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ENERGY PLANNING AND MANAGEMENT IN MOUNTAIN DISTRICTS OF BHUTAN

A CASE STUDY

Dzongkhag Administration

MIT Series No. 1

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INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT

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Dzongkhag Administration: Thimphu
Royal Government of Bhutan

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International Centre for Integrated Mountain Development (ICIMOD)

Kathmandu, Nepal

PREFACE

A programme on 'Strengthening Rural Energy Planning and Management in the Mountain Districts of the Hindu Kush-Himalayan Region' was organised during the time course of January 1987 to November 1988, funded by the European Economic Community. Various activities were implemented under this programme. Six case studies, relating to 'Energy Management and Planning', covering five regional countries (Bhutan, China, India-2, Nepal, and Pakistan) were also conducted. It is hoped that the ultimate use of these case studies will be to develop energy management and to plan guidelines that could be used for training district level officers working in the field of energy-related issues. Dr. Ganesh Bahadur Thapa, a consultant, reviewed and improved the presentation of these six case studies.

This study is one among these six cases studies, and was conducted in Thimphu District, lying in the catchment of the Thimphu River. It attempts to document the energy use pattern in Thimphu District and suggests ways to improve the rural energy supply.

CONTENTS

List of Abbreviations

Gewog = Sub-district/Block
Dzongkhag = District
Sokshing/Jashing = Private woodlots owned by villagers

Energy Content and Conversion Factors

	Natural Units	kcal ('000)	TCE	TOE	Others
Non-commercial					
Fuelwood	ton	4,000	0.57	0.39	1.43 m^3
	m^3	2,800	0.40	0.27	700 kg
Dried Dungcake	ton	2,600	0.37	0.25	--
Agricultural Residues	ton	3,000	0.43	0.29	--
Commercial Fuels					
Diesel	kl	9,080	1.29	0.88	0.826 ton
	ton	10,960	1.57	1.07	1,210 litre
Light Diesel Oil	kl	9,350	1.34	0.91	0.853 ton
	ton	10,960	1.57	1.07	1,172 litre
Petrol	kl	8,000	1.14	0.78	0.709 ton
	ton	11,290	1.61	1.10	1,411 litre
Kerosene	kl	8,660	1.24	0.84	0.778 ton
	ton	11,130	1.59	1.08	1,285 litre
Liquefied Petroleum Gas	ton	11,760	1.68	1.14	--
Coal	ton	6,000	0.86	0.59	--
Electricity	MWh	860	0.12286	0.083576	--
Other Conversion Factors					
1 TCE			1.00	0.680272	
1 TOE			1.47	1.00	

Heat Content of Different Fuel Types

1 kg wood	=	15 Megajoules (MJ)
1 kg coal	=	26.5 MJ
1 litre of kerosene	=	43.6 MJ
1 kWh of electricity	=	3.57 MJ

INTRODUCTION

Background

The most important sources of energy in rural Bhutan are draft power for farming and fuelwood for domestic cooking and heating. Electricity is widely used in accessible areas, mostly for lighting. Non-renewable sources of energy, such as coal and petroleum products, are also used to some extent. Alternative sources of energy, such as solar power, wind power, and biogas, are also being promoted in the country. This report presents the findings of a case study on energy planning and management in the Thimpu District of Bhutan.

Objectives

The major objective of the study is to document the energy use pattern in Thimpu District and to suggest ways to improve the rural energy supply. The specific objectives of the study are stated below.

- To analyse the energy consumption patterns in Thimpu District.
- To assess the electricity supply situation and prospects for grid expansion.
- To assess fuelwood supply and demand in the district.
- To evaluate the potential for the development of alternative sources of energy.
- To identify options for the development of renewable energy sources.

Methodology

This study uses both primary and secondary sources of data. In order to analyse the energy consumption patterns in the district, a survey of 164 households was undertaken in five blocks (sub-districts) representing two of the three agroecological zones. Ten per cent of the total households in each block were randomly selected for interview to collect information. The consumption pattern in the selected blocks in the third zone had to be assessed by a key informant survey because of the lack of accessibility and because of time constraint. Secondary data relating to the supply of various energy sources and demand assessments were collected from government departments and corporations.

