude areas such as Dagana, Tsirang, southern part of Bumthang, Mongar and Trashigang Dzongkhags, the rainfall is comparatively large at 1,500-2,000 mm/year. On the other hand, areas such as Haa, Paro, Thimphu and Punakha Dzongkhags have a relatively small annual rainfall and the micro hydropower potential in these localities is not large compared to other Dzongkhags. The rainfall in northern part of Bhutan seems to be small in the figure above, but this is probably because few rainfall observation data are available in northern mountain areas. In fact, for the Himalayan Mountains, with 7,000 m-class elevations, the total precipitation including snowfall is understood to be more than indicated value in **Figure-11.1.4** below.

The Study Team conducted field surveys on the hydropower potential and social survey with DOE counterparts as part in January 2004 and in June 2004. Discharge measurements and simple topographic surveys using a hand level were conducted at seven (7) sites that were sampled for the micro hydro potential survey. These survey sites were selected from a group of candidate sites from: (i) the UNDP/GEF pre-feasibility study for 31 small hydropower candidate sites selected by DOE in 1999, and (ii) surveys conducted by India in 1980's for proposed hydropower projects. The locations of the seven surveyed sites are listed in **Table-11.1.2** below.



Source: JICA Study Team (based on lean discharge record by DOE, 1992-Apr. 2004. Total 470 data of dry season lean discharge at 75 sites)

Figure-11.1.3 Dzongkhag-wise Mean Specific Dry Season Discharge



Source: e7 Bhutan Micro Hydro Power CDM Project Feasibility Study Report, Kansai/AEP/EDF/HQ, 2003.

Figure-11.1.4 Isohyetal Map of Mean Annual Rainfall (mm/yr)

Table-11.1.2 Field Survey Results of Proposed Micro Hydropower Project Sites Investigated by the JICA Study Team

No.	Date	Dzongkhag	Village	Name of River	GPS Coordinates		Elevation	**Obs. Q**	G.Head	Potentioal	Design	Notes
					Longitude (N)	Latitude (E)	(m)	**(m^3/sec)**	(m)	P (kW)	P (kW)	
1	2004/1/20	Lhuentse	Khoma	Yongla-chu	N 27° 41' 16.1"	E 91° 13' 27.6"	1,325	**1.85**	80	940		Grid Connected in 2002
2	2004/1/21	Lhuentse	Autsho	Phawan-chu	N 27° 28' 45.8"	E 91° 10' 59.7"	944	**0.82**	43	220	150	Swedish Study (1999)
3	2004/1/22	Mongar	Sengor	Manshing-chu	N 27° 21' 52.5"	E 91° 02' 08.7"	2,980	**0.14**	101	90	50	UNDP/GEF Study (2000)
4	2004/1/23	Bhumtang	Tang	Tendegang-chu	N 27° 37' 27.9"	E 90° 52' 35.8"	2,750	**0.39**	55	140	200	Swedish Study (1999)
5	2004/1/23	Bhumtang	Tang	Selgang-chu	N 27° 36' 57.9"	E 90° 53' 13.6"	2,735	**1.21**	106	820	400	UNDP/GEF Study (2000)
6	2004/6/24	Wangdue P.	Lumuzu	Chuba Ling-chu	N 27° 38' 26.2"	E 90° 12' 16.1"	2,414	**0.73**	59	270	110	JICA Study Team (2004)
7	2004/6/24	Wangdue P.	Tara	Ramli-Chu	N 27° 36' 57.0"	E 90° 11' 35.0"	2,266	**5.33**	91	3,100	1,240	JICA Study Team (2004)

Prepared by JICA Study Team

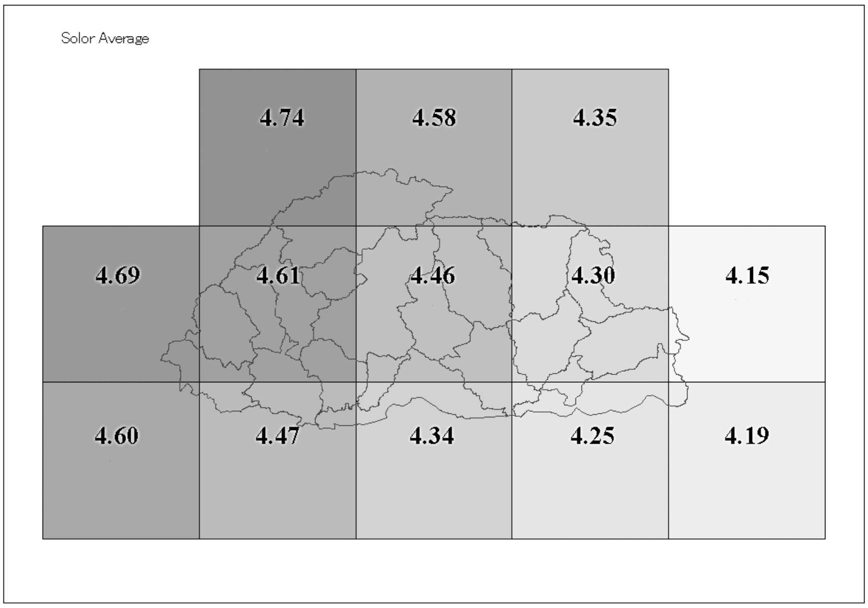
11.1.3 PV, Wind and Biomass Energy Potential

(1) PV Energy Potential

The monsoon season is acompained by frequent cloudy days, and this cannot be ignored in the case of PV power generation in Bhutan. Even though the cloudy weather lasts for some time, to supply the required power, the capacity of a PV power generation system and storage battery capacity needs to be considered carefully when determining the system sizing. The person in charge of DOE's Renewable Energy Division (RED) stated that system sizing it is calculated to provide 4 days of autonomy (i.e., 4 days without sunshine).

When sizing PV power generation systems, solar irradiation data becomes essential. However, these data do not exist in Bhutan at present, except for a few observation data. When there is no solar irradiation data, it may be thought that the duration of sunshine (hours) data could be used to calculate the solar irradiation. However, in actual practice, there is a big error in the value estimated from the duration of sunshine data, and it is not suitable for evaluation purposes. Therefore, satellite data from the National Aeronautics Space Administration (NASA) in U.S.A. are used for making these estimations at present. **Figure-11.1.5** below shows the annual average horizontal[2] solar irradiation of Bhutan that is determined from the NASA satellite data. The monthly distribution of the average horizontal solar irradiation derived from the satellite data is shown in **Appendix A-III-3**. It is understood that in the southeastern part of Bhutan, which has a lot of precipitation in the rainy season, has an average of 4.3 kWh/m^2/day and at Gasa Dzongkhag in the northern part, and also in the western part or the country, there is a higher solar potential of more than 4.6 kWh/m^2/day on average. When the country average is calculated, it is over 4.4 kWh/m^2/day, and it can be said that there is not a lot of difference from the average between each area.

[2] Solar radiation received on a horizontal surface, which is the sum of the direct and diffuse solar radiation.



Prepared by JICA Study Team (based on NASA's data)

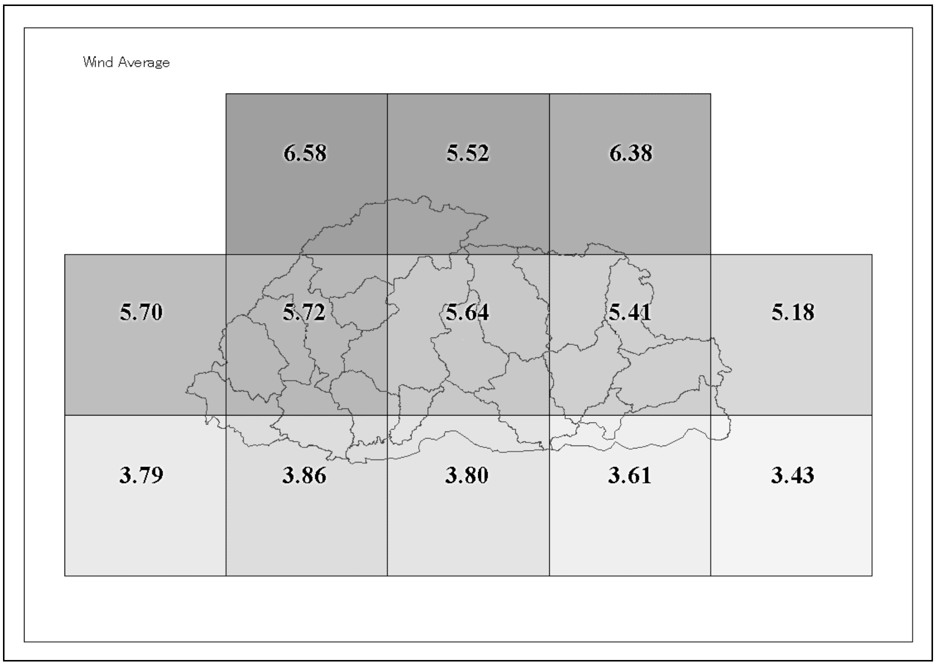
Figure-11.1.5 Estimated Annual Average Horizontal Solar Irradiation (kWh/m^2/day)

(2) Wind Energy Potential

In Bhutan, considering the geographical features and inaccessible high mountains, it is assumed that there would be a high potential for wind energy. However, at present there is no development project using wind power generation. Calculations of wind power generation potential and development of a wind map has not been done.

At the 12 Agro-weather stations (Class-A Station) over the whole country, wind speed and direction are measured at around 2.5 meters above ground level and data are measured manually twice a day (9:00 AM and 2:00 PM) by observation staff. Therefore, it can only collect daily average and integrated wind speed values. Wind changes greatly within a day and sometimes it does not blow at all. Therefore this daily average wind speed data has a limited use, as to accurately estimating the wind power generation potential it is necessary to have at least hourly average data. When NORAD installed automatic data logger units in the first half of 1990s, automatic data recording instruments for wind speed were not included. Therefore, at present, to estimate the wind potential, satellite data are used. However, this method can differ greatly with the ground observations due to area characteristics.

If the difference between the observed wind data and that derived from satellite measurements follows the same trend as solar irradiation, i.e. the true value of the wind speed is higher than indicated by the satellite data, this would mean that, contrary to what the satellite data suggests, there is potential for wind energy generation in the northern part of the country. When the national average wind speed is calculated, it is above 5m/s, but the wind speed in the southern part of Bhutan is 25% lower than the average. **Figure-11.1.6** shows the annual average wind speed for the whole of Bhutan, derived from the satellite data. The monthly distribution of average wind speed data derived from the satellite are shown in **Appendix A-III-3**.



Prepared by JICA Study Team (based on NASA's data)

Figure-11.1.6 Estimated Annual Average Wind Speed (m/s)

(3) Biomass Energy Potential

Most of the land in Bhutan is covered by the forest and it can be assumed that the biomass potential is high. However, there is no biomass power generation plan being formulated at present, and little data are avairable for biomass power generation systems.

Th climate in the southen part of Bhutan is warm, and the agricultural system of half-cropping and half-livestock farming is popular. Thus, the biomass potential is believed to be high. Of all the households in Bhutan, 74% have cattle, 36% have pigs, and 27% have horses. The number of livestock in Bhutan is shown in **Table-11.1.3** below.

Table-11.1.3 Numbers of Livestock by Dzongkhags

Dzongkhag	Cattle	Buffalo	Yaks	Horses	Mules	Donkeys	Sheep	Goats	Pigs
Thimphu	6,990	-	8,699	968	75	2	18	6	762
Paro	12,102	-	3,158	1,084	146	7	15	58	2,511
Haa	9,639	-	5,629	810	530	25	173	12	1,179
Chukha	24,870	67	-	591	56	10	1,375	5,739	3,154
Samtse	29,341	743	-	209	100	2	4,659	10,916	1,185
Punakha	12,125	-	24	1,019	42	3	-	15	2,640
Wangduephodrang	20,893	-	3,057	1,722	78	21	3,884	139	3,304
Gasa	863	-	4,051	380	264	4	196	-	38
Tsirang	14,645	382	-	339	9	1	1,189	5,441	1,451
Dagana	14,296	107	-	383	33	10	732	3,612	2,378
Bumthang	10,002	-	2,672	1,299	107	8	2,147	28	30
Trongsa	11,336	-	-	390	50	6	1,337	7	350
Zhemgang	12,156	-	-	1,434	230	14	7	112	1,618
Sarpang	26,611	425	-	473	7	2	1,588	4,371	1,640
Mongar	26,635	-	46	2,123	505	27	105	341	4,398
Lhuntse	14,089	-	44	1,768	160	22	279	7	1,617
Yangtse	12,505	-	115	1,753	216	18	47	48	2,793
Trashigang	308,258	-	7,369	45,264	719	42	5,047	104	5,640
Pemagatshel	8,570	-	-	479	407	37	20	91	1,414
Samdrup Jongkhar	21,967	29	60	1,842	635	22	61	281	2,599
TOTAL	597,893	1,753	34,924	64,330	4,369	283	22,879	31,328	40,701

Source：Renewable Natural Resourcese Statistics of Bhutan, 2000, MOA

Annual power generation enegy by biogas generation is calculated to be 20.8 GWh using gas engines and small generators, assuming that the energy conversion efficiency is 20% and that 5% of the excrement of all livestock can be recovered. This predicted figure covers the energy demand of approximetly 14,000 households in Bhutan when the demand is set at 120 kWh/month, as described later in **Chapter 12**. If the above biogas energy was applied directly as a heat source for cooking, the calorific value corresponds to the equivalent energy of 5,821 tonnes of LPG gas or 582,100 x 10 kg cylinders of LPG gas annually.

One current issue for the application of biogas systems is the unwillingness of users to undertake the continuous collection of animal dungs.

11.2 Technical Criteria Applied to Existing Off-Grid Electrification

11.2.1 Micro Hydropower

At present, 16 micro hydropower plants with individual installed capacities of less than 300 kW have been constructed in Bhutan. Of these, and 13 have been funded by the grant aid from Japan. The principal criteria and ideas applied to the micro hydropower projects with grant aid from Japan are shown in **Table 11.2.1**.

(1) Civil Structures

Table-11.2.1 Technical Criteria Applied to Designing for the Civil Structures of Existing Small Hydropower Plants

	Structures	Applied Criteria and Ideas
1	Intake Weir	・ The construction site where the riverbed is stable and firm is to be selected. ・ The intake weir is to be a concrete structure. ・ Install a pipe screen on the opening of the intake to prevent ingress of stones/rocks. ・ Standardize the structure, considering design, construction cost and maintenance.
2	Sand Settling Basin	・ Build a sand settling basin near the intake weir. ・ Build a sand flush facility (scouring gate) at the end of the sand settling basin. ・ The average velocity in the basin is 0.2m/sec, the average depth is 1 m as a standard, and the length is to be determined. ・ Standardize the structure.
3	Canal (Channel)	・ Open channel type in principle. ・ Manning's formula is to be used in the hydraulic calculation of the flow discharge. ・ Adopt the optimum section of channel that allows the maximum hydraulic radius at the same cross-sectional area of flow. ・ The maximum average velocity is to be not more than the allowable velocity (approximately 1 m/sec), which will not erode the inner surface of the channel.
4	Head Tank (Fore bay)	・ Install a head tank at the entrance of the penstock. ・ The capacity of the head tank is to be adequate to supply the maximum water consumption for more than 30 seconds. ・ No outlet gate is to be installed but an inlet valve is to be set up at the power plant end of the penstock pipe instead. ・ Set up the free over flow type spillway at the side of head tank. ・ Install a sand trap (scouring) gate for sediments, which is to be a spindle gate for manual operation. ・ The head tank is to be a reinforced concrete structure.
5	Penstock	・Common water pipe with a flange is to be adopted for the penstock pipe. ・To be laid underground for protection. ・The design velocity in the pipe is 3.5 m/sec maximum, and the pipe diameter is to be unified.
6	Power House	・ Retain space for inspection and dismantling of equipments and disassembled components etc. ・ Power house building is to have concrete walls 1 m from the foundation. ・ Structured to prevent flood/sediment influx and damage by rock falls. ・ Generators and equipment are to be installed inside the building. ・ Consider ventilation by setting up air vents with insect screens.
7	Tailrace	・Design to keep the necessary water depth in the bottom outlet and to ensure uniform flow without vortices from the outflow from turbine.

Source: The Basic Design Study on Establishment Project for Micro Hydro Power Facilities in Bhutan, 1998/99, JICA.

(2) Electrical Utilities

Table-11.2.2 Technical Criteria Applied to Designing for the Electrical Utilities of Existing Small Hydropower Plants

	Equipments	Applied Criteria and Idea
1	Hydraulic Turbine	・ For moderate head or small discharge, a cross flow type hydraulic turbine is to be adopted, which has a simple structure for maintenance and is economical. ・ In the case of around 50 kW output, the method below is to be adopted. Use of an automatic guide-vane servo-motor is not recommended as it makes the mechanism complicated and difficult to maintain, and it is eventually not economical. ➢ Flow regulation: Control the guide-vane manually by the load. ➢ Governor: Use an electronic servo-less governor (speed adjusting device), a static governor that sets up dummy loads to stabilize the frequency to meet the load and control the rotating speed. ➢ Inlet valve: Manual gate valve To be designed so as not to suffer mechanical damage under unrestrained rotating speed in case of the failure of the governor
2	Generator	・The plant is under unmanned control and to be designed for proper operation with one check up a day. ➢ Control method: by automatic voltage regulator (AVR). [Generator] • Type: 3-phase alternating current (AC) brushless synchronous generator • Frequency: 50 Hz • Voltage: AC400V • Connection: Pentagram, 3 phases 4 line conductors ・The generator is to be connected directly to the turbines to prevent a decrease in the connection efficiency and complication in maintenance by belt type connection. ・A turbine efficiency of 71%, generator efficiency of 85%, and combined efficiency 60% are used in general.

Source: The Basic Design Study on Establishment Project for Micro Hydro Power Facilities in Bhutan, 1998/99, JICA.

11.2.2 PV Power Generation

Since 2003, DOE-RED has had experience with the installation of solar home systems (SHS) in households, monasteries, temples, schools, health clinics and so on with cooperation from international organizations. These installations have been based on the design parameters shown on **Table-11.2.3**.

Table-11.2.3 The Design Parameters Used by DOE-RED for Installing SHS

S. no.	Parameter	Value	Unit
1	Annual average Horizontal Solar Irradiation (Country Average)	4.25	$kWh/m^2 \cdot day$
2	FCL Lights (Number of lights 5)	11	Watt
3	Ballast Efficiency of Light	80	%
4	Daily operation hours	4.5	Hours
5	PV module specification (55Wp x 2 nos.)	110	Wp
6	De-rating factor of PV module (Dust, temperature and so on)	10	%
7	Days of Autonomy	4	Days
8	Battery Efficiency	85	%
9	Depth of Discharge (DOD)	80	%
10	Coldest average temperature	-20	℃
11	Storage Battery Capacity (@C10 rate, Tubular)	110	Ah
12	Temperature de-rating factor of Storage Battery	80	%
13	Charge Controller (12 VDC type)	10	Amp
14	Provided length of Cable (Size: 2.5 Sq. mm, Copper)	70	meter

Source : Renewable Energy Division (RED) / DOE

As there is no ground observatory station for solar irradiation in Bhutan, average data have been calculated by referring to the solar irradiation data for the nearest available point in a neighboring country. These data have been used as the average data for Bhutan. Although in general the size of a PV power generation system is based on utilizing the inclined solar irradiation of the locality, in Bhutan the size of a system is based on the calculated average horizontal radiation data.

The storage battery capacity shows a tendency of being over designed because it is computed for 4 days of autonomous operation (96 hours) and the calculated value is taken as the 10 hour rate to decide the installed capacity. From the above mentioned points, although the difference is not large in relation to small systems, as the system capacity grows, there is a possibility that the capacity of PV and storage batteries becomes excessive. It is possible to make a uniform standard for the whole country, but depending upon the site there could be a great variance in the possible utilization hours. This could make the unit price expensive, and also have a negative affect on the lifespan of the storage batteries.