Introduction to the Study Area

Thimpu District (*dzongkhag*), lying in the catchment of the Thimpu River, consists of ten blocks (*gewogs*) with a total population of 58,600. It has three agro-ecological zones: alpine, temperate, and subtropical. The temperate and subtropical zones contain 96 per cent of the total population of the district. The people of the alpine areas are nomadic herders who move into temperate and subtropical areas during the winter months and remain in the alpine areas during summer.

Agro-ecological Zones

Alpine Zone. The alpine zone consists of four blocks with a total population of 3,026, as of 1987. The major economic activity of this zone is animal husbandry, as the high altitude (4,000 m and above) and rocky terrain permit limited cultivation of potato, turnip, and barley. Animal husbandry focusses primarily on yak rearing for manure, draft power, butter, and cheese. Trading ties with areas at lower elevations and the winter migration of cattle make the people of these blocks nomadic. Trade mainly consists of exchanges of yak by-products such as butter, cheese, wool, and meat for clothes and food supplies like rice, salt, chillies, etc.

Although climatological data for this zone are not available, the climate is characterised by a very long dry period, a long period of frost (3-6 months), and perpetual snow above the snowline (4,800-5,000 m). The area is environmentally fragile with vegetation consisting of scrubs, grasslands, stunted rhododendrons, juniper, and some fir forests at lower altitudes.

Temperate Zone. The temperate zone consist of four of the ten blocks of the district with a total population of 21,604 in 1987. Agriculture is the main economic activity in this zone. Paddy and wheat are the major cereal crops and apples and potatoes are the important cash crops grown in the area. The farmers of this zone have adopted modern agricultural technology such as improved tools and equipment, fertiliser, and pesticides. Cattle are reared in this zone for manure, draft purposes, butter, and cheese. The animals migrate to the eastern region during the winter months.

The mean annual rainfall in the temperate zone varies from 1,000 to 2,000mm and the number of rainy days ranges between 100 and 120 days. The annual mean temperature is 10 degrees C and the dry season lasts for four to six months. Dense evergreen oak, blue pine, grasslands, coniferous forests, and bamboo groves are found in the area.

Subtropical Zone. This zone consists of two blocks with a total population of 8,668. Agriculture and animal husbandry are the main occupations of the people in this area. Agriculture is practised on hillside terraces with shifting cultivation. Paddy, maize, and wheat are the major foodgrain crops grown in this zone.

The mean annual rainfall in this zone is less than 2,000mm. The number of rainy days ranges between 100 and 150 and the duration of the dry season is 3 to 5 months. The mean annual temperature is between 15 and 20 degrees C. The vegetation consists of dense evergreen and semi-evergreen forests, open woodland, and degraded forests.

Institutions and Administration

District Administration System. The Fifth Five Year Plan (1982-1987) of Bhutan has laid down a firm foundation for district planning and management through the implementation of five major policies: (i) district self reliance, (ii) decentralisation of development administration, (iii) control of maintenance expenditure, (iv) people's participation, and (v) mobilisation of internal resources.

As a part of the *Dzongkhag* self-reliance policy, a certain degree of capability in district planning and implementation has been achieved. The preparation of detailed individual *Dzongkhag* plans has facilitated the incorporation of more realistic local level needs and development programmes based on the potential of the district. The devolution of the responsibilities of planning and implementation of development programmes at the *Dzongkhag* level has necessitated the strengthening of decentralised development administration. People's participation in community and public works has been a longstanding Bhutanese tradition, but has been increasingly undermined in the development programmes undertaken by the Government.

Institutions for District Energy Development

The *Dzongkhag* set-up has a Technical Services' Division for the implementation of programmes related to agriculture and irrigation, animal husbandry, health, primary education, rural water supply, etc. However, power, forests, science and technology, and urban development are not represented in this

Division. Some functions relating to these are entrusted to the *Dzongkhag* administration. For example, in the forestry sector, the district administration is given the responsibility of seedling distribution, afforestation, and forest fire control.