11.2.3 Biomass Energy

There is no information about electricity generation using biomass at present in Bhutan. One case was proposed for the introduction of methane fermentation biogas to reduce firewood consumption. However, this scheme was suspended because of the difficulty of materials collection.

11.3 Technical Standard and Model for the Master Plan

11.3.1 Micro Hydropower Generation

(1) Micro Hydropower Generation Technical Criteria to be Applied

The 13 micro/small hydropower generation plants constructed with grant aid from Japan are mostly still in operation without any serious problems, even though more than 10 years has passed since they were installed. They have significantly contributed to the development of the community and provide their basic human needs (BHN). In this Master Plan Study, there are no foreseen problems in following the technical criteria that were applied to the previously cited micro/small hydropower generation plants constructed by Japanese grant aid.

Regarding the transmission voltage, 6.6 kV was adopted in the power plants installed with Japanese grant aid. However, this voltage is not common in Bhutan. Therefore, 11 kV or other standard voltage in Bhutan is desirable, considering the availability of spare parts and future connection to the national grid.

(2) The Rural Electrification Model by Micro/Small-Hydropower

Based upon their experience, DOE/BPC considers that the power demand will soon exceed supply, despite the construction of hydropower plants, and that this will cause trouble. Lately in Bhutan, an increasing number of households have used electric home appliances (such as rice cookers, etc.) even in the rural areas, which causes an unexpected increase in the power demand. This cannot be fully accommodated by most micro hydropower plants.

It is essential to design micro hydropower plants so as to deal with an unexpected demand increase as well as to estimate the future demand carefully. Also, as for the civil structures (intake utilities, headrace, penstock etc.), which are hard to expand after the construction work has been completed, it is desirable to design them to provide flexibility or design them to allow for future modification. When it comes to the local villages, each household has a similar lifestyle, e.g., the peak load appears all at once in the morning or evening when the rice cookers, etc. are used. At other times, especially the midnight hours, there is little power demand and surplus electricity is dumped by using a dummy load in the power plant. If the capacity of the head tank is increased and water is stored when the load is low, the peak demand can be catered for to some extent. This modification is applicable, not only to new micro hydropower plants, but also to existing ones.

In the case of construction of micro/small hydropower plants, access roads for trucks to bring generators in are required. However, it often happens that the proposed sites are not easily accessible, and then micro/pico-hydropower generators (village hydropower, less than 10 kW), which does not require access roads, will be effective. Since such pico-scale hydropower generators costs less and are easy to build, operate and maintain, they need to be considered as one of the alternatives.

11.3.2 PV, Wind and Biogas Power Generation Systems

(1) PV Power Generation Systems

Bhutan targets 100% electrification nation wide by 2020, and electrification using renewable energy such as solar power (excluding small hydropower) will be one of the effective methods for areas where it is difficult to extend the grid. DOE considers that it is preferable to supply stable electricity in rural electrification in order to reduce the regional economic disparities, to prevent population concentration in urban areas and to activate the local economy.

In general, the compact solar home system (SHS) and solar lanterns are often used only for lighting. Therefore, the condition to be targeted by solar energy is assumed as follows:

- Small scale PV system : only for lighting
- Large scale PV system : lighting and cooking (only rice cooker)

It is necessary to achieve a stable power supply, so an inclined angle PV array needs to be designed in such a way that the amount of power generation is constant throughout the whole year. As there are no ground stations that measure actual solar irradiation data, NASA satellite data were used to determine the system capacity.

(a) Small Scale PV Power Generation Systems

There are two basic types of electrical supply systems: alternating current (AC) and direct current (DC). In this study, a DC system was selected to reduce the cost of the system. **Table-11.3.1** below summarizes the system sizing parameters that were used to decide the capacity of a small scale PV power generation system.

Table-11.3.1 System Sizing Parameters for a Small Scale PV Power Generation System

Item	Parameter	Value	Unit	Remarks
1	Inclined solar irradiation (15 deg)	4.9	$kWh/m^2/day$	Whole country average (from NASA satellite data)
2	Module de-rating factor	10	%	Decrease of output due to temperature, dirt, years of use, and so on.
3	Columbic efficiency	90	%	To charge the battery effectively.
4	Charge controller consumption	10	mA / hour	Depends on manufacturer.
5	Battery depth of discharge (DOD)	80	%	Maximum useable capacity.
6	Temp. de-rating factor for battery sizing (at -15 deg Celsius)	80	%	If temperature changes, the value changes.
7	Battery rate factor	1.4	%	To bring the battery back to manufacturer's standard rate.
8	System voltage (DC)	12	V	For better system performance and availability of equipment.
9	LED lamp (2 Watts each)	10	Watt	2 Watts each x 5 numbers
10	Days of autonomous operation	5	days	To adjust the size and expand the life of batteries.
11	Hours of use	6	hour/day	Considering the maximum use in winter.

Prepared by JICA Study Team

When a system is built based on the parameters shown in **Table-11.3.1** above, the form and size of the system are:

- PV Optimum Voltage (Vpm) : Above 16 Volt
- PV Optimum Amp (Ipm) : Above 2.5 Amp
- PV total capacity : 45 Wp and above
- Number of Module in series : 1 nos.
- Battery capacity (Deep Cycle) : 50 Ah (Above 40 Ah at 10 hours rate)
- Charge Controller Capacity : 10 Ah (12 V DC)

Emphasis was placed on the availability of equipment in the commercial market. Therefore, the storage battery and charge controller capacity were adjusted to match the capacity that can be obtained on the market, and a system unit price was computed. Referring to the system equipment currently available on the market in Bhutan, the price of the system described above is estimated to be around US$500. This system price does not include the cost of transportation, installation, excavation and so on. **Table-11.3.2** below summarizes the cost components of a small scale PV power generation system.

Table-11.3.2 Cost of Small Scale PV Power Generation System

Item	Required		Market		Cost (US$)
	Qty.	Unit	Price	Unit	
PV Module	45	Wp	152	Nu./Wp	152.0
Charge Controller (12 VDC, 10 A)	1	Nos.	1,250	Nu./nos.	27.8
LED Lights (2 W)*	5	Nos.	1,400	Nu./nos.	155.6
Battery (50Ah, 12V Deep cycle)*	1	Nos.	3,200	Nu./nos.	71.1
Accessories (Wires 70 m., Nails, Screw and so on)	1	Set	4,000	Nu./Set	88.9
Total (US$)					495.3

Prepared by JICA Study Team Note: * = estimated values.

As is shown in **Table-11.3.2** above, effective use of the system becomes possible by using LED lamps. For example, if one of the lights is a portable one, such as a flashlight that uses rechargeable batteries, it will be possible to reduce the use of dry cell batteries. Furthermore, if the hours of use of the lights are reduced from 6 to 4 hours per day, and the days of autonomy (reserve) are reduced from 5 to 3 days, use of a radio/cassette with a power consumption of around 15 W becomes possible for about 3 hours per day. For both cases, there is no need to change the charge controller or the storage battery. Therefore, it is possible to establish a flexible system without any significant change in the system cost. Also, by enlarging the capacity of the PV module from 45 Wp to 50 Wp, it becomes possible to build a system that includes two more LED lamps, increasing the number of lamps to 7, and also permits use of a 15 W radio/cassette for 3 hours a day while increasing the battery reserve to 4 days. This can be achieved with only a small increase in cost. If the system caters only for lighting, it is possible to decrease the system capacity. However, in an actual practice, small sized deep cycle batteries are costly compared to larger sizes. If consumers would like to use a radio and so on later, it will be necessary to increase the capacity of the system, which makes the total cost more expensive.

When a lighting system is built using 5 x 2 W LED lamps and provides 4 hours use per day, and 3 days of reserve power, while maintaining all other parameters applying in **Table-11.3.1**, the form and size of the system are:

- PV Optimum Current (Ipm) : 1.0 Amp and above
- PV total capacity (around) : 18 Wp and above
- Battery Capacity (Deep Cycle) : 15 Ah and Above (at 10 hours rate)
- Charge Controller Capacity : 3 Ah and Above(12 VDC)

For the above PV module, the capacity of the charge controller and storage battery becomes smaller, but only a little over 10% of the whole cost of the system can be reduced. Unit Wattage cost of a small size PV module is high compared to a large module because a cell division process becomes necessary, which increases the work of PV module manufacturing. Therefore, if it is planned to increase the system capacity in the future, considering the needs and long term utilization, there is no advantage in miniaturizing the system size for initial installation.

(b) Large Scale PV Power Generation Systems

Here, to compare the cost of electrification by renewable energy with that of grid extension, the condition to be targeted by solar energy is assumed to be the same in quality as grid connection, and the scale of the utilities and cost for the system are estimated accordingly.

When electricity is supplied to the households, it is predicted that it will be used for cooking. Therefore, the PV power generation system components must be based on an AC system for use of the electric rice cooker. It is possible to use DC in lighting, but it is better to use an AC system because of the difference in the system maintenance, and to avoid accidents. The system is designed for the condition that an electric rice cooker (640 W) is used for 25 minutes 3 times per day, and 5 x 11 Watt CFL lights (having 80% efficiency) are used for 4 hours per day.

Table-11.3.3 below summarizes the system sizing parameters used to decide the capacity of a large scale PV power generation system.

Table-11.3.3 System Sizing Parameters for a Large Scale PV Power Generation System

No.	Parameter	Value	Unit	Remarks
1	Total load in a day (AC)	1.08	kWh/day	Assumption
2	Peak load	0.71	kW	Assumption
3	Inclined solar irradiation (15 deg)	4.9	kWh/m^2/day	Whole country average (from NASA satellite data)
4	Module de-rating factor	10	%	Decrease of output due to temperature, dirt, years of use, and so on.
5	Inverter efficiency (Average)	80	%	Depends on manufacturer, wave type and load factor.
6	Columbic efficiency	90	%	To charge the battery effectively.
7	Charge controller consumption	40	mA / hour	Depends on manufacturer.
8	Battery depth of discharge (DOD)	80	%	Maximum useable capacity.
9	Days of autonomy	3	days	Days of reserve power.
10	Temp. de-rating factor for battery sizing (at -15 deg Celsius)	80	%	If temperature changes, value changes.
11	Battery rate factor	1.4	%	To bring back the battery back to the manufacturer's standard rate.
12	System voltage (DC)	12	V	For better system performance and availability of equipment.

Prepared by JICA Study Team

Based on the parameters shown in **Table-11.3.3** above, the form and size of the system are:

- PV Optimum Voltage (Vpm) : Above 16 Volts
- PV Optimum Amp (Ipm) : Above 3.0 Amps
- PV total capacity : 550 Wp and above
- Number of Module in series : 1 nos.
- Battery capacity (Deep Cycle) : 450 Ah (438 Ah and above in 10 hours rate)
- Charge Controller Capacity : 40 Ah (34 Ah and above, 12V DC,)
- Inverter Capacity (Sine wave) : 1 kW (Out put 220 V, 50 Hz)

Emphasis is placed on the availability of equipment in the commercial market. Therefore, the storage battery and inverter capacity were adjusted to match the capacity that can be obtained on the market, and a system unit price was computed. Referring to the system equipment currently available on the market in Bhutan, the price of the system described above is estimated to be around US$4,128. This system price does not include the cost of transportation, installation, excavation and so on. Table-11.3.4 below summarizes the cost of a large scale PV power generation system.

Table-11.3.4 Cost of a Large Scale PV Power Generation System

Item	Required		Market		Cost (US$)
	Qty.	Unit	Price	Unit	
PV Module	550	Wp	152	Nu./Wp	1,857.8
Inverter (1 kW rating)	1	Nos.	60,000	Nu./kW	1,333.3
Charge Controller (12 VDC, 40 Amp)	1	Nos.	7,700	Nu./nos.	171.1
CFL Lights 11 Watt (14 W with 80% eff.)	5	Nos.	1,280	Nu./nos.	142.2
Battery (90 Ah, 12 V Deep cycle)	5	Nos.	4,400	Nu./nos.	488.9
Asocceries (Wire 70 m, Nails, Screw and so on)	1	Set	4,000	Nu./Set	88.9
				Total	4,082.1

Prepared by JICA Study Team

In the case of the large scale PV power generation system, the effective use of the system becomes possible in the same way as the small scale PV system. For example, if the CFL lamps are replaced by LED lamps, it is possible to use a 15 W radio/cassette for 5 hours a day, and increase the number of lamps from 5 to 7. In this case, the system cost would not change much because there is no need to change either the capacity of the storage battery or the charge controller. If there is no change in lamp numbers or usage hours, the capacity of the system would become smaller and the system cost would decrease slightly. Since the lifetime of LED lamps is very long, regular exchange is not required. Furthermore, when this type of system is designed for operation in a group of surrounding households, rather than individual systems of each household, the system equipment can be shared,. This will reduce the system cost. However, the system would requires a larger space, and system operators would be needed too.

(2) Wind Power Generation Systems

Even though wind speed data is indispensable for calculating the capacity of wind generator systems, there are no ground observation data in Bhutan. Therefore the equipment capacity of wind power generation systems that will match the local demand has been calculated in the same way as used for the PV power generation systems described above. This was necessary in order to decide the size of the equipment that needs to be installed. Generally, computation of the capacity in this way is not an appropriate method. However, here the capacity has been calculated for the purpose of the comparison only.

Wind generators need to be chosen in such way that when a system is built, it will supply stable power constantly through the whole year in the same way as in PV power generation systems. As the price of the wind generator increase for smaller the sized units, here only systems that could support use of an electric rice cooker are considered. This is the same case as for a large scale PV power generation system. **Table-11.3.5** below summarizes the design parameters used to calculate the capacity of a wind generator.

Table-11.3.5 Design Parameters for a Wind Power Generation System

No.	Parameter	Value	Unit	Remarks
1	Total load in a day (AC)	1.08	kWh/day	Assumption
2	Peak load	0.71	kW	Assumption
3	Capacity factor	13	%	To get the actual output.
4	Conversion efficiency	80	%	Generated power to charge the battery.
5	Inverter efficiency	80	%	Depends on manufacturer, type of waves and load factor.
6	Charge controller consumption	60	mA / hour	Depends on manufacturer.
7	Columbic efficiency	90	%	To charge the battery effectively.
8	Battery depth of discharge (DOD)	80	%	Maximum useable capacity.
9	Days of autonomy	3	days	Days of reserve.
10	Temperature de-rating factor for battery sizing (at -15 deg Celsius)	80	%	If temperature changes, value changes.
11	Battery rate factor	1.4	factor	To bring the battery back to the manufacturer's standard rate.
12	System voltage (DC)	12	V	To adjust the availability of equipment.

Prepared by JICA Study Team

When a system is built based on the parameters shown in **Table-11.3.5** above, the form and size of the system are:

- Required Wind Generator Capacity : 0.6 kW and above
- Wind Generator Capacity : 0.9 kW (Purchase possible capacity)
- Battery Capacity (Deep Cycle) : 540 Ah and above (at 10 hours rate)
- Charge Controller Capacity : 60 Ah (12 V DC)
- Inverter Capacity (Sine Wave) : 1.0 kW (Out put 220 V, 50 Hz)

When constructing the system, emphasis must be placed on the equipment that can normally be purchased on the market in Bhutan. Therefore, the unit price is computed by adjusting the capacity of the wind generator, storage battery and inverter to match the capacity that is available on the market. The cost of the system described above is estimated to be US$4,716 when the present market base price of the equipment is used. This system price does not include the cost of transportation, installation, excavation and so on. **Table-11.3.6** below summarizes the cost of the wind power generation system.

Table-11.3.6 Cost of Wind Power Generation System

Item	Required		Market		Cost (US$)
	Qty.	Unit	Price	Unit	
Wind Turbine	0.9	kW	2,609	US$/kW	2,348.1
Inverter (1 kW rating)	1	Nos.	60,000	Nu./kW	1,333.3
Charge Controller (12 VDC, 60 Amp)	1	Nos.	13,000	Nu./nos.	288.9
CFL Lights 11 Watt (14 W with 80% eff.)	5	Nos.	1,280	Nu./nos.	142.2
Battery (90 Ah, 12V Deep cycle)	5	Nos.	4,400	Nu./nos.	48.9
Asocceries (Wires 70 m, Nails, Screw and so on)	1	Set	4,000	Nu./Set	89.9
				Total	4,690.3

Prepared by JICA Study Team

In the case of the wind generator, the cost varies depending upon manufacturer, structure of the wind generator and size. At present, it is not possible to purchase these units on the commercial market in Bhutan. Therefore, the price of the system is calculated based on the availability of equipment from foreign sources. Here, emphasis has been given to selection

As a result of the calculation, it was determined that wind power generation systems are more costly than PV power generation systems. However, as there is not sufficient energy potential data, this determination only represents a prediction. In the case of the wind power generation system, if actual renewable energy potential data is measured and systems are built, it will be possible to reduce the days of autonomy and the resultant cost of the system will become cheaper. Depending upon wind patterns, if it is possible to make a hybrid system that combines a PV and wind power generation system, then each sub-system will become smaller in size and much more reliable. The result is that the overall system cost will become cheaper.

(3) Large Capacity Double-Layer Electric Capacitor

In accordance with the Rural Electrification policy for sustainability a proper disposal or recycling system is needed for batteries that are no longer usable. This will avoid possible environmental hazards caused by improper battery disposal. However, the financial cost of doing this may be more than is affordable by each individual household or by the respective organization/institution (e.g. Gewog administrators). Even though it is rather costly, considering the previously mentioned facts, the use of large capacity double-layered electric capacitors could be an alternative option to the use of storage batteries. The life of these capacitors is considerably longer than that of storage batteries. For example, it has nearly 10 times longer than shallow cycle batteries (e.g. a truck battery) and more than 2 times longer compared to deep cycle batteries. At present, large capacity double-layered capacitors are more than 10 times more expensive than a comparative storage battery. In addition, large capacity double-layered capacitors are not available commercially at present, as they are manufactured only on an actual order basis. Although the cost of the capacitors is rather high, manufacturers are working hard to commercialize their products as well as to reduce the price. Even so, some manufacturers in Japan have plans to put their products on the market from middle of 2005, but their plans have not yet been publicly announced. Once the actual market price of the large capacity double-layered capacitors is available, the cost estimation for the SHS should be done by applying those values.

11.3.3 Biomass Energy

(1) Outline

Electricity generation systems that use biomass are categorized into three types:

a) Direct combustion of biomass in a boiler-turbine to generate electricity,

b) Biomass gasification to produce a fuel for powering an engine generator, and

c) Biomass fermentation to produce a fuel (methane) for fuel and powering an engine generator.

The characteristics of the above systems are summarized in the **Table-11.3.7** below. The scale of a biomass boiler-turbine electricity generation system applies to grid supply, for which the established power source is a large hydro system in Bhutan. Thus, a boiler-turbine type of generator would not be suitable for use as an off-grid power source. As for gasification, biomass collection is necessary, such as rice husks, wood chips, or saw dust. The amount of biomass that needs to be collected is on the scale of rice mill or saw mill production from the economic point of view. It is highly possible that such places are already connected to the grid, or are to be electrified by grid extension, and are not suitable for use of an off-grid power source.