Socioeconomic Infrastructure and Services

Education. Thimpu District has nine primary schools, two junior high schools, and two high schools. Primary schools are run by the *Dzongkhag* administration whereas junior high and high schools are administered by the Department of Education. Education is free to all Bhutanese citizens up to the Bachelor's level. There are also a number of monastic schools in Thimpu which impart education in Buddhist studies, painting, and sculpture. These schools are run by the Special Commission for Cultural Affairs.

Health. Health services are provided free of cost by three levels of health facilities available in the district: hospitals, basic health units, and dispensaries. Hospitals provide comprehensive health services whereas basic health units provide clinical services, immunisations, emergency services, first aid, and disease investigation services. Dispensaries provide clinical and emergency services and are responsible for alerting district health authorities about epidemics.

Agriculture. Agricultural extension offices provide subsidies for soil conservation works and for the improvement of local manure resources. There are two government farms, one specialising in research and the commercial cultivation of apples and potatoes and the other specialising in mushroom research and vegetable cultivation. Four veterinary service centres located in the district provide free services such as vaccination, deworming, general treatment, and breeding.

Transportation and Communication. The motorable road network is limited to the main valleys whereas many areas of the district depend on mule paths and suspension bridges as means of access to other areas. District roads built by the Logging Corporation of Bhutan extend to some forest areas of the district. Since the capital city of Bhutan is located in this district, it has good telecommunication facilities. Six of the ten blocks of Thimpu District have limited telecommunication facilities. Branch post offices are located in some remote areas.

ENERGY CONSUMPTION PATTERNS IN THE DISTRICT

A survey of 164 households covering 5 blocks and two agro-ecological zones was conducted to elucidate the energy consumption pattern of the households. Ten per cent of the total households in each block was randomly selected for interviews. The consumption patterns of the alpine blocks were assessed by the key informent method because of inaccessibility and time constraint. The major findings are discussed below.

Energy Consumption Patterns in the Temperate and Subtropical Zones

Types of Energy

Firewood. The average annual firewood consumption rates per household were 13.8m^3. in the temperate zone and 12.2m^3. in the subtropical zone. The survey showed that 72 per cent of the of the household firewood needs were met by oak, while only 28 per cent were met by pine. Oak is preferred because of higher energy content.

The ownership of wet land as a proxy for household income was observed to have little effect on the firewood consumption rate for cooking. However, statistical tests showed that per capita firewood consumption varied with family size. The average per capita annual consumption of firewood for cooking ranged from 0.55 m^3 for a 22 member household to 18 m^3 for a one member household. The mean firewood consumption for cooking in these two zones was 13.2m^3 per household.

Firewood for cooking is gathered from two main sources: (i) a green tree may be felled at will from nearby State forest land paying a royalty of Nu. 95 per trunk and is usually stored for use after cutting and drying, and (ii) dead fallen trees may be collected at will from State forests free of cost. Usually a tree is felled around May and the product is used until cull collection is needed around September.

Income plays an important role in determining the use of firewood for heating. Households owning at least 1.33 acres of wet land are the only users of firewood for heating. The mean firewood use for heating is 0.28m^3. The location of blocks strongly influences the time spent in collecting firewood. On average, households collect firewood four times a week after their stocks from the felling of green trees are used up. Overall, 30.5 per cent of households take two hours or less to collect firewood whereas 69.5 per cent of the households take more than two hours. The mean time spent to collect firewood on a trip was 3.77 hours.

Liquid petroleum gas (LPG) is used by a very few rural households which are located along the roads and have enough income to support its use. LPG is imported by a private company and is sold mainly in the urban areas. Electricity is not used for heating even in the urban areas although the cost of heating with electricity compares with the cost of using firewood.

Kerosene. The data show that kerosene use for lighting is uniform across blocks and agro-ecological zones. This is to be expected because there is no substitute to kerosene use for lighting except in urban areas and in a few rural areas which receive electricity supplies. The use of kerosene for lighting was not observed to be influenced by income levels. On average, 31.2 litres of kerosene per household were used for lighting.

Electricity. The use of electricity for lighting is confined to the temperate zone blocks supplied by grid extension. The average number of electric outlets per household using electricity is 3.6. Thirty one per cent of the households use two outlets, 23 per cent use three outlets and 46 per cent use four or more outlets. Income levels affect electricity use.

Petrol and Diesel. Petrol and diesel are mostly used for transporting logs and agricultural products and for public transportation to some extent. The use of these fossil fuels is independent of block location or agro-ecological zones. Households with 0.5 to 3 acres of wet land used up to 2,000 litres/year of these fuels whereas those with 4 to 8 acres used up to 9,000 litres/year.

Among agro-processing activities only grinding used any non-animate energy in the sample: one household used 1,000 litres of diesel per annum. Grinding is usually carried out manually or with traditional water wheels and threshing is carried out manually.

Organic Manure and Fertiliser. The use of organic manure or fertiliser does not vary significantly by block or agro-ecological zone. The ownership of wet land is not a good proxy for income in explaining organic manure or fertiliser use as they are mostly used in kitchen gardens. The average use of organic manure and fertiliser is estimated to be 8.84m^3 and 39.6 kilograms per household respectively.

The Energy Consumption Pattern in the Alpine Zone

Energy Uses

Cooking and Heating. The people in some blocks of this zone use dried cowdung cakes mixed with scrubs whereas in other blocks pine trees and dung cakes are used. The dung cakes are dried, stored, and used whereas the scrubs and pine tree biomass are collected at will from surrounding areas. A tin box with a grill cover is used for cooking and heating, the side of the box has a small door to insert cowdung and wood. The daily consumption of dung cakes varies from 10 kg to 20 kg depending upon the family size.

Lighting. Kerosene is the most important lighting fuel in this zone followed by torchwood (Pine tree) and glow from the cooking fire. Kerosene is scarce in the area because of transportation difficulties. However, lighting is not in great demand because people go to sleep at dusk.

ELECTRICITY SUPPLY AND PROSPECTS FOR FUTURE EXPANSION

Electricity Supply Situation

The first power plant was installed in Bhutan in the early sixties with the commissioning of a 360 kW power station in Thimpu. With the rapid growth of Thimpu, this plant was not able to meet the demand after a few years, and a 1,250 kW hydropower station was constructed at Gidakom in 1973. Even this addition could not keep up with the demand in Thimpu and the surrounding rural areas.

A series of diesel generators were installed from 1977 onwards with a total capacity of 3,755 kW. A 66 kV line supplements the energy requirement via Chukha Hydel Project from the Indian grid. The supply of power in Thimpu is now much more reliable after the commissioning of the first two units of the Chukha Hydel Project (336 MW). A 30 kW micro-hydropower station has been recently commissioned under the Japanese grant aid.

A few photovoltaic units have been installed by the Department of Power to tap solar energy for lighting. Some such units have also been installed by the Swiss Aid Agency, Helvetas. A few experimental water heating systems have been installed for the monasteries around Thimpu.

Thimpu District is presently supplied by a network of 84.6 km of LT line and 77 km of 11 kV line. A 66 kV line feeds the system and a 220 kV line is under construction. Twenty one villages and one town of the district have so far been electrified. The per capita consumption of electricity in Thimpu is 136.6 units compared to only 45.8 for Bhutan as a whole. Tables 1 and 2 show data on electricity use in Thimpu and Bhutan respectively from 1980/81 to 1986/87.