Table-11.3.7 Types of Biomass System for Electricity Generation

System Type	Boiler-turbine generation plant	Gasification	Methane Fermentation Biogas
Outline	Burn biomass directly in a boiler, rotate a turbine with steam pressure, and generate electricity.	Use a gasification system to produce a gas mixture of hydrogen and carbon monoxide (syngas),as a fuel, rotate an engine, and generate electricity.	Use anaerobic fermentation to produce methane (gas) fuel, rotate an engine, and generate electricity.
Scale	1-10 MW	5-1000 kW	1 kW-150 kW (20% efficiency)
Strong Point	・ Applicable to a large scale.	・ Applicable to 10-1,000 households. ・ Small capital investment. ・ Suitable for rice mill and sawmill.	・ Applicable to household scale. ・ Small capital investment. ・ Thermal supply is possible by the direct combustion of methane. ・ Good quality liquid fertilizer is also obtained.
Weak point	・ When the fuel moisture content is high, combustion efficiency is reduced. ・ Large scale collection of material is necessary. ・ Complicated system and large initial capital cost.	・ When the fuel moisture content is high, the efficiency of the process is reduced. ・ Collection of material is necessary.	・ Moist materials can be used. ・ Material collection work is a problem. ・ An engine-generator is needed to generate electricity.

Prepared by JICA Study Team

In contrast, biogas (methane) produced by biomass fermentation is applicable to household-scale energy consumption. Assuming 25% of animal droppings and human excrement can be collected for a household, the droppings produced by 10 head of cattle or 28 pigs is estimated to be needed to cover the demand of 120 kWh/month (see Chapter 12) when biogas energy is converted to electricity. However, it would be much more efficient to burn the biogas directly to supply the energy for cooking from a gas stove or a light from a gas lantern. If this was done, the cooking heat requirements of one household with 5 families could be met using the droppings produced by 1 to 2 head of cattle or 4 to 5 pigs. This approach is applicable to isolated households that conduct small-scale livestock breeding. When the gas is burnt directly for cooking or lighting, a gas engine and a generator is not needed, which makes the system simple and inexpensive. However it is noted that for a gas lantern 97% of the energy is released as a heat. It would be no problem to use the gas lantern outside the house, but indoor use would need to be selective, especially in summer months.

Accordingly, the proposed policy for the utilization of biomass in Bhutan is that biogas be used as the energy source for cooking and that a photo-voltaic (PV) system be used for lighting. Therefore, use of a biogas system for cooking would supplement the off-grid solar home (small scale PV) system used for lighting.

(2) Cost for Biogas Facility

When the biogas (methane) is supplied to cooking, approximately 1.5 m^3/day of gas is needed per a household. From experience gained in other countries, 0.25 m^3 of gas is produced per 1 m^3 of a tank volume. Consequently, a fermentation tank having a volume of 6-8 m^3 is needed for household use. The cost estimation for a standard sized tank (8 m^3) is shown in **Table-11.3.8** below.

Table-11.3.8 Cost of Biogas Facility for a Household Scale (8m^3 tank)

Item	Q'ty	Unit	Unit Cost	Price (Nu.)	Note
Tank					
Cement	6	bag	315	1,890	1 bag = 25 kg
Sand	1.5	m^3	1190	1,785	can be prepared locally
Gravel	2	m^3	1190	2,380	
brick	300	pieces	4.8	1,440	
Timber	1	L.S.	775	775	
Insulator	25	m^2	630	15,750	Depends on ambient temperature
Pipe					
PVC pipe 8'	3	m	2250	6,750	
PVC Pipe 4'	1.5	m	585	878	
PVC bend	8	pieces	150	1,200	
Vinyl hose	20	m	122	2,440	
Pressure meter	1	Set	850	850	
Desulfurization					
PVC pipe	0.4	m	2250	900	
Ian oxide	8	kg	150	1,200	can be obtaind from waste construction material
Saw dust	5	kg	10	50	
Lime	5	kg	50	250	
Labor work					
Skilled engineer	5	man-days	300	1,500	
Unskilled labor	10	man-days	150	1,500	
Transportation	1	L.S.	5000	5,000	per a track
TOTAL				46,538	
TOTAL in US$				US$1,034	

Prepared by JICA Study Team

The cost per household is estimated to be about US$1,000. However, the price will vary depending on transportation costs and the need for an insulator. The volume of gas generated by the fermentation process depends on the temperature. The temperature of the inside of a tank needs to be more than 20 degrees Celsius. Therefore, a fermentation tank should be laid under the ground surface and be covered by an insulator. The insulator cost accounts for a high percentage (34%) of the items listed in the cost estimate. In southern areas of Bhutan, where the elevation is low and temperatures are comparatively high throughout a year, it would be possible to decrease the cost by reducing the amount of insulation material that is used.

It is essential that users of the biogas system continuously collect the biomass, i.e. livestock dungs, to continue the operation of the biomass fermentation process. Using a biogas system will reduce the amount of labor work for firewood collection, and contribute to forest preservation. However, the willingness and commitment of users for the introduction and continued operation of a system greatly affects the sustainability of the system.

It takes about 3 to 6 months to start the production of biogas after installation of the tank. In order to reduce the startup time, it is suggested that users obtain “seed” material from another operational biogas tank that already has methane fermentation bacteria.

(3) Guidelines for the Introduction of a Biogas System

As discussed above, the current barrier for the introduction of biogas is thought to be that there is little awareness of the technology in Bhutan. Accordingly, it is proposed to introduce the following three processes:

Stage 1: Pilot Project Stage (experimental introduction): 1 year

Stage 2: Promotion Stage (for promotion and publicizing the technology): 1.5 years

Stage 3: Private Development Stage (for installation of systems by the private sector)

Stage 1, is a pilot project stage that will be set up by the DOE-RED (Renewable Energy Division). The purpose of is the pilot project is to find and solve operation and maintenance problems for household use. It is also the stage where personnel from DOE-RED will obtain skills and experiment with the system.

DOE-RED will select several households after collection information for a candidate people who hope to introduce biogas for off-grid households, and install biogas generation facilities. Technical assistance from donors will be applicable for this project. **Table-11.3.9** below shows various assistance schemes (mainly from Japan) that are possible to apply to the introduction of biogas. Depending on the scheme, the main implementation agency should be a NGO or a local government such as a Dzongkhag, Gewog, or village. The DOE-RED personnel will participate in the project as the governmental-side manager.

Table-11.3.9 Assistance Schemes for Biogas Introduction

Name of Schemes	Budget	Fund Source	Outline
Pilot plant included in the Feasibility Study fore rural electrification	(Included in the budget for a development study)	JICA	Includes biogas pilot plant construction and technical assistance as a scope of the feasibility study for rural electrification.
Grass Roots Grant	10 million Yen (US$90,000@ 1$=110JPY)	EOJ	The administrative channel is the Embassy of Japan in India. It is impossible for the central government to be a main implementation body. NGO, village, and local government will be the main management body.
PROTECO	According to JICA country-based technical assistance budget (around 100 million yen)	JICA	Possible to apply for rural development and environment preservation. There are two types: host country's request type and JICA's development theme type. The technical adviser must be from a Japanese private company or organization. It aims technology transfer of Japanese technology.
GEF-SGP	US$ 50,000	UNEP/ UNDP/WB	The target is the prevention of the Climate Change. The implementation body will be a NGO or CBO (Community Based Organization). There are 728 installation examples in Nepal (as of December 2004).

Prepared by JICA Study Team

In addition to the above, grant assistances from India, Nepal, and European Countries are also be possible. In particular, India and Nepal have good experience of biogas introduction, for example, developing promotion programs for introducing private sector projects for biogas to households. When biogas is accepted in Bhutan, their interest will be not small since those private companies will have a good market.

When selecting households to be used as pilot project tests sites, it is important to select semi-agricultural or semi-pastoral households that already collect livestock droppings for use as fertilizer. As there is no experienced private sector group in Bhutan, the contractor may need to be selected from other country at first. The responsible DOE-RED officers will participate in the installation work with the private company. During the implementation, issues on the operation of biogas facilities are to be found and countermeasures for solving problems are to be studied. The DOE-RED officers will be in charge of the selection of the households, education of the residents, and management of the installation work. Also, they will monitor the facility and its operation once or twice a month after the biogas is being generated and utilized as an energy source.

After confirmation that there are no major issues for implementation or management of biogas systems, and ensuring that any required countermeasures have been determined, the implementation will shift to Stage 2: Promotion Stage. One or more off-grid villages in each Dzongkhag will be selected as biogas promotion bases. Biogas systems will be installed in several households in each village. Candidate villages may be ones that is waiting for the grid extension to occur in the 11th FYP.

The Promotion Stage implementation will be contracted to the private sector after bidding. At this stage, requests for the participation of private companies with enough experience in other countries, such as India and Nepal, may be issued. In this case, if the project is carried out on condition of a joint venture with Bhutan companies and entrepreneurs that currently have no experience with biogas systems, know-how will be developed in Bhutan's private sectors.

The Promotion Stage is defined as a promotion project. Therefore, the selected sites should have good accessibility by the road, as the aim is to appeal to surrounding villagers and make the use of biogas systems more widespread. The administrative system set up for the Promotion Stage should encourage the private sector, and the reward obtained by the companies should be tied to the actual spread of biogas system users. For example, subsidies could be provided, based on the installation results.

In the Promotion Stage, it is preferable that part of the installation cost be recovered from users. This will enhance the user's sense of ownership for the biogas system, as well as the solar home system described in **Chapter 19.4.3**. It would also be possible to utilize the funding schemes presented previously in **Table-11.3.9** above.

The last stage of the biogas system implementation is Stage 3: Private Development Stage. Here, all advertising and installation of biogas systems will be done by the private sector. There will be a need to increase the incentive for private sector development by introducing subsidies, taking the user's income into consideration. In Nepal, the government applies a system to provide subsidies (with limitation amount) according to the volume of the biogas tank and the remoteness of the user. An example of the subsidy system is described in **Appendix C-IV-1**. DOE-RED will prepare the plan for the target biogas system introduction level, determine and provide the subsidy, manage private sector licenses, and carry out regular monitoring with the aim of achieving the sustainable spread of biogas systems in Bhutan.

The introduction of biogas systems is strongly linked to agricultural development. In particular, operation of the biogas system could be made an integral part of farming operations. For example, studies of livestock need to be made for planning animal dropping (feedstock) collection for energy potential and tank design and utilization of liquid fertilizer after the fermentation process has taken place. Because of this, it is recommended that cooperation with Ministry of Agriculture be done to share information and roles for the publicity, education, installation, operation and maintenance of biogas systems.

Table-11.3.10 below shows a schedule for the biogas system experimental Pilot Project, Promotion Stage, and Private Development Stage as a reference for future planning. It should be noted that the preferred season for starting biogas production is in the summer, when the temperatures are high and methane fermentation bacteria will be more active. The schedule considers the season for starting biogas production.

Table-11.3.10 Schedule for Biogas Introduction by Stages

Year/month	2007				2008				2009				2010			
	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.	Jul.	Oct.	Jan.	Apr.
Stage-1: Pilot Stage																
Planning and fund arrangement																
Technical training of personnel																
Selection of pilot households																
Selection of contructor																
Installation and operation																
Monitoring and evaluation																
Stage-2 Promote Stage																
Planning and fund arrangement																
Raise and Selection of pilot households																
Bidding and Selection of contructor																
Installation and operation																
Promotion activity																
Monitoring and evaluation																
Stage-3 Private Stage																
Subsidy planning																
Advatisement and promotion																
Implementation by private sector																
Operation by household																
Periodical monitoring																

Prepared by JICA Study Team

CHAPTER 12 POWER DEMAND FORECAST

12.1 Demand Forecast Method in the Past Rural Electrification Projects

The rural electrification (RE) projects in Bhutan have been implemented under assistance of the Asian Development Bank (ADB). The numbers of electrified households planned were 3,000 by the ADB/RE-1 project during 7th Five Year Plan (FYP) period, and over 8,000 by the ADB/RE-2 project in 8th FYP. The ADB/RE-3 project is currently in progress to electrify 8,357 households during 9th FYP period.

12.1.1 Demand Forecast Method of ADB/RE-1 (by WORLEY)

A demand forecast model LOADFOR-R for rural areas (Microsoft Excel program) developed by WORLEY was applied to estimate peak power demand and annual energy demand.

The projection was formulated based on results of the field survey for the socio-economic situation in 12 Dzongkhags. The base data used were number of customers for domestic / commercial / public / industrial sectors, growth rates of population / energy consumption / electrification of each sector, diversity factor for industrial demand, and daily load pattern of each sector. The forecast model can set the gradual and rapid growths.

12.1.2 Demand Forecast Method in ADB/RE-2 (by TATA)

The project covered 17 Dzongkhags in the eastern, central, and western regions of the country. The socio-economic survey was conducted in two villages (electrified and non-electrified) in 17 Dzongkhags. Information from the survey was reflected in the demand forecast. Customers were classified into domestic, commercial, public and industrial sectors.

(1) Domestic Demand

Energy consumption per metered consumer in the recently electrified village was estimated 60-80 kWh/month, while the average consumption per consumer without a demand meter in Trongsa was estimated to be 103 kWh/month. TATA mentioned that the willingness to pay for electricity was 200Nu./month (about US$4.5/month). This amount was equivalent to consumption of 400 kWh/month. However, in consideration of the future increase of power tariff, TATA assumed the reasonable consumption per consumer to be 180 kWh/month.

TATA estimated the average energy consumption of domestic customer to be 120 kWh/household in the initial phase of electrification (2001) and to increase to 180 kWh/household at 10th year. It results in the average annual growth rate of 4% (3% as a whole). They also assumed that the initial peak demand of electrified consumers of 1.2 kVA/household would grow to 1.6 kVA/household (5 A) at 10th year with annual growth rate of 2%.

(2) Commercial Demand

Commercial consumers in the rural areas are mostly small shops or stores running in their residences. The average load was assumed to be 100 W for lighting and additional 2 kW for heating in winter season. Average annual consumption was estimated at 2,800 kWh with 10 hours/day for lighting over a year and 10 hours/day for heating over 4 months, and an average annual growth rate of consumption was assumed to be 2%.

(3) Public Demand

Public consumers are hospitals, schools, offices, etc. Average load of a customer was assumed for a 100 W light per room and a 2 kW heater (2 kW×2 for schools). Average annual energy consumption per room was estimated at 3,300 kWh for a hospital, 2,700 kWh for a school and 1,600 kWh for an office taking into account holidays of 2 days/week for offices and 1 day/week with 2 months vacation/year for schools. Average annual growth rate of the sector was assumed to be 2%.

(4) Industrial Demand

Industrial demand in the rural areas is mainly made up of flourmills, sawmills and rice mills. There were no large industries in the study areas, and therefore the future demand was estimated on the existing consumers only. It was assumed that a factory would be operated for 2,400 hours/year and a 2 kW heater would be used for 800 hours/year by a factory

12.1.3 Demand Forecast Method in ADB/RE-3 (by SMEC)

The maximum demand per household is assumed to be 2 kW for designing. No other details for the forecast were indicated.

12.2 PSMP's Methodology for Power Demand Forecast

Demand forecast are conducted category-wise and district-wise for 4 sectors of domestic, industrial, commercial, and public consumers up to the year 2022. Energy sales to each category are projected form the sales in the year 2001/02, and then total energy requirements of the country are estimated as the sum of the sales to the existing consumers, sales to new consumers connected in the year, and the assumed system losses.

Energy sales to domestic consumers are estimated from GDP growth per capita and income elasticity. Energy sales to industrial, commercial and public (government) consumers are estimated on the basis of GDP growth rate of the sector and GDP elasticity. Assumptions applied for the demand forecast in PSMP are as follows:

(1) Domestic Demand (Household Demand)

(a) Annual growth rate of GDP per capita (8.0-6.0%) and income elasticity (1.3-1.2%) are the main factors for the forecast. Data on the income elasticity is not available in Bhutan, and therefore data of the similar South Asian countries is commonly applied for both urban and rural areas.

(b) New connections of domestic consumers to the grid will increase at an annual growth rate of 17% to 4% (different rate to different Dzongkhag) from total numbers of domestic customer in the previous year.

(c) Monthly average energy consumption of new consumers in the first year after electrified is assumed at 90 kWh to 50 kWh (different consumption to different Dzongkhag). It is assumed that initial consumption of later connections to grid will be less.

(2) Industrial Demand

(a) Consumptions of large scale industries are expected to remain unchanged in the foreseeable future.

(b) Annual GDP growth rate of small scale industries is assumed at 10%, and it will gradually decline to 9% to 8% after the year 2013.

(c) GDP elasticity of small industries is assumed at 1.2 from data in other Asian countries.

(3) Commercial Demand

(a) Annual GDP growth rate of the sector is assumed at 6.5%, and after the year 2018 it is assumed to gradually decline to 5.0%.

(b) GDP elasticity is assumed at a constant 1.4 for the entire forecasting period.

(4) Public (Government) Demand

(a) Annual GDP growth rate of the sector is assumed at 6.0% for the entire forecasting period.

(b) GDP elasticity is assumed at a constant 1.3 for the entire forecasting period.

(5) Energy Loss in the Transmission System

Loss rate in the period of 1994 to 2000 is assumed for individual Dzongkhag. The initial loss rate of Gasa Dzongkhag (not electrified by grid at present) is assumed at 20%. The loss rate is assumed to be constant for some Dzongkhags and to be gradually declined for other Dzongkhags.

(6) Load Factor

The factor is assumed from the past performance. Factors of 76% to 38% for the initial year (2002) are expected to improve, but the factors in many Dzongkhags will still remain at low as 30% to 45% even after 2018. The factors after 2018 of the industrialized Chukha and Samtse Dzongkhags are, however, assumed to be 65% and 60%, respectively.

(7) Energy Demand and Peak Load Demand

Total annual energy requirement of each Dzongkhag is estimated as the sum of the annual energy consumption of each sector and the annual system energy loss. The peak load of each Dzongkhag is worked out from the total energy requirement and the assumed load factor.

The above is an outline of PSMP's methodology for demand forecast. Base case demand forecast does not take into account the demands proposed by new large scale industrial estates or additional demand requested by the existing large scale industries. The reason is that the realization and timing of the proposed demands are uncertain. However, some of those huge industrial demands are included in the forecast for transmission line planning.

12.3 Method of Power Demand Forecast in Non-Electrified Villages Applied to the Master Plan

12.3.1 General

The villages for this master plan study are mostly small-scale. The average number of a village is around 10 households according to the results of the non-electrified village survey by the Study Team. Therefore, power demands of rural villages in Bhutan will be mainly from domestic sector. In the villages that are somewhat larger in size, households would be also the major consumer of electricity, but there would be additional power demands from commercials/shops, schools, clinics, temples or small industries with smaller demands.

In addition to "Survey on Non-Electrified Villages", the Study Team conducted the survey to 13 electrified villages and 51 electrified households for investigating real states of possession and usage of home electric appliance. Results of the survey were used as basic data for the power demand per household.

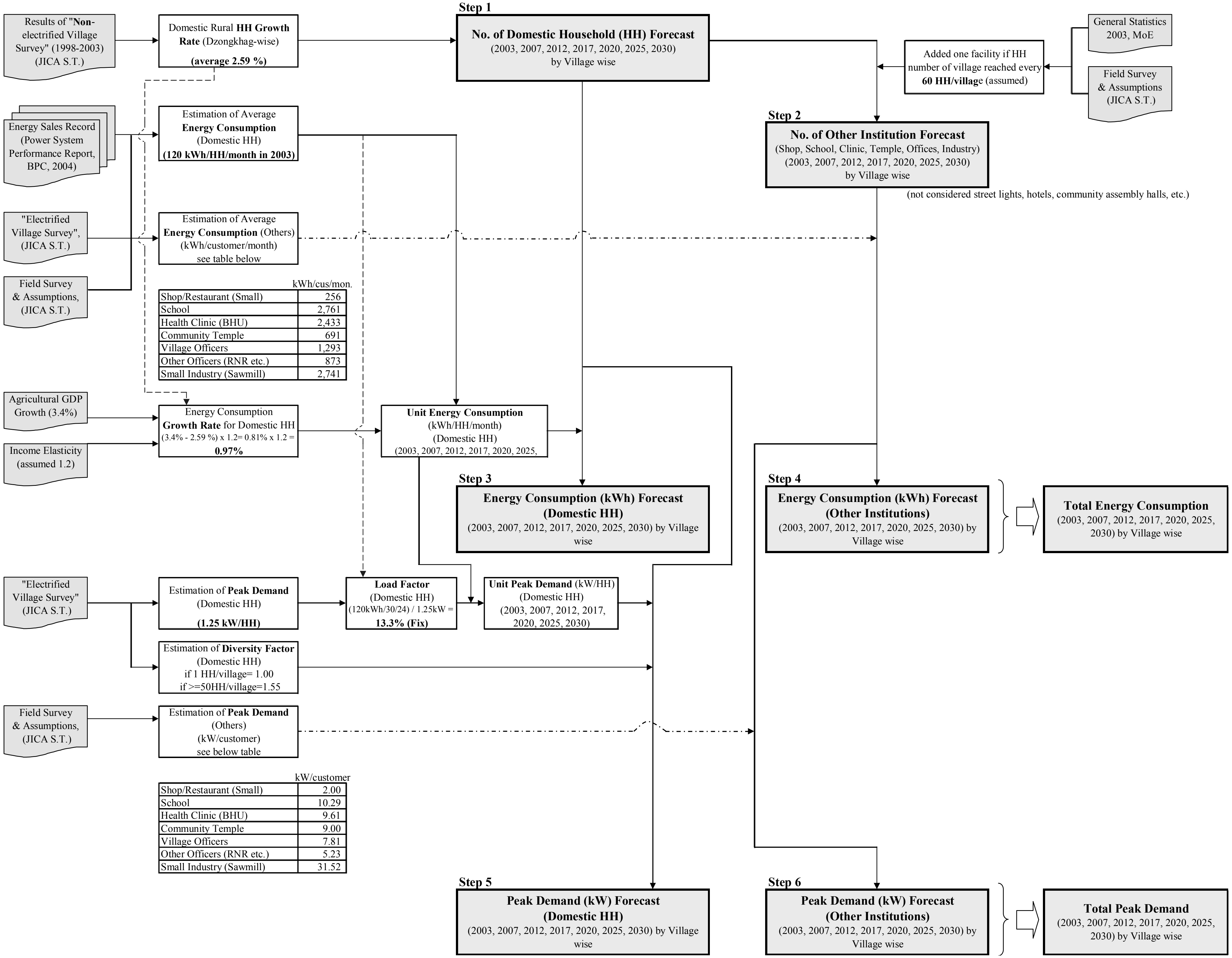
All results of the surveys to 51 domestic consumers and 12 small shops/restaurants are summarized in **Appendix B-III**. The survey results revealed such facts that 65% of the electrified households utilize electric rice-cooker (640 W in average) and 29% households use electric water pot.

A peculiarity of energy demand of rural villages in Bhutan is that electricity is mainly consumed for lighting and cooking. Therefore, the peak of electricity consumption in the country occurs in the same time zone resulting in a low load factor leading to necessity of comparatively large conductor.

In this Mater Plan Study, the Team conducted the Dzongkhag-wise power demand forecasts for both the non-electrified areas and electrified area. The former forecast is used for planning of power facilities in non-electrified villages and the latter is to be used for planning of reinforcement of the existing facilities.

12.3.2 Method of Power Demand Forecast in Non-Electrified Villages

Based on the results of the analysis of actual electric power utilization of the electrified village, unit power consumption per consumer of each sector (domestic, commercial, industry and public) were estimated. Applying the unit energy consumption to number of households and considering growth rate of consumption of each sector, the Team achieved the demand forecast by the specified horizon year 2020. The forecast was carried out in 4 phases of the years 2007, 2012, 2017 and 2020 corresponding to the National Five Year Plan phase. The forecasting period is extended to the year 2030 in accordance with the request of DOE/BPC. The forecast for extended period is prepared at the same trend of forecasted demand.



	kWh/cus/mon.
Shop/Restaurant (Small)	256
School	2,761
Health Clinic (BHU)	2,433
Community Temple	691
Village Officers	1,293
Other Officers (RNR etc.)	873
Small Industry (Sawmill)	2,741

	kW/customer
Shop/Restaurant (Small)	2.00
School	10.29
Health Clinic (BHU)	9.61
Community Temple	9.00
Village Officers	7.81
Other Officers (RNR etc.)	5.23
Small Industry (Sawmill)	31.52

Prepared by JICA Study Team

Figure-12.3.1 Work Flow of Power Demand Forecast in Non-Electrified Village

(1) Step-1 (Estimate of Number of Household)

The Bhutan's first national census was taken in 2003 and the Ministry of Home and Culture Affairs is currently collecting and analyzing the census data. Details of the process are currently not disclosed. Therefore, such data as population, number of households, their growths and other information of individual village necessary for the demand estimate are unknown at this stage. Under the situation, the Study Team estimated Dzongkhag-wise growth rates of households in the non-electrified villages in the period of 1998 to 2003 from results of the Team's field survey. **Table-12.3.1** summarizes the Dzongkhag-wise number of households and average growth rates, from which numbers of households were projected by 2020. Average growth rate over the country worked out is 2.59%. The rate deems appropriate comparing with the annual growth rate of population to be 2.5% generally admitted in Bhutan.

Recent numbers of the households in Tsirang, Sarpang, Dagana and Paro Dzongkhags have been rapidly increased. The growth rate in the period of 1998 to 2003 was more than 3% per annum.

Since continuance of such higher rate to the future is doubtful from the points of agricultural land restriction, the projected rate of more than 3% was assumed to be reduced by 1% every 5 years after 2007. The projected number of category-wise consumers is shown in **Appendix B-III**. Number of households is a key factor of the demand forecast and should govern accuracy of the forecast. Frequent review on the estimated number of households should be carried out for raise of accuracy by updating such key data as growth rates of population and household, average people per household, resettlement of people, etc.

Table-12.3.1 Projected Non Electrified Household by Dzongkhag-wise

No.	District	Non Electrified HH		N.E. Pop.	HH size	**Annual HH**	Assumed HH Growth Rate (%)					Projected Non Electrified Household				
	(Dzongkhag)	1998	2003	2003	(Person/HH)	**Growth ('98-'03)**	2003	2007	2012	2017	2020	2003	2007	2012	2017	2020
1	Thimphu	125	132	908	6.9	**1.10%**	1.10%	1.10%	1.10%	1.10%	1.10%	132	138	145.60	153.76	158.87
2	Chukha	1,535	1,814	12,319	6.8	**3.40%**	3.40%	2.40%	2.40%	2.40%	2.40%	1,814	1,994	2,245	2,527	2,713
3	Haa	215	248	1,663	6.7	**2.90%**	2.90%	2.90%	2.90%	2.90%	2.90%	248	278	321	370	403
4	Paro	138	162	1,250	7.7	**3.26%**	3.26%	2.26%	2.26%	2.26%	2.26%	162	177	198	221	237
5	Samtse	3,820	4,318	33,757	7.8	**2.48%**	2.48%	2.48%	2.48%	2.48%	2.48%	4,318	4,763	5,384	6,086	6,550
6	Tsirang	1,684	2,186	18,922	8.7	**5.36%**	5.36%	4.36%	3.36%	2.36%	2.36%	2,186	2,593	3,058	3,436	3,684
7	Dagana	1,473	1,765	12,442	7.0	**3.68%**	3.68%	2.68%	2.68%	2.68%	2.68%	1,765	1,962	2,240	2,557	2,768
8	Punakha	246	263	2,089	7.9	**1.35%**	1.35%	1.35%	1.35%	1.35%	1.35%	263	277	297	317	330
9	Gasa	297	331	1,936	5.8	**2.19%**	2.19%	2.19%	2.19%	2.19%	2.19%	331	361	402	448	478
10	Wangduephodrang	1,570	1,714	12,167	7.1	**1.77%**	1.77%	1.77%	1.77%	1.77%	1.77%	1,714	1,839	2,007	2,191	2,310
11	Bumthang	394	446	3,137	7.0	**2.51%**	2.51%	2.51%	2.51%	2.51%	2.51%	446	492	557	631	680
12	Sarpang	2,022	2,570	19,116	7.4	**4.91%**	4.91%	3.91%	2.91%	2.91%	2.91%	2,570	2,997	3,459	3,993	4,353
13	Zhemgang	1,474	1,627	17,637	10.8	**1.99%**	1.99%	1.99%	1.99%	1.99%	1.99%	1,627	1,761	1,944	2,145	2,276
14	Trongsa	745	860	7,214	8.4	**2.91%**	2.91%	2.91%	2.91%	2.91%	2.91%	860	965	1,114	1,285	1,401
15	Lhuntse	1,262	1,377	8,827	6.4	**1.76%**	1.76%	1.76%	1.76%	1.76%	1.76%	1,377	1,477	1,611	1,758	1,852
16	Mongar	2,419	2,662	18,617	7.0	**1.93%**	1.93%	1.93%	1.93%	1.93%	1.93%	2,662	2,874	3,163	3,480	3,686
17	Pemagatshel	681	650	4,794	7.4	**-0.93%**	-0.93%	-0.50%	0.00%	0.00%	0.00%	650	637	637	637	637
18	Samdrup Jongkhar	3,268	3,573	25,853	7.2	**1.80%**	1.80%	1.80%	1.80%	1.80%	1.80%	3,573	3,837	4,196	4,587	4,839
19	Trashigang	1,942	2,087	15,175	7.3	**1.45%**	1.45%	1.45%	1.45%	1.45%	1.45%	2,087	2,211	2,376	2,553	2,666
20	Yangtse	1,037	1,157	7,835	6.8	**2.21%**	2.21%	2.21%	2.21%	2.21%	2.21%	1,157	1,263	1,409	1,572	1,679
Grand Total		26,347	29,942	225,658	7.5	**2.59%**	2.40%	2.17%	2.10%	2.05%	2.05%	29,942	32,895	36,762	40,950	43,702

Prepared by JICA Study Team
(Note-1)
The average growth rate of household (2.59%) is slightly bigger than the growth rate of population (2.5%). This deems to be caused by the trend towards the nuclear family in the rural region of Bhutan
(Note-2)
The record shows that the growth rate of household in Pemagatshel district is negative (-0.93%). In consideration that the tendency will cease in the future, the annual growth rates for the district are assumed to be -0.5%by the year 2007 and 0% after the year 2012.

(2) Step-2 (Estimate of Numbers of Other Consumers than Domestic Sector)

Following assumptions were set up for demand forecasts of public, commercial and industrial sectors in non-electrified villages.

- Educational facilities in the area are community school and primary school. In addition to the existing schools, a new school was assumed in every 60 households increase in the village. This assumption is made referring to information of General Statistics (2003 MOE) as shown in **Table-12.3.2** and results of the Team's field survey. The number of expected consumers by category is summarizes in **Appendix B-III** from Statistical Yearbook of Bhutan 2003 (National Statistical Bureau, Catalogue No. 101, March 2004, original source: General Statistics of MOE 2003). There were 188 community schools for 22,502 pupils over the country in the year 2003. Assuming average 2 children from a family to school, one school for 60 households was worked out. Average 3.1 teachers are assigned for a school, and 3 households for teachers was assumed per school. Other public facilities in a village are clinic, office, RNR and temple. A new facility will be added per increase of 60 households in a village.

Table-12.3.2 Number of Schools and Institutions, Staff and Students, Bhutan (2003)

Details	CPS	PS Primary Grade	LSS Junior High Grade	MSS High School Grade	HSS Higher Secodary School	Pvt.	Other Inst.	NFE Center	Total
Grade	**PP-VI**		**PP-VIII**	**PP-X**	**PP-XII**	**PP-XII**			
Number of School and Institution	**188**	**90**	**77**	**23**	**16**	**18**	**14**	**365**	**791**
Teaching Staff (Total)	**592**	**701**	**1,388**	**623**	**466**	**235**	**313**	**428**	**4,746**
National	586	679	1,178	426	287	154	239	428	3,977
Non-Bhutanese	6	22	210	197	179	81	74	0	769
Number of Students	**22,502**	**26,168**	**46,856**	**17,735**	**11,268**	**4,631**	**3,251**	**12,838**	**145,249**
Male	11,949	13,850	23,968	9,319	6,388	2,363		4,164	
Female	10,553	12,318	22,888	8,416	4,880	2,268		8,674	
Student to Teacher	**1:38**	**1:37**	**1:34**	**1:28**	**1:24**	**1:20**	**1:10**	**1:30**	**1:31**
Number of Students per School	120	291	609	771	704	257	232	35	**184**
Number of Students per Household (Assumed)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	**2.0**
Estimated Number of Household per School	**60**	145	304	386	352	129	116	18	**92**
Number of Staff per	**3.1**	7.8	18.0	27.1	29.1	13.1	22.4	1.2	**6.0**

Source: "General Statistics 2003", Policy & Planning Division, MoE, Thimphu.

Notes) **CPS**: Community School, **PS**: Primary School, **LSS**: Lower Secondary School, **MSS**: Middle Secondary School, **HSS**: High Secondary School, **Pvt**.: Private School.

- Commercial sector in rural villages involves small shop (in a dwelling) and small restaurant. Hotel facility was not taken into account. As similar to schools, number of shop and restaurant was assumed to increase at a rate of one per 60 new households.

- Industrial consumer in rural villages is mostly sawmill. Peak demand of a sawmill is assumed to be 26.9 kW (31.5 kVA) referring to the Team's survey results to Haa Dzongkhag. A new sawmill was assumed to be added to a village for 60 new households.

The expected number of potential consumers in the non-electrified villages is projected in **Appendix B-III**.

(3) Step-3 (Estimate of Energy Consumption by Domestic Customers)

(a) Average consumption per household in electrified rural villages

Table-12.3.3 summarizes number of domestic consumers and average energy sales to the sector in rural areas recorded in BPC's Monthly Performance Reports. Average energy consumption of a consumer in the rural villages was recorded to be more than 100 kWh/month in Haa, Bumthang, Wangduephodrang and Thimphu Dzongkhags. The same records for the period of January to June 2004 after amendment of the reporting form indicate that the average monthly energy consumption per consumer was 81.6 kWh in the rural villages over the country. This quantum is confirmed to be appropriate by "Survey on Electrified Villages" and field survey of the Team. While, another average consumption was 109.3 kWh/month/household in Dzongkhags except those facing to shortage of energy supply and recently electrified.

Taking into account accuracy of demand meters installed in the consumers' buildings and non-technical loss (about 10%), average consumption of a domestic consumer in the rural villages was assumed to be 120 kWh/month as of 2003, based on which the forecast was conducted.

(b) Growth rate of energy consumption

Since the areas subject to this Master Plan are mainly farm villages, the growth rate of energy consumption was estimated on the basis of GDP growth rate and income elasticity of the country's agricultural sector. The GDP growth rate of agricultural sector is assumed to be 3.4% from the average rate of 1991-2003 announced by the Planning Commission. Since income data was not available, the income elasticity of 1.2 generally used was applied for the forecast. Accordingly, the growth rate of domestic sector in the rural villages was worked out below:

[(GDP growth rate of agricultural sector) – (average growth rate of domestic sector)] x (income elasticity) = (3.4% - 2.59%) x 1.2 = 0.97%

Sector-wise peak load (kW), monthly average consumption (kWh/month), and assumed parameters adopted to the forecast are summarized in **Table-12.3.4**.

(c) Energy consumption of a consumer and total consumption

Monthly energy consumption per household (unit consumption) was estimated from the above (a) and (b). Total annual energy consumption of the domestic sector was worked out using the unit consumption and number of consumers of Step-1 activity.

Table-12.3.3 Average Monthly Energy Consumption per Household by Dzongkhag

[Domestic Rural]

Unit: kWh/HH/Month

Year	Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	National Average
			Thimphu	Chukha	Haa	Paro	Samtse	Tsirang	Dagana	Punakha	Gasa	Wangdue phodrang	Bumthang	Sarpang	Zhemgang	Trongsa	Lhuntse	Mongar	Pemagatshel	Samdrup Jongkhar	Trashigang	Yangtse	
2002	7	Jul	176.0	149.1	154.5	127.7	89.6	52.7	20.7	97.8		92.0	99.9	82.8	24.5	77.4	85.5	50.1		66.9	64.8	68.3	**87.8**
	8	Aug	232.9	113.4	157.8	103.3	91.5	52.9	16.0	112.8		105.0	89.6	10.8	13.7	77.4	139.1	49.0		74.1	71.1	63.4	**87.4**
	9	Sep	130.7	109.7	155.8	154.5	94.1	50.5	6.4	121.3		92.0	90.8	92.4	16.0	79.7	97.7	43.9		74.5	67.8	32.2	**83.9**
	10	Oct	231.9	108.2	157.8	147.2	84.7	59.0	27.2	101.7		105.1	116.5	92.2	27.0	76.3	65.1	49.0		71.9	71.3	88.0	**93.3**
	11	Nov	231.1	142.0	143.8		89.2	56.2	25.1	105.4		113.9	94.3	88.9	28.4	77.5	99.3	54.4		76.6	84.0	60.3	**92.4**
	12	Dec	368.7	166.7			91.6	63.8	26.4	140.6		137.4	92.3	77.4	47.2	78.4	105.5	53.7		78.3			**109.1**
2003	1	Jan																					
	2	Feb																					
	3	Mar																					
	4	Apr																					
	5	May																					
	6	Jun																					
	7	Jul																					
	8	Aug																		77.4			
	9	Sep																		80.8			
	10	Oct																		83.1			
	11	Nov																		90.1			
	12	Dec																		82.9			
2004	1	Jan	134.4	97.7	131.4	210.4	71.2	32.1	60.4	132.6		139.0	93.6	112.4	61.7	70.3	69.2	93.9	40.7	62.1	66.1	47.7	**90.9**
	2	Feb	129.7	108.7	117.5	195.7	60.3	55.9	69.7	104.4		129.2	87.3	110.3	79.8	64.0	66.5	83.5	46.7	53.9	64.2	37.3	**87.6**
	3	Mar	114.5	82.6	105.6	182.1	77.6	33.8	66.7	101.9		97.9	79.2	99.0	46.5	65.7	61.8	71.9	40.3	53.4	60.8	39.8	**77.9**
	4	Apr	113.4	76.3	124.1	173.6	75.6	41.0	64.0	120.9		71.0	93.8	96.0	36.5	58.2	57.8	73.1	35.9	59.9	55.9	43.0	**77.4**
	5	May	133.2	78.3	113.2	187.0	80.2	53.6	49.3	112.4		85.2	110.6	125.9	36.5	62.7	52.1	59.2	34.7	69.9	52.9	35.6	**80.7**
	6	Jun	109.6	55.7	126.9	174.7	84.2	44.9	32.2	84.5		89.5	109.0	118.6	41.1	53.1	48.5	65.8	41.5	56.5	50.6	35.0	**74.8**
Ave (Jan.2004-Jun.2004)			**122.5**	**83.2**	**119.8**	**187.3**	**74.9**	**43.6**	**57.1**	**109.4**		**102.0**	**95.6**	**110.4**	**50.3**	**62.3**	**59.3**	**74.6**	**40.0**	**59.3**	**58.4**	**39.7**	**81.6**
Ave (Jan.04-Jun.04) w/o Power Supplhy Shortage Dzongkhag			**122.5**	**83.2**	**119.8**	**187.3**	**74.9**	P.Supply Interruption/ L.Shedding	P.Supply Interruption/ L.Shedding	**109.4**		**102.0**	P.Supply Interruption/ L.Shedding	**110.4**	Too Low Energy Consumption	P.Supply Interruption/ L.Shedding	Too Low Energy Consumption	**74.6**	Too Low Energy Consumption	Too Low Energy Consumption	P.Supply Interruption/ L.Shedding	P.Supply Interruption/ L.Shedding	**109.3**

Source: BPC, System Performance Report

Non-technical Loss	Assumed Ave. Consumption (kWh/HH/month)
10%	**120**

Note: Information in the above table is collected from the system performance reports monthly prepared by BPC's branch offices.since the amended form of the report did not include records of category-wise energy sales, information of energy consumption per household was not available for the year 2003.