Table 1 : Electricity Supply in Thimpu District, 1980/81 to 1986/87

Particulars	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Installed Capacity (in MW)							
a) Hydro	1.610	1.610	1.610	1.610	1.610	1.610	1.610
b) Diesel	1.296	1.296	1.805	3.155	3.155	3.755	3.755
Total:	2.906	2.906	3.415	4.765	4.765	5.365	5.365
Energy Generated (in MU)							
a) Hydro							
i) Gidakom	4.057	5.003	5.140	4.866	4.341	4.136	2.420
ii) Thimpu	1.047	0.773	0.714	0.839	0.868	0.780	0.731
b) Diesel	0.900	0.960	1.096	1.649	2.532	3.206	1.295
Total:	6.004	6.816	6.950	7.354	7.741	8.122	4.446
Percentage growth over previous year	14.6	13.5	2.0	5.8	5.3	4.9	-45.3
Auxiliary consumption (MU)	0.150	0.170	0.174	0.176	0.148	0.141	0.130
Export (if any in MU)	0.000	0.000	0.094	0.096	0.028	0.751	0.809
Import - do -	0.000	0.000	1.090	1.355	1.013	2.995	9.440
Energy Requirement (MU)	5.854	6.646	7.772	8.437	8.578	10.225	12.947
Percentage growth over previous year	14.6	12.5	16.9	8.6	1.7	19.2	26.6
Energy sales (in MU)	4.059	4.287	4.550	5.348	5.768	7.838	8.079
Percentage growth over previous year	6.3	4.4	7.4	17.5	7.9	35.9	3.1
Energy Loss (in MU)	4.795	2.409	3.222	3.089	2.810	2.387	4.868
Loss in % of E. Requirement	30.663	36.247	41.457	36.613	32.758	23.345	37.599
Load factor (in %)	40.998	41.010	44.922	36.747	33.883	23.387	26.630
Peak load (in MW)	1.630	1.850	1.975	2.621	2.890	4.991	5.550
Length of H.T. Lines (km)	-	63.500	75.500	76.800	76.800	77.300	77.300
Length of L.T. Lines (km)	-	70.000	70.500	80.600	80.600	84.600	84.600
No. of consumers	-	2100	3116	3132	3325	3596	3902
Connected load (in MU)	-	-	8.906	9.070	9.773	11.837	14.565
No. of villages electrified	-18	18	18	18	21	21	
No. of towns electrified	-	1	1	1	1	1	1

Source: Department of Power, RGB.

Note: MU denotes million units of electricity consumption where 1 unit = 1kWh.

Table 2: Electricity Supply in Bhutan, 1980/81 to 1986/87

Particulars	80/81	81/82	82/83	83/84	84/85	85/86	86/87
Installed Capacity (in MW)							
a) Hydro	3.450	3.450	3.450	3.450	3.450	3.460	3.46
b) Diesel	2.328	2.972	3.052	4.442	4.442	5.442	5.44
Total:	5.778	6.422	6.502	7.892	7.892	8.902	8.90
Energy Generated (in MW)							
a) Hydro	7.314	7.577	8.283	7.946	7.864	6.940	5.45
b) Diesel	1.529	1.573	1.587	2.326	3.152	3.708	1.54
Total:	8.843	9.150	9.870	10.272	10.516	10.648	6.99
Percentage gorwth over previous year	-	3.5	7.9	4.1	2.4	1.3	-34.3
Auxiliary consumption (MU)	0.245	0.267	0.318	0.350	0.286	0.253	0.24
Export (if any in MU)**	0.000	0.000	0.000	0.000	0.280	0.751	0.80
Import - do -	2.464	3.196	4.510	4.890	5.151	8.137	17.50
Energy Requirement (MU)	11.062	12.079	14.062	14.812	15.101	17.781	24.25
Percentage growth over previous year	-	9.2	16.4	5.3	2.0	17.7	36.4
Energy sales (in MU)	7.900	8.471	9.389	10.750	12.218	14.630	17.20
Percentage growth over previous year	-	7.228	10.837	14.496	13.656	19.741	17.62
Energy Loss (in MU)	3.162	3.608	4.673	4.062	2.883	3.151	7.04
Loss in % of E. Requirement	28.584	29.870	33.231	27.424	19.091	17.721	29.05
Load factor (in %)	34.721	33.689	35.180	31.658	26.644	24.820	30.54
Peak load (in MW)	3.637	4.093	4.563	5.341	6.470	8.178	9.06
Percentage growth over previous year	-	12.5	11.5	17.1	21.1	26.4	10.9
Length of H.T. Lines (km)	-	282.8	285.78	288.4	291.6	303.0	353.9
Length of L.T. Lines (km)	-	297.6	318.0	342.7	342.2	347.7	349.1
No. of consumers	-	6482	8695	9262	9751	10583	11360
Connected load (in MW)	-		23.806	27.887	29.382	31.795	37.12
No. of villages electrified	-	87	92	93	95	98	98
No. of towns electrified	-	14	15	16	16	17	17

Source: Department of Power, RGB.