Table-12.3.4 Estimated Initial Load/Consumption Parameters for Non-Electrified Villages

		Peak Load (kW/customer)	Energy (kWh/customer)
NON-INDUSTRIAL			
Domestic HH			
	Domestic HH (Average in 2003)	1.25	120.0
Commercial			
	Shop/Restaurant (Small)	2.00	256.1
Public Service			
	School	10.29	2,760.8
	Health Clinic (BHU)	9.61	2,433.1
	Community Temple	9.00	690.6
	Village Officers	7.81	1,293.4
	Other Officers (RNR etc.)	5.23	872.7
INDUSTRIAL			
	Small Industry (Sawmill)	26.90	2,741.0
	Flour mills	4.43	
	Water pumps		
	Average Efficiency (n) of Motor	0.8	
	Power Factor (cos-t)	0.8	
	Demand Factor ofMotor	75%	
	Diversion Factor for Motor	1.1	
	Small Industry / Saw mill (kVA)	**31.52**	
Income Growth and Income Elasticity			
	Agricultural GDP Growth Rate	3.40%	
	HH Growth Rate	2.59%	
	Growth Rate of Income	0.81%	
	Income Elasticity	1.2	
Diversity Factor			
	Village HH	Diversity Factor	
	50 HH	1.55	
	1 HH	1.00	
Average number of HH in Village for Estimation of Additional Facilities			
	Shop/Restaurant (Small)	60 HH	
	School	**60 HH**	
	Health Clinic (BHU)	60 HH	
	Community Temple	60 HH	
	Village Officers	use existing nos.	
	Other Officers (RNR etc.)	60 HH	
	Small Industry / Saw mill	60 HH	

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(4) Step-4 (Energy consumptions of other sectors than domestic sector)

(a) Estimate of average consumption

Average scale of facility was estimated referring to results of the Team's field survey. Assuming numbers of room/lamp/home-electric-appliances and their using hours, energy consumption and peak load were projected. **Appendix B-III** shows results of the projection.

(b) Sector-wise energy consumption

Sector-wise annual energy consumptions were Dzongkhag-wise projected from sector-wise number of consumers estimated in Step-2 activity and average consumption worked out in the above (a).

From the results of Step-3 and Step-4, annual energy consumptions were projected Dzongkhag-wise and sector-wise.

(5) Step-5 (Estimate of peak load of domestic sector)

(a) Peak load of a consumer and pattern of energy consumption

Peak loads of 1.25 kW in the winter season and 1.10 kW in the summer season were estimated from results of the "Survey on Electrified Areas" compiled in **Appendix B-III.**

Figure-12.3.2 shows the average daily load curves of 51 domestic consumers in the electrified rural area. The curves are typical pattern of household's energy consumption in farm villages of Bhutan. The first peaking time comes out around 5 to 6 o'clock for cooking, and other peak loads appear in lunch and dinner times. Load in the daytime except lunchtime and loads in the midnight and early morning are extremely low.

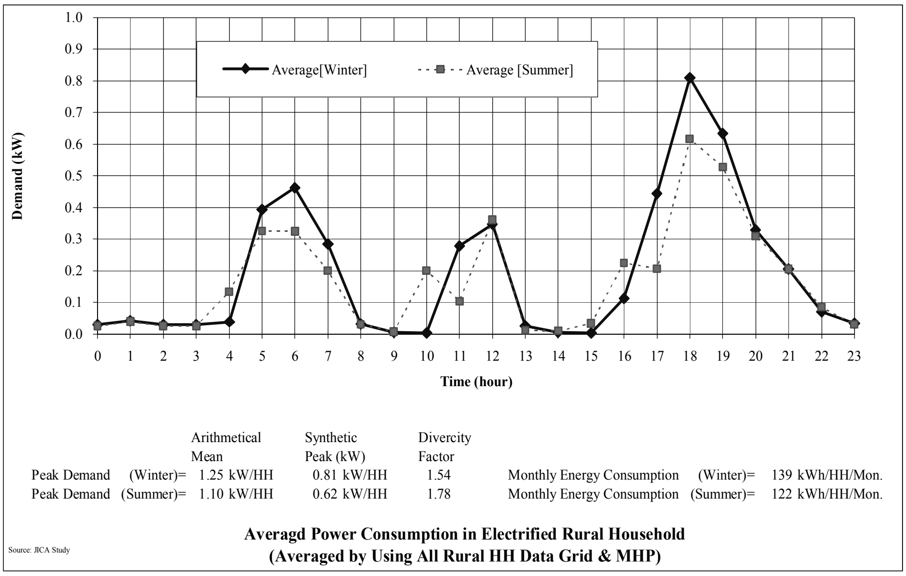

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Figure-12.3.2 Typical Daily Load Curves of Domestic Consumer in Electrified Rural Area

(b) Diversity factor

Peak load of the surveyed 51 households was in the range of 0.12 - 4.55 kW/household in the winter season and 1.10 kW/household in the summer season. Assuming those 51 households are in one village, peak load of the village with diversity factor is worked out from average load at each hour. Thus, average peak demand of a consumer was worked out at 0.81 kW in the winter season and

0.62 kW in the summer season. Diversity factor for villages of more than 51 households was estimated at 1.55 (=1.25/0.81).

(c) Load factor

Average monthly energy consumption in the rural villages is 120 kWh/household as discussed in the foregoing Section 12.3.3 (3) (a). Peak load of consumer is assumed at 120 kW as worked out in **Table-12.3.3**. Load factor of domestic sector in the rural villages is therefore 13.3%.

[(120 kWh/30 days/24 hours)/1.25 kW = 0.133]

This load factor is assumed to be constant through the study period.

(d) Peak load of domestic consumers (year-wise)

Peak load of a domestic consumer was worked out from annual energy consumption projected in the foregoing Section 12.3.3 (c) and load factor assumed in the above (c).

(e) Estimate of peak load of domestic sector

The peak load of domestic sector was projected from number of domestic consumers, peak load per household and diversity factor.

(Peak Load of Village) = [(Peak Load per Consumer) x (Number of Consumers)]/(Diversity Factor)

(6) Step-6 (Peak load of other sectors than domestic sector)

(a) Estimate of peak load per consumer

Peak load per sector-wise consumer was estimated from results of the Team's field survey (**Appendix B-III**). Thus estimated peak loads for various consumers are exhibited on **Figure-12.3.1**. The estimated loads were assumed constant throughout the forecasting period.

(b) Estimate of total peak load

Annual village-wise peak loads for the sectors were worked out from number of the sector consumers (estimated in Step-2) multiplied by the sector-wise unit peak load (estimated in the above (a)).

The peak load of village is sum of village-wise peak load of domestic sector and village-wise peak load of other sectors.

12.4 Method of Power Demand Forecast in Electrified Area

12.4.1 Outline

This part discusses the method of demand forecast of the present consumers (as of 2002/03). Demand of potential customers in non-electrified area is separately analyzed and forecasted in Clauses **12.2.2** and **12.5.1**.

The forecast is principally conducted on the basis of the historical tendencies of the power sector and under the following preconditions.

(a) Reference

- Power Data of 2002/03 (Twenty First Edition) of DOE
- Various information and data from DOE and BPC
- Final Report of PSMP (2004)

The "Power Data" presents actual and historical performance of the power sector Dzongkhag-wise and consumers' category-wise. However, all information for the following Dzongkhags is reported in combination with other Dzongkhags.

- Wangduephodrang Dzongkhag and Punakha Dzongkhag
- Trashigang, Pemagatshel and Yangtse Dzongkhag
- Bumthang and Trongsa Dzongkhag

In the "Power Data" the number of sector-wise consumers is not recorded, but BPC's statistics in **Table-12.4.4** details the sector-wise numbers of consumers of each Dzongkhag. Allotment to individual Dzongkhag of the combined data was generally estimated in proportion to the number of Dzongkhag-wise and sector-wise consumers.

(b) Consumer's category

Following to DOE/BPC's classification, the forecast was carried out for 6 consumer s' categories.

- Domestic sector
- Industrial sector
- Commercial sector
- Government Office sector
- Bulk Supply sector
- Public Lighting sector

(c) Growth scenarios

Forecast was examined for 3 growth scenarios: high, base (medium), and low scenarios. The detailed scenarios assumed for each sector are mentioned in the respective clause.

(d) Estimate of energy sales, energy requirement, and peak load

Energy sales were projected sector-wise and Dzongkhag-wise on the basis of results of analysis on the historical records and the number of consumers. Annual energy requirement of each sector was worked out from the energy sales and assumed energy losses in the network and station-use energy as well as auxiliary energy consumed for the network operation.

Annual peak load of each Dzongkhag was estimated from the energy requirements and assumed load factor. The load factors for each Dzongkhag are assumed in **Table-12.4.1**.

Table-12.4.1 Assumed Load Factor in Electrified Area (%)

Dzongkhag	2002/03	2003/04~06/07	2007/08~011/12	2012/13~16/17	2017/18~29/30
Bumthang	26	26~34	35~39	40~44	45~50
Chukha	52	52~54	55~59	60	60
Dagana	28	28~29	30~34	35~39	40
Sarpang	38	38~44	45~54	55~59	60
Haa	40	40~44	45~54	55	55
Lhuntsen	34	34~39	40~44	45	45
Mongar	25	25~34	35~40	41~44	45~50
Paro	40	40~44	44~49	50~54	55~60
Pemagatshel	31	31~34	35~39	40~44	45~50
Punakha	45	45~48	49~50	51~54	55~60
Samtse	62	62	62	60	60
Thimphu	37	37~39	40~44	45~49	50~54
Trongsa	26	26~34	35~39	40~44	45~50
Samdrup-J	70	70~61	60	60	60
Trashigang	31	31~34	35~39	40~44	45~50
Yangtse	31	31~34	35~39	40~44	45~50
Tsirang	33	33~34	35~39	40~44	45~50
Wangdue	45	45	45~49	50	50
Zhemgang	37	37~39	40~44	45~49	50~54
Gasa	n.a	30~34	35	35~39	40

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(e) Loss factors

System energy loss increases in proportion to the increase of energy consumption in the system and decreases in proportion to improvement of the system facilities. **Table-12.4.2** presents the loss factor of each Dzongkhag assumed from the actual factors in the year 2002/03.

Table-12.4.2 Assumed Loss Factor in Electrified Area (%)

Dzongkhag	2002/03	2003/04~06/07	2007/08~011/12	2012/13~16/17	2017/18~29/30
Bumthang	15~19	20	20	20	20
Chukha	4	5	6	7	7
Dagana	35	35~26	25~21	20	20
Sarpang	15	15~19	20	20~16	15
Haa	27	27~26	25~21	20	20
Lhuntsen	20	20	20	20	20
Mongar	15	15	15	15	15
Paro	27	27~29	30~26	25~21	20
Pemagatshel	15	15	15	15	15
Punakha	26	26	25~21	20	20
Samtse	7	7~8	9~10	11	11
Thimphu	21	21~24	25~21	20~16	15
Trongsa	15	15~19	20	20	20
Samdrup-J	30	30~21	20~16	15	15
Trashigang	15	15	15	15	15
Yangtse	20	20	20	20	20
Tsirang	20	20	20	20	20
Wangdue	26	26	25~21	20	20
Zhemgang	40	40~21	20~16	15	15
Gasa	20	20	20	20	20

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(f) Coincidental factor

Historical coincidental factor worked out from "Power Data" in the country varies from 73% to 91% as shown in **Table-12.4.3**. Factor of 90% was assumed for the demand forecast.

Table-12.4.3 Historical Peak Loads in Electrified Area

Dzongkhag (BPC Divisions)		Peak Demand (MW)					
		1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
Thimphu	a	14.100	14.950	16.560	19.360	24.330	23.191
Paro	b	2.950	3.640	3.540	3.890	4.640	4.860
Haa	c	1.080	1.220	1.440	1.420	1.600	1.870
Wangduephodrang/Punakha	d	1.232	2.630	3.030	2.561	3.303	4.268
Puntsholing/Lhamoizingkha	e	3.400	2.480	3.270	4.840	4.360	8.900
Pasakha	f	47.980	48.340	52.400	51.530	54.840	57.290
Gedu/Tala	g	1.800	15.500	6.410	10.580	11.820	11.240
Tsimalakha	h	0.000	0.000	0.000	0.000	1.240	4.000
Samtse	i	0.900	1.200	0.943	0.943	10.010	13.910
Chengmari/Nainital/Ghumauney	j	0.300	0.350	0.360	0.360	0.000	0.000
Sipsu/Chargharey	k	0.140	0.428	0.319	0.319	0.313	0.370
Gomtu/Pugli	l	9.500	8.550	8.197	8.197	0.000	0.000
Gelephug/Sarpang/Kalikhola	m	1.580	1.900	1.900	1.950	1.828	2.210
Samdrup-Jongkhar/Deothang	n	0.672	0.698	0.700	0.750	1.200	1.200
Daifam	o	0.065	0.058	0.060	0.065	0.000	0.000
Trasigang/Khaling/Pemagatshel/Yangtse	p	1.194	1.845	2.112	3.000	3.820	3.890
Mongar	q	0.256	0.254	0.252	0.800	1.360	1.360
Lhuntse	r	0.000	0.000	0.091	0.180	0.260	0.317
Bumthang/Trongsa	s	0.465	0.750	0.750	1.530	1.947	1.999
Zhemgang	t	0.140	0.130	0.140	0.160	0.490	0.850
Dagana	u	0.145	0.145	0.150	0.145	0.330	0.370
Tsirang	v	0.000	0.105	0.105	0.132	0.284	0.390
Total of Division Peak Loads (MW)	w = sum(a~v)	87.899	105.173	102.729	112.712	127.975	142.485
Country-wise Instantaneous Peak Loads (M\	x	80.000	89.000	92.000	92.630	93.107	112.000
Coincident Factor (%)	y = (x/w)	**91**	85	90	82	**73**	79

Source: Power Data 2003-04, DOE

12.4.2 Forecast of Energy Consumption in Electrified Area

(a) Domestic sector

The forecast was conducted to the present consumers and therefore number of consumers was set constant. Total energy consumption was estimated based on the number of consumers (**Table-12.4.4**) and projected annual energy consumption per consumer.

Assuming that the ratio (80%) of the number of domestic consumers to total number of consumers of all sectors was not changed in the last several years, numbers of sector-wise consumers in the last several years were worked out. Applying those numbers of consumers to the historical energy consumption of the sector, tendency of the historical consumption per consumer (unit consumption) were estimated. **Table-12.4.5** shows those unit consumptions.

Considering tendency of the unit consumption and the differences of grade of electrification, spread of electric home-appliances, and socio-economic environment among Dzongkhags, Dzongkhags were classified into the following 5 groups, and the growth scenarios of each group were assumed in **Table-12.4.6**.

- Group-1: Thimphu Dzongkhag
- Group-2: Chukha Dzongkhag
- Group-3: Trongsa, Paro, Haa, Punakha and Trashigang Dzongkhags (annual unit consumption of more than 2,000 kWh)
- Group-4: Bumthang, Sarpang, Samtse, Samdrup-Jongkhar, Tsirang and Wangduephodrang Dzongkhag (annual unit consumption of more than 1,000 kWh)
- Group-5: Dagana, Lhuntse, Mongar, Pemagatshel, Zhemgang and Yangtse Dzongkhag (annual unit consumption of less than 1,000 kWh)

The average unit consumption in Thimphu Dzongkhag is remarkably high. It will not grow unlimitedly, and there will be some ceiling quantum. The ceiling of annual unit consumption is assumed at around 7,000 kWh.

(b) Industrial sector

The existing large-scale industries are BFAL, BCCL, and Bhutan Boards Private Limited (BBPL) in Pasakha in Chukha Dzongkhag and PCAL in Samtse Dzongkhag. All other industrial demands are deemed small-scale. Energy consumption of the large-scale industries is assumed to be constant till their expansion plans will be approved. Energy consumptions and peak demands planned and approved for expansion of the existing large-scale factories and new large-scale factories (**Table-12.4.7**) are also assumed to be constant. While, the demands of the small-scale factories were assumed to increase at the growth rate estimated from historical performance. **Table-12.4.5** shows the historical performance of energy consumption by the industrial sector.

High growth scenario is under assumption that (i) the existing large-scale industries will consume energy in the quantum indicated in **Table-12.4.7**, (ii) consumption of the existing small-scale industries will continue to increase at the higher historical growth rate (**Table-12.4.6**), but the rate will gradually decline, and (iii) consumption of the large-scale industries will be fully realized as planned in **Table-12.4.7**. Medium growth scenario is under the assumptions that (i) the existing large-scale industries will consume energy in the quantum indicated in **Table-12.4.7**, (ii) consumption of the existing small-scale industries will continue to increase at moderate growth rates but the rates will gradually decline, and (iii) new large-scale factories will consume 70% of the energy in **Table-12.4.7** and their commencement of operation will be 5 years behind the planned program, considering affect of the tariff increase enforced in 2004. Low growth scenario is under assumptions that (i) the existing large-scale industries will consume energy in the quantum indicated in **Table-12.4.7**, (ii) consumption of the existing small-scale industries will grow at lower growth rates, and (iii) new large-scale factories will consume 50% of the energy in **Table-12.4.7** and their commencement of operation will be 5 years behind the planned program.

(c) Commercial sector

Energy consumption of the sector was assumed to grow referring to the historical rates. The historical energy sales and average annual growth rates are district-wise analyzed in **Table-12.4.6**.

Growth scenarios assumed for the sector are as below:

(i) Initial growth rate of the High Growth Scenario is 12.5% being the average of the whole country in the period of 1998/99 to 2002/02 and this rate is applied to all Dzongkhags.

(ii) The growth rate 9.0% recorded in the period of 1998/99 to 2001/02 is applied to all Dzongkhags for the Base (Medium) Growth Scenario.

(iii) Average growth rate 8% recorded in the period of 1998/99 to 2002/03 (except highly growing 5 Dzongkhags of Bumthang, Dagana, Mongar, Paro, and Tsirang) is applied to all Dzongkhags as an initial rate of the Low Growth Scenario.

(d) Government (Public) sector

The total number of government offices was 2,539 as of 2002/03 sharing 6.3% of total customers in the country, and the sector's energy consumption in 2002/03 was 23,472 GWh equivalent to 4.26% of the total energy consumption in the year.

Consumption of the sector was estimated to increase at the past average growth rate of total consumption of the respective district.

Historical district-wise energy sales to the sector are summarized in **Table-12.4.5**. The growth rates under 3 scenarios are assumed in **Table-12.4.6**.

(i) High Growth Scenario : Sector's average rate 18.50% in the period of 1998/99 to 2002/03 to be the initial rate for all Dzongkhag.

(ii) *Base Growth Scenario* : Average rate of high and low growth rates 12.8 % to all districts as the initial rate.

(iii)*Low Growth Scenario* : The sector's overall average rate 7.0% in the period of 1998/99 to 2001/02 to all Dzongkhags as the initial rate.

(e) Bulk supply sector

Bulk consumer is a unit that plural consumers are connected to a main demand meter. Many such consumers are registered in Sarpang, Chukha, and Trongsa Dzongkhag, while about 50% of Dzongkhags have not this sector. Number of consumers of this sector in 2002/03 was 0.2% of total consumers, and its consumption was 12.14% of total consumption in the country. Quantum of consumption of this sector was a match for the domestic sector's consumption. It may be a future tendency that consumers of this sector will gradually decrease by shifting to other sectors due to improvement of facilities, promotion of electrification, or amendment of electricity regulations. However, the present demand of this sector will not decrease but its demand will just shift to other sectors.

Historical energy consumptions of the sector are analyzed in **Table-12.4.5**. For projecting the energy consumption of this sector, growth rates applied to domestic sector were applied. Referring to the historical energy consumption, the sector was classified into 5 groups and the forecast was examined for each group.

- Group-1: Thimphu Dzongkhag
- Group-2: Chukha Dzongkhag
- Group-3: Trongsa and Zhemgang Dzongkhags
- Group-4: Bumthang, Sarpang, Punakha, Samtse, Samdrup-Jongkhar, Tsirang, Haa, and Wangduephodrang Dzongkhags
- Group-5: Dagana, Lhuntse, Mongar, Paro, Pemagatshel, Trashigang, and Yangtse Dzongkhags

The growth rate of each scenario was Dzongkhag-wise assumed in **Table-12.4.6**.

(f) Public lighting sector

Table-12.4.5 shows the historical energy consumption of this sector. Although energy consumption by the existing facilities will not grow because of non-increase in bulb wattage, number of facilities is expected to increase.

For the forecasting purpose, Dzongkhags are classified into the following 4 groups from the installing degree of street lighting.

- Group-1: (considerable facilities installed) Chukha, Sarpang, Thimphu, and Samdrup-Jongkhar
- Group-2: (facilities increasing recently) Haa, Paro, Punakha, and Wangduephodrang

- Group-3: (less facilities) Bumthang, Mongar, Pemagatshel, Trongsa, Trashigang, and Zhemgang
- Group-4: (no facilities at present) Dagana, Lhuntse, Samtse, Yangtse, Tsirang, and Gasa

The growth rate of each group was Dzongkhag-wise assumed in **Table-12.4.6**.

12.4.3 Energy Requirements and Peak Demands

Dzongkhag-wise energy requirements and peak demands were projected from energy consumption worked out under the methodology and assumptions stated above.

Energy requirement = (Energy Sales=Energy Consumption)/ (1-Loss Factor)

Peak load = (Energy Requirement/8,760)/ (Load Factor)

Table-12.4.4 Number of Customers (As of April 2004)

Voltage Class	Sector	Bum-thang	Chukha	Dagana	Sar-pang	Haa	Lhu-entse	Mongar	Paro	Pema-gatsel	Puna-kha	Samtse	Sam-drup	Thim-phu	Trongsa	Trashi-gang	Yangtse	Tsirang	Wang-due	Zhem-gang	Total
LV	Domestic	1,049	3,471	371	1,821	983	680	2,148	3,447	981	1,944	2,018	1,471	9,433	332	5,319	1,103	236	1,775	332	38,914
	Commerce	200	716	64	118	95	23	91	385	57	61	179	306	1,367	54	259	80	74	179	23	4,331
	Industry	14	95	0	12	11	8	11	83	2	9	18	12	25	1	39	19	0	30	3	392
	Public	101	267	55	137	112	12	76	182	39	131	185	121	551	28	302	103	15	99	30	2,546
	Street Light	0	26	0	11	4	1	4	1	2	2	16	4	19	0	3	0	0	1	7	101
	Bulk Supply	0	89	4	153	4	0	7	0	0	0	4	10	8	49	4	0	0	16	0	348
	Others	8	121	4	218	40	36	47	0	52	46	6	20	124	101	8	73	15	35	235	1,189
	Total	1,372	4,785	498	2,470	1,249	760	2,384	4,098	1,133	2,193	2,426	1,944	11,527	565	5,934	1,378	340	2,135	630	47,821
MV	Domestic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	Commerce	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Industry	0	4	0	0	0	0	0	0	3	0	12	0	1	0	0	0	0	0	0	20
	Public	0	0	0	0	0	0	0	3	1	0	0	0	2	0	0	0	0	0	0	6
	Street Light	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bulk Supply	0	13	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	24
	Others	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	3
	Total	0	17	0	0	0	0	0	3	4	0	12	1	16	0	0	0	1	0	0	54
HV	Industry	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3
Total No. of Custormers		1,372	4,804	498	2,470	1,249	760	2,384	4,101	1,137	2,193	2,439	1,945	11,543	565	5,934	1,378	341	2,135	630	47,878
Share of Domestic (%)		76.46	72.25	74.5	73.72	78.7	89.47	90.1	84.05	86.28	88.65	82.74	75.63	81.72	58.76	89.64	80.04	69.5	83.14	52.7	81.28

(Source : Customer Service Department of BPC)

(Note) Share of domestic consumer in the combined data of plural districts (for use of analysis of the past tendency)

-1 Bumthang : Trongsa = 1,049 : 332 = 75.96% : 24.04%

-2 Pemagatshel : Trashigang : Yangtse = 981 : 5,320 : 1,103 = 13.25% : 71.85% : 14.90%

-3 Punakha : Wangdue = 1,944 : 1,775 = 52.27% : 47.73%

Table-12.4.5 Historical Energy Sales in Electrified Area (1/2)

Histroical Energy Sales to Domestic Sector (MWh/year)

Dzongkhag	Period (year)						Growth Rate (%)	
	97-98	98~99	99~00	00~01	01~02	02~03	(97/98~02/03)	(00/01~02/03)
Bumthang	650	682	1,168	1,267	1,131	1,551	19	10.64
Chukha	2,067	2,443	2,713	3,259	3,837	6,651	26.33	42.86
Dagana	125	121	200	271	267	259	15.69	-2.2
Sarpang	1,237	1,599	1,990	2,445	3,108	3,196	20.91	14.33
Haa	449	555	770	879	1,219	1,672	30.08	37.92
Lhuentse	0	0	0	212	324	529	57.96	57.96
Mongar	320	432	503	508	854	998	25.54	40.16
Paro	1,416	1,416	1,683	2,103	1,672	2,717	13.92	13.66
Pemagatsel	200	293	388	436	520	647	26.46	21.82
Punakha	577	643	1,013	1,179	1,687	1,993	28.13	30.02
Samtse	916	1,074	1,227	1,735	1,968	1,889	15.58	4.34
Thimphu	19,628	21,446	29,305	32,029	39,667	40,641	15.67	12.64
Trongsa	204	214	367	398	356	488	19.05	10.73
Samdrup-Jongakha	1,149	1,327	1,522	1,549	1,652	2,131	13.15	17.29
Trashigang	1,085	1,591	2,104	2,365	2,819	3,509	26.46	21.81
Trashi-Yangtse	225	330	436	491	585	728	26.47	21.77
Tsirang	5	6	30	26	65	221	113.35	191.55
Wangdue	526	588	925	1,076	1,541	1,819	28.16	30.02
Zhemgang	225	237	361	324	405	492	16.94	23.23
Gasa	0	0	0	0	0	0	0	0
Total	31,004	34,998	46,707	52,552	63,676	72,130	18.4	17.07

Histroical Energy Sales to Industrial Sector (MWh/year)

Dzongkhag	Period (Year)						Growth Rate (%)	
	97~98	98~99	99~00	00~01	01~02	02~03	(98/99~02/03)	(98/99~01/02)
Bumthang	n.a	124	169	191	171	450	38.02	11.31
Chukha (small)	n.a	9,862	9,344	8,106	9,732	11,483	3.88	-0.44
Chukha (large)	n.a	266,633	280,624	208,555	278,902	295,046	constant	constant
Dagana	n.a	0	0	0	0	0	0	0
Sarpang	n.a	210	239	258	339	572	28.47	17.3
Haa	n.a	56	71	64	74	166	31.21	9.74
Lhuentse	n.a	0	0	0	5	9	80	80
Mongar	n.a	36	52	48	53	95	27.45	11.73
Paro	n.a	214	261	353	534	561	27.24	35.64
Pemagatshel	n.a	8	8	9	16	10	5.74	25.99
Punakha	n.a	41	34	41	113	64	11.78	40.21
Samtse (small)	n.a	1,202	1,192	1,579	1,645	54,572	11.02	11.02
Samtse (large)	n.a	44,780	45,658	47,013	50,938	n.a	constant	constant
Thimphu	n.a	224	300	288	335	1,975	72.32	14.36
Trongsa	n.a	10	13	15	13	35	36.78	9.14
Samdrup-Jongkhar	n.a	317	346	337	281	280	-3.06	-3.06
Trashigang	n.a	64	62	70	126	78	5.07	25.33
Trashi-Yangtse	n.a	31	30	34	61	38	5.22	25.32
Tsirang	n.a	0	0	0	0	0	0	0
Wangdue	n.a	138	115	136	378	215	11.72	39.92
Zhemgang	n.a	14	13	14	16	14	0	4.55
Gasa	n.a	0	0	0	0	0	0	0
Total		323,963	338,531	267,111	343,732	365,663	3.15	1.99
(Sales to small industries)		12,550	12,249	11,543	13,892	70,617	54.02	3.44

Histroical Energy Sales to Commercial Sector (MWh/year)

Dzongkhag	Period (Year)						Growth Rate (%)	
	97~98	98~99	99~00	00~01	01~02	02~03	(98/99~02/03)	(98/99~01/02)
Bumthang	n.a	172	227	250	343	521	31.93	25.87
Chukha	n.a	4,637	4,912	5,119	5,634	6,366	8.25	6.71
Dagana	n.a	26	52	67	67	113	44.39	37.1
Sarpang	n.a	422	438	500	628	445	1.34	14.17
Haa	n.a	165	186	186	243	277	13.83	13.77
Lhuentse	n.a	0	0	58	64	59	0.89	10.34
Mongar	n.a	115	175	228	522	778	61.28	65.57
Paro	n.a	1,649	2,042	2,598	2,196	4,151	25.96	10.02
Pemagatsel	n.a	51	52	62	85	99	18.04	18.56
Punakha	n.a	417	462	476	294	595	9.29	-11
Samtse	n.a	247	273	325	383	432	15	15.74
Thimphu	n.a	3,578	4,717	4,513	5,096	4,166	3.88	12.51
Trongsa	n.a	46	61	68	92	141	32.32	25.99
Samdrup-Jongkhar	n.a	361	382	430	490	692	17.67	10.72
Trashigang	n.a	230	235	282	386	448	18.14	18.84
Trashi-Yangtse	n.a	71	73	87	119	138	18.07	18.79
Tsirang	n.a	2	22	8	40	175	205.85	171.44
Wangdue	n.a	1,222	1,357	1,396	861	1,747	9.35	-11.02
Zhemgang	n.a	80	96	92	120	149	16.82	14.47
Gasa	n.a	0	0	0	0	0	0	0
Total		13,490	15,762	16,745	17,663	21,492	12.35	9.4
(Total except 5 districts (*)		11,526	13,244	13,594	14,495	15,754	8.13	7.94

(*) : Bumthang, Dagana, Mongar, Paro, & Tsirang of high growing district

Source: Power Data 2002/03

Table-12.4.5 Historical Energy Sales in Electrified Area (2/2)

Histroical Energy Sales to Government Sector (MWh/year)

Dzongkhag	Period (year)					Growth Rate (%)	
	98~99	99~00	00~01	01~02	02~03	(98/99~02/03)	(98/99~01/02)
Bumthang	313	381	394	397	584	16.87	8.25
Chukha	4,873	17,363	30,668	3,346	3,808	-4.81	-11.78
Dagana	12	20	29	51	183	97.61	61.98
Sarpang	418	427	543	748	573	8.2	21.41
Haa	367	435	603	533	520	9.1	13.25
Lhuentse	0	0	211	138	143	-17.68	-34.6
Mongar	256	482	386	424	623	24.9	18.32
Paro	1,220	1,607	1,905	1,550	2,271	16.81	8.31
Pemagatshel	59	87	109	127	135	23	29.12
Punakha	554	824	915	1,288	1,311	24.03	32.48
Samtse	383	411	490	527	639	13.65	11.23
Thimphu	1,687	2,055	2,049	2,389	9,031	52.11	12.3
Trongsa	87	105	109	110	162	16.82	8.13
Samdrup-Jongkhar	506	346	410	447	556	2.38	-4.95
Trashigang	445	654	820	957	1,019	23.01	29.08
Trashi-Yangtse	152	223	280	326	347	22.92	28.96
Tsirang	3	12	5	25	270	208.01	102.74
Wangdue	418	623	692	973	991	24.09	32.53
Zhemgang	140	212	217	220	305	21.49	16.26
Gasa	0	0	0	0	0	0	0
Total	11,893	26,266	40,835	14,576	23,471	18.53	7.02

Histroical Energy Sales to Bulk Supply Sector (MWh/year)

District	Period (Year)					Growth Rate (%)	
	98~99	99~00	00~01	01~02	02~03	(98/99~02/03)	(98/99~01/02)
Bumthang	0	0	0	0	0	0	0
Chukha	2,561	2,876	1,174	43,715	52,135	112.41	157.48
Dagana	0	0	0	0	0	0	0
Gelephu (Sarpang)	273	273	402	359	481	15.21	9.56
Haa	880	999	1,450	1,585	1,503	14.32	21.67
Lhuentse	0	0	0	0	0	0	0
Mongar	0	0	0	0	0	0	0
Paro	1,126	1,105	1,757	1,156	2,214	18.42	0.88
Pemagatsel	0	0	0	0	0	0	0
Punakha	0	0	0	0	0	0	0
Samtse	391	368	489	566	589	10.79	13.12
Thimphu	60	79	80	90	6,913	227.63	14.47
Trongsa	0	0	0	0	0	0	0
Samdrup-Jongkhar	0	218	135	307	451	27.42	18.67
Trashigang	591	623	727	1,067	2,015	35.89	21.77
Trashi-Yangtse	0	0	0	0	0	0	0
Tsirang	0	0	0	0	0	0	0
Wangdue	277	264	168	353	548	18.6	8.42
Zhemgang	0	0	0	0	0	0	0
Gasa	0	0	0	0	0	0	0
Total (*1)	5,218	5,682	5,188	47,613	64,780	87.71	108.97
Total (*2)	941	1,123	1,194	1,585	2,069	21.77	18.98
Total (*3)	0	0	0	0	0	0	0
Total	6,159	6,805	6,382	49,198	66,849	81.51	99.9

(*1) : Chukha, Paro, Thimphu and Trashigang
(*2) : Sarpang, Samtse, Samdrup-J and Wangdue (*3) : Others

Histroical Energy Sales to Public Lighting Sector (MWh/year)

Dzongkhag	Period (Year)					Growth Rate (%)	
	98~99	99~00	00~01	01~02	02~03	(98/99~02/03)	(98/99~01/02)
Bumthang	2	2	3	3	3	-	-
Chukha	77	90	94	72	85	2.5	-2.21
Dagana	0	0	0	0	0	0	0
Gelephu (Sarpang)	91	92	97	125	249	28.61	11.16
Haa	12	15	15	29	26	21.32	34.2
Lhuentse	0	0	0	0	0	0	0
Mongar	0	0	0	0	41	-	-
Paro	14	15	16	21	102	64.3	14.47
Pemagatsel	3	2	2	4	4	7.46	10.06
Punakha	0	0	5	3	149	445.89	-40
Samtse	0	0	0	0	0	0	0
Thimphu	45	59	56	64	137	32.09	12.46
Trongsa	2	2	3	3	3	-	-
Samdrup-Jongkhar	44	57	73	83	70	12.31	23.56
Trashigang	4	3	4	5	7	15.02	7.72
Trashi-Yangtse	0	0	0	0	0	0	0
Tsirang	0	0	0	0	0	0	0
Wangdue	0	0	2	2	75	512.37	0
Zhemgang	2	2	2	2	2	-	-
Gasa	0	0	0	0	0	0	0
Total	295	339	372	416	952	34.03	12.14
Total (*)	68	83	109	134	379	53.65	25.37

(*) : Total except Chukha, Sarpang, Paro and Thimphu

Source: Power Data 2002/03

Table-12.4.6 Growth Scenario of Sectors in Electrified Areas (Annual Growth Rates) (1/2)

Domestic Sector (Annual Growth Rate)

Scenario	Group	02/03~06/07	07/08~11/12	12/13~16/17	17/18~21/22
High	G-1	1.14	1.09	1.06	1.04
	G-2	1.07	1.05	1.05	1.04
	G-3	1.15	1.1	1.07	1.04
	G-4	1.15	1.11	1.08	1.04
	G-5	1.17	1.12	1.09	1.05
Medium	G-1	1.075	1.06	1.05	1.04
	G-2	1.05	1.05	1.04	1.04
	G-3	1.1	1.08	1.06	1.04
	G-4	1.13	1.1	1.07	1.04
	G-5	1.12	1.11	1.07	1.04
Low	G-1	1.06	1.05	1.04	1.03
	G-2	1.03	1.03	1.03	1.03
	G-3	1.08	1.06	1.04	1.03
	G-4	1.08	1.07	1.05	1.03
	G-5	1.09	1.08	1.06	1.03

Group-1: Thimphu Dzongkhag
Group-2: Chukha Dzongkhag
Group-3: Trongsa Paro, Haa, Punakha and Trashigang Dzongkhags
(annual unit consumption of more than 2,000 kWh.)
Group-4: Bumthang, Sarpang, Samtse, Samdrup Jongkhar, Tsirang,
and Wangduephodrang Dzongkhags (annual unit consumption of
more than 1,000 kWh)
Group-5: Dagana, Lhuntse, Mongar, Pemagatshel, Zhemgang and
Yangtse Dzongkhags (annual unit consumption of less than 1,000 kWh)

Industrial Sector (Annual Growth Rate)

Scenario	Group	02/03~06/07	07/08~11/12	12/13~16/17	17/18~21/22
High	G-1	1.3	1.2	1.1	1.08
	G-2	1.12	1.1	1.09	1.08
	G-3	1.035	1.035	1.035	1.035
	G-4	0	0	0	0
Medium	G-1	1.2	1.1	1.08	1.07
	G-2	1.1	1.09	1.07	1.05
	G-3	1.035	1.035	1.035	1.035
	G-4	0	0	0	0
Low	G-1	1.035	1.035	1.035	1.035
	G-2	1.035	1.035	1.035	1.035
	G-3	1.035	1.035	1.035	1.035
	G-4	0	0	0	0

Group-1: Sarpang, Lhuntse, Paro, Punakha, Yangtse, Wangduephodraung,
Pemagatshel, and Trashigang Dzongkhags
Group-2: Haa, Mongar, Samtse, Thimphu, and Trongsa Dzongkhags
Group-3: Bumthang,, Chukha, Samdrup-J, and Zhemgang Dzongkhags
Group-4: Dagana, Tsirang, and Gasa Dzongkhags

Prepared by JICA Study Team

Table-12.4.6 Growth Scenario of Sectors in Electrified Areas (Annual Growth Rates) (2/2)

Commercial Sector (Annual Growth Rate)

Scenario	02/03~06/07	07/08~11/12	12/13~16/17	17/18~21/22
High	1.125	1.1	1.08	1.07
Medium	1.09	1.08	1.07	1.07
Low	1.06	1.06	1.06	1.06

High : Initial growth rate to High Scenario is assumed at 12.5 % of average during the period of 98/99~02/03 of the entire country and it is commonly applied to all Dzongkhags.

Medium : The rate of 9.0 % recorded during the period of 98/99 ~01/02 is commonly applied for the initial rate to all Dzongkhags in the medium growth scenario.

Low : Average growth rate of 6.0 % recorded during the period of 98/99~02/03 except abnormally high growth Bumthang, Dagana, Paro and Tsirang Dzongkhags is commonly applied as the initial rate in the low growth scenario.

Government Sector (Annual Growth Rate)

Scenario	02/03~06/07	07/08~11/12	12/13~16/17	17/18~21/22
High	1.185	1.1	1.08	1.07
Medium	1.128	1.09	1.07	1.06
Low	1.06	1.06	1.06	1.06

High : Initial growth rate of high growth scenario is assumed at 18.5 % of average rate of 98/99 ~02/03.

Medium : Initial rate for the medium scenario is mean rate of the high and low scenarios.

Low : The rate of 7.0 % being an overall average rate in the period of 98/99~01/02 is commonly applied to all Dzongkhags in the low scenario.