Electricity Supply Trend

The demand for electricity in Thimpu is not constant but varies tremendously at different times of the day. To meet the peak requirements for power, the Department of Power has installed oversized machines.

The demand for electricity is constantly on the rise with the use of power for space heating, cooking, water heating, and industrialisation in addition to the traditional use of electricity for domestic lighting. While urban areas in the district have economic activities which can both use and pay for electricity, a few electrified rural areas use electrical energy only as a substitute for kerosene for lighting.

Table 3 shows sectoral demand for electricity and growth rates for the district. After the construction of a 66 kV line and the commissioning of a sub-station, electricity will be supplied to additional rural areas.

For the efficient use of the power supply from Chukha Hydel Project, existing sub-stations around Thimpu are being upgraded. At the same time, the overhead lines in Thimpu are being laid underground. When the upgrading of existing sub-stations is completed, the older hydropower stations can be overhauled. Since plenty of power supply is now available from Chukha, there are no plans for future construction of hydropower stations in Thimpu Valley.

Table 3 : Volume and Growth Rate of Electricity Sales by Sector in Thimpu District, 1986

Sector	Average % Growth Rate Per Annum in Electricity Sales to Sector	Proportionate Share of the Sector	Units Sold to Sector in 1986 (MU)
Domestic	8.18	0.31	2.5
Commerce and Government	28.48	0.39	3.14
Industries	11.23	0.05	0.404
Bulk	6.33	0.24	1.97
Public Lighting	32.45	0.01	0.065

Source: Department of Power, RGB.

Constraints to Grid Extension

There are two major constraints to grid extension in Thimpu. First, the network of motorable roads is limited in Thimpu District and most blocks can only be reached by trails and mule tracks. The transportation of the materials required for grid extension is very costly and tedious. Second, the villages and households are scattered and this limits grid extension because of high transmission costs and low load factors. In 1986/87 line losses were estimated to be 37.6 per cent. With the increase in line length, line losses would further increase. Outdated transmission and distribution lines add to line losses.

Alternatives to Grid Extension

There are several possibilities that could be considered as alternatives to grid extension for electricity supply. Important alternatives in Thimpu are as outlined in the following passages.

Types

Micro-hydels. Like the rest of the country, Thimpu District is also endowed with plenty of natural streams which have huge hydropower potentials. Micro-hydels are ideal for rural electrification as they can be set up in user localities reducing transmission costs. Also, they can cater to small-scale industries.

However, micro-hydels have some inherent problems associated with their installation and maintenance. Most areas with potential for micro-hydels are not accessible by vehicle, thus making the transportation of equipment difficult. Micro-hydels installed with Japanese aid involve a relatively high level of technology. Spare parts for these cannot be manufactured indigenously, thus making their maintenance very difficult.

Solar Photovoltaics. An experimental photovoltaic system for lighting has been installed in one location recently. Although the plan was to expand the use of solar energy on a larger scale for lighting and heating, the cost factor has so far deterred the implementation of this plan. At 1985 prices, Helvetas was paying Nu. 221,000 per kWP of solar electricity generation. However, the cost of solar panels has been continuously declining with the rapid advances made in technology. At current prices, it would cost about Nu. 130,000 per kWP generation.

Experimental photovoltaic systems installed across the country show that the solar energy intensity is sufficient to charge batteries capable of meeting the domestic lighting requirements. A large-scale solar power unit needs a huge amount of capital investment and occupies plenty of space.

Although an individual unit solar photovoltaic system for a single household (assumed to use 4 outlets of 20 W each) costs only Nu. 10,000, in terms of energy costs per kW these systems are the most expensive. More specifically, the cost/kW for photovoltaics, grid extension, and micro-hydel are Nu. 130,000, Nu. 50,000, and Nu. 7,000 respectively.