Bulk Supply Sector (Annual Growth Rate)

The same rates as those for the domestic sector are applied for respective growth scenario.

Public Lighting Sector (Annual Growth Rate)

No scenario is assumed for this sector, but the rate for each Dzongkhag is assumed as follows:

Group	02/03~06/07	07/08~11/12	12/13~16/17	17/18~21/22
G-1	1.07	1.05	1.04	1.03
G-2	1.1	1.08	1.06	1.03
G-3	1.12	1.08	1.06	1.04
G-4	0	1.15	1.1	1.07

Group-1: Dzongkhags developing considerable number of facilities: Chukha, Sarpang, Thimphu, and Samdrup Jongkhar

Group-2: Dzongkhags recently increasing the facilities: Haa, Paro, Punakha, and Wangduephodrang

Group-3: Dzonghags having the facilities: Bumthang, Mongar, Pemagatshel, Trongsa, Trashigang, and Zhemgang

Group-4: Dzongkhags having no facilities at present: Dagana, Lhuntse, Samtse, Yangtse, Tsirang, and Gasa

Prepared by JICA Study Team

Table-12.4.7 Schedule of Expansion and New Construction of Large Scale Factories

Dzongkhag	Existing Large-scale Industries (as of 2000)				Approved Expansion of Existing Factory				Approved New Large Industries				
	Industry	Energy (GWh)	Load Factor	Peak (MW)	Operation Start	Load Factor	Peak (MW)	Energy (GWh)	Operation Start	Industry	Peak (MW)	Load Factor	Energy (GWh)
Chukha-Pasakha	BFAL	181.7	0.8	25.928	2007	0.8	14.5	101.616	2007	Bhutan Jute	0.4	0.7	2.453
	BCCL	98.412	0.89	12.623	2007	0.89	11	85.7604	2007	Bhutan Steel	2.5	0.8	17.52
	Construction	-	-		2006	0.8	0.4	2.8032	2007	Singye (SiC)	22.1	0.8	154.877
	Bhutan Board	5.695	0.2	3.251	-	-	-	-	2007	ND (F. Silicon)	15.3	0.8	107.222
	Total	285.807	-	41.801	-	-	25.9	190.1796	2007	Gyeltsen Ind.	3.8	0.8	26.63
	Coincident		0.78						2012	Pasakha	30	0.7	183.96
										Total	74.1	-	492.662
Chhukha-Phuentsholing									2006	Druk Iron/Steel	3.5	0.8	24.528
									2007	RSA Poly Product	0.32	0.8	2.243
									2007	Yarkay Poly Prod.	1	0.8	7.008
										Total	4.82	-	33.779
Samtse	PCAL	36.52	0.62	6.724	2007	0.62	5	27.156	2007	Lhaki Cement	0.6	0.8	4.205
									2022	Samtse or Gomtu	40	0.8	280.32
Zhemgang									2007	Tingtibi	3	0.8	21.024
Samdrup-Jongkhar									2007	Shankazuli	20	0.8	140.16
									2017	Deothang	20	0.8	140.16
Sarpang									2010	Chowabari/Gelephu	50	0.8	350.4
									2012	Chowabari	25	0.8	175.2
Mongar									2007	Bongdyma	3	0.8	21.024
Thimphu									2007	Jemina	30	0.8	210.24
Pemagatshel									2007	Plaster/Gypsum	2.3	0.8	16.118

Source : PSMP and Comments of DOE

12.5 Results of Demand Forecasts of Master Plan

12.5.1 Results of Demand Forecast for Non-Electrified Villages

Projected peak demand and energy consumption in the non-electrified villages are detailed in **Appendix B-III**. The Dzongkhag-wise peak load and energy consumption are exhibited in **Table-12.5.1** and **Table-12.5.2**.

Table-12.5.1 Projected Dzongkhag-wise Peak Loads in Non-Electrified Villages (kW)

	Dzongkhag	2003	2007	2012	2017	2020	*2025*	*2030*
1	Thimphu	221	230	248	263	274	295	316
2	Chukha	2,243	2,456	2,819	3,215	3,461	4,017	4,622
3	Haa	336	370	421	478	519	602	734
4	Paro	316	336	368	407	428	479	531
5	Samtse	4,396	5,035	5,806	6,822	7,450	8,747	10,287
6	Tsirang	2,261	2,739	3,419	3,920	4,276	4,955	5,842
7	Dagana	2,035	2,325	2,683	3,099	3,373	4,026	4,764
8	Punakha	457	480	516	554	587	631	679
9	Gasa	448	486	541	601	639	717	803
10	Wangduephodrang	2,943	3,121	3,382	3,673	3,857	4,207	4,624
11	Bumthang	837	900	979	1,082	1,152	1,277	1,428
12	Sarpang	2,915	3,469	4,052	4,771	5,209	6,346	7,546
13	Zhemgang	2,493	2,660	2,909	3,224	3,427	3,782	4,216
14	Trongsa	1,492	1,606	1,779	1,971	2,140	2,421	2,791
15	Lhuntse	2,191	2,337	2,548	2,775	2,931	3,199	3,525
16	Mongar	3,619	3,942	4,387	4,844	5,190	5,794	6,466
17	Pemagatshel	887	917	949	982	1,002	1,038	1,075
18	Samdrup Jongkhar	4,494	4,946	5,442	6,043	6,424	7,087	7,995
19	Trashigang	2,727	3,001	3,265	3,562	3,784	4,139	4,516
20	Yangtse	1,676	1,815	2,011	2,251	2,454	2,735	3,059
	Total	38,988	43,173	48,524	54,536	58,578	66,492	75,820

Prepared by JICA Study Team

The village-wise projected peak demands and energy consumptions are exhibited in GIS maps.

The average annual growth rate of the projected peak demand in the period of 2003 to 2020 is 2.4% at the country level. The growth rates of Samtse, Tsirang, Dagana, and Sarpang Dzongkhags are higher than those of other Dzongkhags. Higher potential is foreseen for Samtse, Mongar and Samdrup-Jongkhar Dzongkhags.

The Dzongkhags-wise and category-wise peak demand forecasts are summarized in **Appendix B-III**.

Table-12.5.2 Projected Dzongkhag-wise Energy Consumption in Non-Electrified Villages (MWh/month)

	Dzongkhag	2003	2007	2012	2017	2020	2025	2030
1	Thimphu	33.7	35.5	38.6	41.4	43.3	46.9	50.7
2	Chukha	324.5	358.6	436.3	509.2	558.8	690.6	826.6
3	Haa	42.0	47.3	55.3	64.6	71.3	88.7	128.7
4	Paro	35.3	38.2	43.0	48.5	51.8	59.1	66.9
5	Samtse	597.6	737.8	884.2	1,106.7	1,237.8	1,543.7	1,917.8
6	Tsirang	345.5	459.0	641.1	745.5	823.5	976.2	1,199.9
7	Dagana	306.9	383.3	459.3	546.8	593.7	764.0	962.7
8	Punakha	60.3	64.1	69.8	75.9	80.7	87.8	95.6
9	Gasa	65.2	71.7	84.5	94.9	101.7	115.2	130.1
10	Wangduephodrang	393.8	424.7	468.5	526.7	558.5	627.9	708.5
11	Bumthang	110.3	120.6	138.3	155.7	167.5	193.3	219.4
12	Sarpang	396.5	512.8	619.2	757.6	829.0	1,116.6	1,381.9
13	Zhemgang	374.3	409.3	457.2	534.3	589.0	664.3	767.5
14	Trongsa	229.6	262.5	295.7	332.7	375.8	448.7	542.6
15	Lhuntse	264.3	287.2	320.0	364.6	393.9	437.8	500.4
16	Mongar	512.9	594.0	677.8	757.8	840.6	946.6	1,096.0
17	Pemagatshel	131.6	149.1	156.5	164.2	169.1	177.5	186.3
18	Samdrup Jongkhar	603.8	741.5	832.8	974.1	1,049.1	1,165.9	1,402.8
19	Trashigang	392.3	477.1	533.1	595.0	651.1	729.6	799.9
20	Yangtse	235.9	267.8	306.9	363.3	437.0	488.4	558.4
	Total	5,456	6,442	7,518	8,759	9,623	11,369	13,542

Prepared by JICA Study Team

Average annual growth rate of energy consumption in the period of 2003 to 2020 were 3.4% at the country level. Those of Samtse, Tsirang, Dagana, and Sarpang Dzongkhags are higher than other Dzongkhags. The Dzongkhag-wise and category-wise energy consumption forecasts are summarized in **Appendix B-III**.

12.5.2 Results of Demand Forecast for Electrified Areas

Projected Dzongkhag-wise peak demand and energy consumption in the electrified areas (Base Growth Scenario) are abstracted into **Table-12.5.3** and **Table-12.5.4**.

The results of the projected demand are shown in **Appendix B-III**.

Total peak load and energy requirement for the medium growth scenario at the country level in the horizon year 2020 will grow to 3 times and 4 times that in the year 2003, respectively. Average annual growth rates in the same period are respectively 6.7% and 8.6%. Industrial sector shares 80% of total energy requirement of the country. Average annual growth rates of industrial and domestic sectors by 2020 are 9% and 5%, respectively. Higher growth of energy consumption is resulted in Sarpang, Zhemgang, Mongar, and Samdrup-Jongkhar Dzongkhags where large-scale factories are planned.

Table-12.5.3 Projected Peak Loads in Electrified Areas (Base Growth Scenario) (MW)

	Dzongkhag	2003	2007	2012	2017	2020	2025	2030
1	Thimphu	24.33	34.67	35.07	55.37	55.94	58.56	65.86
2	Chukha	72.26	77.04	84.45	140.41	166.00	173.22	184.37
3	Haa	1.60	2.26	2.62	3.42	3.90	4.49	5.26
4	Paro	4.64	6.73	8.81	10.25	11.27	13.32	17.55
5	Samtse	10.23	10.22	11.46	16.65	17.35	18.45	47.86
6	Tsirang	0.28	0.43	0.57	0.70	0.77	0.90	1.18
7	Dagana	0.33	0.46	0.55	0.66	0.75	0.92	1.20
8	Punakha	1.42	2.05	2.78	3.46	3.80	4.42	5.70
9	Gasa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Wangduephodrang	1.88	2.84	3.68	4.88	5.72	7.09	9.31
11	Bumthang	1.54	1.94	2.49	2.96	3.20	3.65	4.59
12	Sarpang	1.83	2.80	3.50	39.14	57.13	57.69	58.56
13	Zhemgang	0.49	0.53	0.64	2.87	2.94	3.02	3.22
14	Trongsa	0.41	0.53	0.65	0.77	0.84	0.91	1.07
15	Lhuntse	0.26	0.42	0.59	0.78	0.89	1.07	1.36
16	Mongar	1.36	1.52	1.96	4.53	4.77	5.20	6.16
17	Pemagatshel	0.37	0.55	0.75	2.52	2.59	2.71	3.00
18	Samdrup Jongkhar	1.20	1.51	2.17	16.87	37.30	51.98	52.79
19	Trashigang	2.93	4.38	5.90	7.03	7.51	8.43	10.56
20	Yangtse	0.52	0.82	1.11	1.34	1.46	1.67	2.14
	TOTAL	127.98	151.68	169.75	314.61	384.13	417.70	481.74

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Table-12.5.4 Projected Energy Requirement in Electrified Areas (Base Growth Scenario) (GWh/year)

	Dzongkhag	2003	2007	2012	2017	2020	2025	2030
1	Thimphu	62.86	85.36	106.79	271.10	282.47	300.97	330.87
2	Chukha	375.57	399.75	449.18	831.77	983.02	1,018.29	1,072.79
3	Haa	4.16	6.46	9.79	13.18	15.03	17.31	20.26
4	Paro	12.02	18.41	27.97	38.30	45.03	55.99	73.81
5	Samtse	61.57	65.28	70.77	98.63	101.91	303.32	309.87
6	Tsirang	0.67	1.03	1.56	2.14	2.52	3.14	4.13
7	Dagana	0.56	0.86	1.31	1.81	2.11	2.59	3.36
8	Punakha	4.11	6.38	9.61	13.08	15.19	18.58	23.96
9	Gasa	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Wangduephodrang	5.40	8.29	12.48	17.11	20.05	24.85	32.61
11	Bumthang	3.10	4.63	6.81	9.13	10.54	12.79	16.09
12	Sarpang	5.52	8.75	13.26	263.24	388.60	391.12	395.01
13	Zhemgang	0.96	1.42	2.07	17.52	17.98	18.48	19.28
14	Trongsa	0.83	1.22	1.77	2.38	2.76	3.18	3.76
15	Lhuntse	0.74	1.16	1.82	2.46	2.82	3.39	4.27
16	Mongar	2.54	3.85	5.85	22.68	24.05	26.27	29.85
17	Pemagatshel	0.90	1.40	2.19	14.27	14.70	15.39	16.46
18	Samdrup Jongkhar	4.18	6.36	9.56	110.95	112.86	214.01	217.63
19	Trashigang	7.08	11.09	17.14	23.01	26.28	31.39	39.30
20	Yangtse	1.25	1.96	3.05	4.15	4.80	5.84	7.48
	TOTAL	553.99	633.63	752.97	1,756.89	2,072.70	2,466.87	2,620.80

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12.5.3 Demand Forecast for Whole Country

Projected total peak load and energy consumption of the non-electrified villages and electrified areas (Base Growth Scenario) are exhibited in **Tables-12.5.5**.

Table-12.5.5 Forecast of Peak Demand and Energy Consumption in Whole Bhutan (Base Case Scenario)

	Dzongkhag	Area	Projected Peak Demand (MW)							Projected Energy Consumption (GWh)						
			2003	2007	2012	2017	2020	2025	2030	2003	2007	2012	2017	2020	2025	2030
1	Thimphu	N.E	0.22	0.23	0.25	0.26	0.27	0.30	0.32	0.40	0.43	0.46	0.50	0.52	0.56	0.61
		E	24.33	34.67	35.07	55.37	55.94	58.56	65.86	62.86	85.36	106.79	271.10	282.47	300.97	330.87
		Total	24.55	34.90	35.32	55.63	56.21	58.86	66.18	63.27	85.79	107.25	271.60	282.99	301.53	331.48
2	Chukha	N.E	2.24	2.46	2.82	3.22	3.46	4.02	4.62	3.89	4.30	5.24	6.11	6.71	8.29	9.92
		E	72.26	77.04	84.45	140.41	166.00	173.22	184.37	375.57	399.75	449.18	831.77	983.02	1,018.29	1,072.79
		Total	74.50	79.50	87.27	143.63	169.46	177.24	188.99	379.47	404.05	454.41	837.88	989.72	1,026.57	1,082.71
3	Haa	N.E	0.34	0.37	0.42	0.48	0.52	0.60	0.73	0.50	0.57	0.66	0.78	0.86	1.06	1.54
		E	1.60	2.26	2.62	3.42	3.90	4.49	5.26	4.16	6.46	9.79	13.18	15.03	17.31	20.26
		Total	1.94	2.63	3.04	3.90	4.42	5.09	5.99	4.66	7.02	10.46	13.95	15.89	18.37	21.80
4	Paro	N.E	0.32	0.34	0.37	0.41	0.43	0.48	0.53	0.42	0.46	0.52	0.58	0.62	0.71	0.80
		E	4.64	6.73	8.81	10.25	11.27	13.32	17.55	12.02	18.41	27.97	38.30	45.03	55.99	73.81
		Total	4.96	7.07	9.18	10.66	11.70	13.80	18.08	12.44	18.87	28.49	38.88	45.65	56.70	74.61
5	Samtse	N.E	4.40	5.04	5.81	6.82	7.45	8.75	10.29	7.17	8.85	10.61	13.28	14.85	18.52	23.01
		E	10.32	10.22	11.46	16.65	17.35	18.45	47.86	61.57	65.28	70.77	98.63	101.91	303.32	309.87
		Total	14.72	15.26	17.27	23.47	24.80	27.20	58.15	68.74	74.13	81.38	111.91	116.76	321.84	332.88
6	Tsirang	N.E	2.26	2.74	3.42	3.92	4.28	4.96	5.84	4.15	5.51	7.69	8.95	9.88	11.71	14.40
		E	0.28	0.43	0.57	0.70	0.77	0.90	1.18	0.67	1.03	1.56	2.14	2.52	3.14	4.13
		Total	2.55	3.17	3.99	4.62	5.05	5.86	7.02	4.81	6.53	9.25	11.09	12.40	14.85	18.53
7	Dagana	N.E	2.04	2.33	2.68	3.10	3.37	4.03	4.76	3.68	4.60	5.51	6.56	7.12	9.17	11.55
		E	0.33	0.46	0.55	0.66	0.75	0.92	1.20	0.56	0.86	1.31	1.81	2.11	2.59	3.36
		Total	2.37	2.79	3.23	3.76	4.12	4.95	5.96	4.24	5.46	6.82	8.37	9.23	11.75	14.91
8	Punakha	N.E	0.46	0.48	0.52	0.55	0.59	0.63	0.68	0.72	0.77	0.84	0.91	0.97	1.05	1.15
		E	1.42	2.05	2.78	3.46	3.80	4.42	5.70	4.11	6.38	9.61	13.08	15.19	18.58	23.96
		Total	1.88	2.53	3.30	4.01	4.39	5.05	6.38	4.84	7.15	10.44	13.99	16.16	19.63	25.11
9	Gasa	N.E	0.45	0.49	0.54	0.60	0.64	0.72	0.80	0.78	0.85	1.01	1.14	1.22	1.38	1.56
		E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Total	0.45	0.49	0.54	0.60	0.64	0.72	0.80	0.78	0.85	1.01	1.14	1.22	1.38	1.56
10	Wangdue	N.E	2.94	3.12	3.38	3.67	3.86	4.21	4.62	4.73	5.10	5.62	6.32	6.70	7.53	8.50
		E	1.88	2.84	3.68	4.88	5.72	7.09	9.31	5.40	8.29	12.48	17.11	20.05	24.85	32.61
		Total	4.83	5.96	7.06	8.55	9.58	11.30	13.93	10.12	13.38	18.10	23.43	26.76	32.38	41.11
11	Bumthang	N.E	0.84	0.90	0.98	1.08	1.15	1.28	1.43	1.32	1.45	1.66	1.87	2.01	2.32	2.63
		E	1.54	1.94	2.49	2.96	3.20	3.65	4.59	3.10	4.63	6.81	9.13	10.54	12.79	16.09
		Total	2.38	2.84	3.47	4.04	4.35	4.93	6.02	4.42	6.07	8.47	11.00	12.55	15.11	18.72
12	Sarpang	N.E	2.92	3.47	4.05	4.77	5.21	6.35	7.55	4.76	6.15	7.43	9.09	9.95	13.40	16.58
		E	1.83	2.80	3.50	39.14	57.13	57.69	58.56	5.52	8.75	13.26	263.24	388.60	391.12	395.01
		Total	4.74	6.27	7.55	43.91	62.34	64.04	66.11	10.27	14.90	20.69	272.33	398.55	404.52	411.59
13	Zhemgang	N.E	2.49	2.66	2.91	3.22	3.43	3.78	4.22	4.49	4.91	5.49	6.41	7.07	7.97	9.21
		E	0.49	0.53	0.64	2.87	2.94	3.02	3.22	0.96	1.42	2.07	17.52	17.98	18.48	19.28
		Total	2.98	3.19	3.55	6.10	6.37	6.80	7.44	5.45	6.33	7.56	23.93	25.04	26.45	28.49
14	Trongsa	N.E	1.49	1.61	1.78	1.97	2.14	2.42	2.79	2.76	3.15	3.55	3.99	4.51	5.38	6.51
		E	0.41	0.51	0.65	0.77	0.84	0.91	1.07	0.83	1.22	1.77	2.38	2.76	3.18	3.76
		Total	1.90	2.12	2.43	2.74	2.98	3.33	3.86	3.59	4.37	5.32	6.37	7.27	8.56	10.27
15	Lhuntse	N.E	2.19	2.34	2.55	2.78	2.93	3.20	3.53	3.17	3.45	3.84	4.38	4.73	5.25	6.00
		E	0.26	0.42	0.59	0.78	0.89	1.07	1.36	0.74	1.16	1.82	2.46	2.82	3.39	4.27
		Total	2.45	2.76	3.14	3.56	3.82	4.27	4.89	3.91	4.60	5.66	6.84	7.55	8.64	10.28
16	Mongar	N.E	3.62	3.94	4.39	4.84	5.19	5.79	6.47	6.15	7.13	8.13	9.09	10.09	11.36	13.15
		E	1.36	1.52	1.96	4.53	4.77	5.20	6.16	2.54	3.85	5.85	22.68	24.05	26.27	29.85
		Total	4.98	5.46	6.35	9.37	9.96	10.99	12.63	8.69	10.98	13.98	31.77	34.14	37.63	43.00
17	Pemagatshel	N.E	0.89	0.92	0.95	0.98	1.00	1.04	1.08	1.58	1.79	1.88	1.97	2.03	2.13	2.24
		E	0.37	0.55	0.75	2.52	2.59	2.71	3.00	0.90	1.40	2.19	14.27	14.70	15.39	16.46
		Total	1.26	1.47	1.70	3.50	3.59	3.75	4.08	2.47	3.19	4.07	16.24	16.73	17.52	18.69
18	Samdrup-J	N.E	4.49	4.95	5.44	6.04	6.42	7.09	8.00	7.25	8.90	9.99	11.69	12.59	13.99	16.83
		E	1.20	1.51	2.17	16.87	37.30	51.98	52.79	4.18	6.36	9.56	110.95	112.86	214.01	217.63
		Total	5.69	6.46	7.61	22.91	43.72	59.07	60.79	11.43	15.26	19.56	122.64	125.45	228.00	234.46
19	Trashigang	N.E	2.73	3.00	3.27	3.56	3.78	4.14	4.52	4.71	5.73	6.40	7.14	7.81	8.76	9.60
		E	2.93	4.38	5.90	7.03	7.51	8.43	10.56	7.08	11.09	17.14	23.01	26.28	31.39	39.30
		Total	5.66	7.38	9.17	10.59	11.29	12.57	15.08	11.78	16.81	23.54	30.15	34.09	40.15	48.90
20	Yangtse	N.E	1.68	1.82	2.01	2.25	2.45	2.74	3.06	2.83	3.21	3.68	4.36	5.24	5.86	6.70
		E	0.52	0.82	1.11	1.34	1.46	1.67	2.14	1.25	1.96	3.05	4.15	4.80	5.84	7.48
		Total	2.20	2.63	3.12	3.59	3.91	4.41	5.20	4.08	5.17	6.73	8.50	10.04	11.70	14.18
	Total	N.E	38.99	43.17	48.52	54.54	58.58	66.49	75.82	65.48	77.30	90.22	105.11	115.48	136.43	162.51
		E	127.98	151.68	169.75	314.61	384.13	417.70	481.74	553.99	633.63	752.97	1,756.89	2,072.70	2,466.87	2,620.80
		Total	166.96	194.85	218.28	369.15	442.71	484.19	557.56	619.47	710.93	843.19	1,862.00	2,188.18	2,603.29	2,783.31

N.E : Non-Electrified Area
E : Electrified Area

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The country level peak load in the year 2020 is projected at 440 MW in the Base Growth Scenario (540 MW in High Growth Scenario and 350 MW in Low Growth Scenario). Average annual growth rate of the peak load in the period of 2003 to 2020 is 7.4%, and that of the energy consumption is 9.2%.

Energy consumption of the non-electrified villages to the total consumption is the 10% mark before operation of new industries and declined to the 5% mark after operation of the large-scale industries. Power market of Bhutan is largely influenced by the industrial sector. The forecast should be frequently reviewed following the changes of socio-economic circumstances, the development plans of each sector, and others.

Although they said “Satellite Town” is under planning and partly construction in Thimphu, its entire plan is not opened at present. Those indefinite plans are not included in the forecast. But, when such indefinite demands would be cleared, the demand should be taken into the forecast.

12.5.4 Estimate of Substation Loads

The projected peak demands were allocated to the existing and planned MV substations under the following assumptions.

(1) In case of only one substation operated or planned in a Dzongkhag, the projected whole load of the Dzongkhag is supplied by this sole substation.

(2) Demands of large-scale factories in Chukha and Samtse Dzongkhag will be directly supplied by the existing HV or MV substation through the exclusive feeder(s).

(3) In case of plural substations are operated or planned in a district, burden of individual substation is estimated under the following assumptions

(a) Chukha Dzongkhag

- Energy supply from Chukha substation (annexed to power station) to its neighboring area was worked out from energy sales in 2002/03, assumed load factor and loss factor.
- The existing Pasakha substation will continue to supply energy to the existing large-scale factories. This substation will also supply energy to the planned factories.
- The existing Phuntsholing substation will supply energy to new factories planned in its area.
- Other substations will feed energy to other demands than demands of large-scale factories at the same ratios of actual records in 2002/03.
- The existing Singhegaon substation is only 2 km away from the existing Pasakha substation. Therefore, both substations will share their burden.

(b) Sarpang Dzongkhag

- Three (3) new substations in addition to the existing Gelephu substation are planned in the Dzongkhag. The Gelephu substation will supply energy to the existing factories. New factories will be connected to the planned Chowabari substation.
- Other loads than the industrial load factories will be supplied by Gelephu substation (65%), Sarpang substation (10%), Kalikhola substation (15%), and Chowabari substation (10%).

(c) Samtse Dzongkhag

- The existing Gomtu substation feeds to PCAL factory and general demand at present. Supply to the general demand is only 1% of total supply of the substation.
- The Gomtu substation will feed to industrial demand including the new factories. All other demands will be met by the existing Samtse substation.

(d) Thimphu Dzongkhag

- Jemina substation will supply energy to the new factory of 30 MW load and general demand in the area.
- Burdens of other substations are estimated on the basis of the historical performance.

(e) Samdrup-Jongkhar Dzongkhag

- There are 3 existing substations (Nanglam, Deothang, and Samdrup/Daifam) in operation. Burdens of the substations are estimated at 46% for Nanglam, 28% for Deothang, and 26% for Samdrup/Daifam.
- The new 40 MW factory will be connected to the Deothang substation.

The substation burdens worked out from the above assumptions under the Base Growth Scenario are summarized in **Table-12.5.6**.

Table-12.5.6 Peak Loads of Substations (for Base Growth Scenario)

Dzongkhag	Substation	Exist or Plan	Peak Demand (MW) of Medium Growth Scenario																			
			2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
Bumthang	(Jakar Sw. Station)	2007	1.538	1.863	1.92	1.979	1.941	2.051	2.158	2.21	2.316	2.492	2.592	2.684	2.781	2.869	2.962	3.037	3.117	3.2	3.288	3.312
Chukha	Chukha P/S	Exist.	4.453	4.923	5.194	5.48	5.674	5.929	6.134	6.345	6.566	6.798	7.058	7.373	7.704	8.05	8.413	8.787	9.178	9.588	10.018	10.467
	(Singhegaon)	Exist.	Combined with Pasakha																			
	Pasakha/Sinhegaon	Exist.	54.926	54.935	54.941	54.946	54.950	54.955	54.959	54.963	54.967	55.252	103.977	103.983	103.989	103.996	104.003	125.010	125.018	125.026	125.034	125.043
	Phuentsholing	Exist.	4.011	4.434	4.679	4.937	5.111	5.341	5.526	5.716	5.915	8.574	9.732	10.016	10.314	10.626	10.953	11.290	11.642	12.012	12.398	12.804
	Gedu	Exist.	12.602	13.931	14.699	15.509	16.058	16.780	17.359	17.956	18.582	19.239	19.974	20.866	21.801	22.781	23.809	24.867	25.974	27.134	28.350	29.623
	Watsa	Exist.	0.720	0.796	0.840	0.887	0.918	0.959	0.992	1.026	1.062	1.100	1.142	1.193	1.246	1.302	1.361	1.421	1.485	1.551	1.621	1.693
Dagana	(Dagana Sw. St)	2007	0.330	0.389	0.415	0.433	0.456	0.477	0.498	0.519	0.532	0.550	0.572	0.595	0.617	0.640	0.661	0.678	0.713	0.751	0.790	0.832
Sarpang	Gelephu	Exist.	1.828	2.205	2.393	2.583	2.802	2.580	2.646	2.652	2.865	2.978	2.393	2.471	2.551	2.618	2.688	2.738	2.870	3.008	3.111	3.194
	Kalikhola	2007	0.000	0.000	0.000	0.000	0.000	0.455	0.467	0.468	0.506	0.526	0.552	0.570	0.589	0.604	0.620	0.632	0.662	0.694	0.718	0.737
	Sarpang	2012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.368	0.380	0.392	0.403	0.414	0.421	0.441	0.463	0.479	0.491
	Chowabari	2012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.368	0.380	0.392	35.403	35.414	52.921	52.941	52.963	52.979	52.991
Haa	Haa	Exist.	1.600	1.830	2.046	2.169	2.264	2.396	2.475	2.540	2.561	2.621	2.719	2.898	3.077	3.243	3.419	3.572	3.732	3.900	4.076	4.233
Lhuentse	Tangmachhu	Exist.	0.260	0.348	0.390	0.411	0.424	0.456	0.491	0.525	0.557	0.588	0.616	0.659	0.700	0.739	0.780	0.817	0.855	0.894	0.936	0.980
Mongar	Kilikhar	Exist.	1.360	1.514	1.452	1.461	1.522	1.620	1.718	1.813	1.914	1.963	4.149	4.232	4.309	4.391	4.531	4.606	4.684	4.767	4.853	4.945
Paro	Paro	Exist.	4.640	5.109	5.557	6.120	6.727	7.207	7.593	8.065	8.435	8.807	9.116	9.404	9.683	9.959	10.249	10.486	10.869	11.272	11.695	12.140
Pemagatshel	Nangkhor	Exist.	0.371	0.434	0.470	0.509	0.551	0.591	0.634	0.676	0.716	0.753	2.396	2.430	2.461	2.493	2.521	2.542	2.564	2.587	2.611	2.637
Punakha	(Punakha Sw. St.)	Exist.	1.420	1.584	1.733	1.891	2.050	2.166	2.327	2.442	2.604	2.776	2.875	3.003	3.137	3.262	3.457	3.567	3.682	3.803	3.929	4.061
Samtse	Gomtu (Industry)	Exist.	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	11.920	11.920	11.920	11.920	11.920	11.920	11.920	11.920	11.920	11.920
	Samtse	Exist.	2.323	1.599	1.784	1.982	2.215	2.450	2.680	2.937	3.172	3.462	3.704	3.948	4.191	4.472	4.725	4.948	5.182	5.427	5.684	5.954
Thimphu	Simtokha	Exist.	13.868	14.775	16.176	15.083	16.109	14.561	14.966	14.902	15.153	15.080	14.973	14.892	14.835	14.796	14.780	13.700	13.484	13.628	13.790	13.970
	Olakha	Exist.	10.462	11.146	12.203	11.463	12.493	11.094	11.403	11.354	11.277	11.222	10.446	10.390	10.350	10.323	10.312	10.275	10.027	10.134	10.254	10.388
	Chuzom	Exist.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Jemina	2006	0.000	0.000	0.000	2.715	2.959	7.281	7.483	6.742	6.343	5.962	26.920	26.887	26.865	26.849	26.843	26.822	26.878	26.591	26.657	26.731
	Pangrizampa	2005	0.000	0.000	0.000	0.905	1.315	1.734	1.782	2.484	2.467	2.455	2.786	2.771	2.760	2.753	2.750	3.082	3.457	3.494	3.536	3.582
	Motihang	2010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.351	0.696	0.693	0.690	0.688	0.687	1.370	1.729	2.097	2.122	2.149
Trongsa	Trongsa	2007	0.409	0.476	0.493	0.479	0.506	0.538	0.567	0.592	0.620	0.649	0.673	0.699	0.722	0.746	0.772	0.793	0.814	0.837	0.861	0.871
	Mangdeshhu P/S	2017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	For new consumers				
Samdrup-J	Deothang	Exist.	0.336	0.309	0.350	0.390	0.422	0.462	0.498	0.533	0.570	0.606	14.640	14.680	14.722	14.762	14.804	34.842	34.882	34.924	34.968	35.015
	Nanglam	Exist.	0.552	0.507	0.576	0.641	0.693	0.759	0.818	0.875	0.936	0.996	1.052	1.118	1.187	1.252	1.321	1.384	1.450	1.519	1.591	1.667
	Samdrup/J & Daifam	Exist.	0.312	0.287	0.325	0.362	0.392	0.429	0.462	0.495	0.529	0.563	0.594	0.632	0.671	0.708	0.747	0.782	0.819	0.858	0.899	0.942
	Bangtar	2007	For new connected consumers																			
Trashigang	Kanglung	Exist.	2.930	3.326	3.725	4.041	4.380	4.703	5.005	5.309	5.610	5.904	6.160	6.383	6.619	6.817	7.025	7.178	7.339	7.508	7.685	7.713
Yangtse	(Yangtse Sw. St)	Exist.	0.520	0.626	0.701	0.760	0.822	0.879	0.942	1.001	1.058	1.114	1.163	1.208	1.256	1.299	1.344	1.380	1.417	1.456	1.497	1.509
Tsirang	(Damphu Sw. St)	2007	0.284	0.333	0.372	0.401	0.431	0.456	0.486	0.514	0.542	0.570	0.595	0.619	0.644	0.669	0.695	0.717	0.741	0.765	0.791	0.802
Wangdue	Lobesa	Exist.	1.883	2.070	2.313	2.572	2.841	3.061	3.225	3.376	3.526	3.681	3.813	4.068	4.335	4.600	4.881	5.146	5.426	5.723	6.036	6.368
Zhemgang	Tingtibi	Exist.	0.490	0.547	0.544	0.505	0.525	0.548	0.571	0.595	0.617	0.640	2.759	2.786	2.812	2.839	2.867	2.891	2.915	2.941	2.959	2.972
Gasa	Gasa	2007	For new connected consumers																			
	Damji	2012	For new connected consumers																			

Prepared by JICA Study Team

12.6 Comparison of Forecast with PSMP Forecast

The industrial demand sharing about 80% of the total country demand should influence the overall demand forecast. **Table-12.6.1** compares the demands forecasted by PSMP and the Team.

Table-12.6.1 Comparison with Forecast of PSMP

	The Year 2013							The Year 2020						
	PSMP	JICA Team (Growth Scenario)			Difference (JICA-PSMP) (Growth Scenario)			PSMP	JICA Team (Growth Scenario)			Difference (JICA-PSMP) (Growth Scenario)		
		(High)	(Base)	(Low)	(High)	(Base)	(Low)		(High)	(Base)	(Low)	(High)	(Base)	(Low)
Entire Energy Sales (GWh)														
Domestic (*1)	177	206	196	179	29	19	2	272	259	242	213	-13	-30	-59
Industrial (*2)	741	2,077	1,070	869	1,336	329	128	988	2,243	1,583	1,233	1,255	595	245
Commercial	58	59	49	40	1	-9	-18	95	103	78	60	8	-17	-35
Public (Governmental)	54	97	87	70	43	33	16	91	149	127	97	58	36	6
Public Light & Bulk (*3)	0	132	119	99	132	119	99	0	183	158	124	183	158	124
Total	**1,030**	**2,571**	**1,521**	**1,256**	**1,541**	**491**	**226**	**1,446**	**2,937**	**2,188**	**1,727**	**1,491**	**742**	**281**
Non-CoincidentPeak Loads (MW)														
Base Forecast	268	475	315	269	207	47	1	366	540	443	350	174	77	-16
Forecast for System Planning	397				78	-82	-128	370				-370	-370	-370
Coincident Peak Load (MW) (*4 (Factor of 90%)	269	428	284	242	159	15	-27	329	486	398	315	157	69	-14

Source : PSMP Final Report & JICA Study Team

(*1) Both PSMP and JICA Team's forecasts include loads of the existing consumers and potential consumers in the non-electrified areas.
(*2) JICA Team's Growth Scenario : (High) = As scheduled in the programs for expansion of the existing large-scale factories and for construction of new factories.
(Base) = Demand assumed to be 70% of the plans and to be operated 5 years behind the program.
(Low) = Demand assumed to be 50% of the plans and to be operated 5 years behind the program.
(*3) No forecast indicated for the Public Lighting and Bulk Supply sectors in PSMP's froecast. They might be included in other sectors.
(*4) Forecast for the System Planninng in PSMP includes some of demands of new large-scale factories.

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There are differences in the Industrial, Public Lighting and Bulk Supply sectors between PSMP's and JICA's forecasts. As aforementioned, it seems that PSPM took only partial demand of expansion plans of the existing factories and development plans of new factories approved by DOE evaluating those plans negatively. JICA's forecast takes into account whole demands of the plans, although some modifications on the demands and development years are made in Medium and Low Growth Scenarios. Although PSMP did not project the demands of Bulk Supply and Public Lighting sectors, those demands are deemed to be included in other sectors. Thus, both forecasts are almost similar except the projection for the Industrial sector.

12.7 Balance of Demand and Supply

Special features of the existing Bhutan's power system are all hydropower stations to be of run-of-river type and two individual power networks operated in the country. Run-of-river type power station will lower its production in dry season due to less water-inflow. Accordingly, the balance of demand vs. supply was examined for cases of (a) annual and dry season of the entire country and (b) annual and dry season of the eastern and western power system separately.

Annual balance was examined on the basis of peak demands and energy requirements estimated under high and medium growth scenarios. Monthly peak demand and energy requirement considered for the examination of balance in dry season were worked out by applying the tendency of historical monthly demands in the last several year to the forecasted annual demands.

Annual supply capacity of the existing power stations was estimated from average historical production of each power station, while those of planned power stations were worked out from "Mean Annual Energy and Output" of each station examined in PSMP. Average supply capacity in dry season of the existing station was assumed from average monthly production in its historical performance, and those of the planned power stations were assumed to be "base load outside peaking hours" estimated in PSMP report.

Historical power data indicates that the maximum demand in a year has been recorded during the winter season. On the other hand, the minimum production has been recorded in February. The balance in dry season was examined for the month February.

In the DOE's system expansion plan, a 400 kV transmission line from Punatsangchhu-I power station to India via Sarpang is to be completed by 2012, and a new 132 kV line from Sarpang is to be connected with the eastern power system by the same time. Completion of Mangdechhu power station scheduled to be commissioned in 2017 will supply bulk energy into the eastern power system. Therefore, the balance for individual power system was examined by the year 2012.

Following are results of the balance examination.

(a) Annual balance in the entire country: Supply capability exceeds demands of both peak and energy.

(b) Balance in dry season in the entire country: Sufficient supply for demands under medium growth scenario, but little shortage in energy supply foreseen during 2 years (2010 and 2011). However, the shortage will be fully recovered by commissioning of Punatsangchhu-I power station in 2012.

(c) Annual and dry season balances of each power system: Sufficient supply capacity in the western power system. Following shortage are foreseen in the eastern power system during a period of 2007-2012.

Under the high growth scenario: annual and dry season energy and peak load

Under the medium growth scenario: annual peak load

Transfer of surplus in the western system to the eastern system will fully solve shortage in the eastern system. Transfer will be through the Indian grid, because 132 kV line of Tsirang-Chowabari or Punatsangchhu-Sarpang-Chowabari-Gelephu are scheduled in 2012.

Demand forecast and implementation schedule of the planned industrial estates should be frequently reviewed, and necessary measures should be taken in advance.