Biogas Plants. Almost all households in Thimpu District own some animals. Although no quantitative data are available, most households have enough animal waste which can be converted into cooking fuel to meet the demand for cooking or into electricity for lighting. But most biogas plants available in the market are designed for areas that lie in the subtropical zone. In Thimpu District only two blocks have temperatures suitable for methane gas production as the production of this gas decreases drastically below 10 degrees celsius.

Diesel Generating Sets. Diesel sets were originally used in Thimpu District to supplement power supply but are now used as back-up units in cases of power failure in Chukha Hydel Project. Diesel generating sets are highly unsuitable for rural electrification. Although installation works are easily accomplished, the costs of operating and maintaining these sets are invariably very high. Transportation difficulties add to these costs.

Prospects for the Expansion of Electricity Supply

The extension of the electricity supply system in Thimpu faces different problems and constraints in two different ecological environments. As soon as the new 66 kV line is completed, the grid system along the Thimpu Valley can be extended to both sides of the valley to cover wider areas of the temperate and subtropical blocks.

Four blocks in the alpine zone are not designated to revive grid supply as these blocks neither have the population concentration nor do they have a sizeable energy demand to justify grid extension. However, electricity can be used in this area both in the domestic sector for cooking, heating, and lighting and in the industrial sector for yak wool weaving. Moreover, the pressure from increasing human and yak populations on the fragile environment further justifies an alternative source of electricity supply.

Micro hydels can meet all the domestic energy needs while the solar photovoltaic system is suitable for lighting and limited weaving applications. However, the cost and technical feasibility of the solar photovoltaic system are well known but the technical feasibility of micro hydels is not known. In view of the current plans of the Department of Power to install photovoltaic systems in the service centres in the first part of the Sixth Five Year Plan, the feasibility of micro hydels for the electrification of the alpine blocks should be explored.

FUELWOOD DEMAND AND SUPPLY IN THIMPU DISTRICT

Wood is the most commonly used fuel for domestic heating, cooking, and lighting in the district. Most villages in the temperate and sub-tropical zones are located near forests which meet the fuelwood needs of the people. Villagers own private woodlots called "*Sokshing*" and "*Jashing*" for collecting litter which is used as farm manure by mixing it with dung. Fuelwood in the form of twigs and small branches are also obtained from such woodlots. Villages in the alpine areas lie scattered high above the tree line and villagers have to walk more than 10 km to collect fuelwood from the forests. They rely on readily available scrub such as Rhododendron and Juniper for cooking their food and heating the rooms. Yak dung is also a commonly used fuel in these areas.

The supply of fuelwood to the rural and urban populations of Thimpu District comes from the government-owned forests and they are collected in one of four forms: dead trees and fallen branches, green trees by selective felling, lops and tops from logging areas, and saw log residues and offcuts.

Current Fuelwood Consumption

Table 4 shows the annual availability of residual volume from the logging areas in Thimpu District which can be used as firewood. The total annual volume of firewood available in the district is estimated to be approximately 165,000m^3 Assuming the present annual consumption rate to be 3.3m^3 per capita in the rural areas of Thimpu District, the total consumption of firewood in the district comes to 116,912m^3. This leaves a surplus of about 48,000m^3, which can be used to meet the demand of the urban population in Thimpu.

Annually a total of about 11,300m^3 of firewood is supplied to Thimpu township (Tables 5 and 6). With the urban population at 33,784, the present per capita consumption of firewood in Thimpu township works out to be 0.33m^3 per year. The low firewood consumption rate in Thimpu township reflects the use of other sources of energy such as electricity, LPG, and kerosene.

The demand for firewood is also met by felling oak and other broad-leaved trees from the forests. These trees are felled on a selective basis by first removing dead/dying and malformed trees. A total of 9606m^3 of firewood is supplied annually to urban areas by selective felling (Table 6) and 6,697m^3 of firewood is collected by villagers by felling green trees (Table 7).

Table 4: Forest Area, Total Growing Stock, and Annual Timber and Residual Yields in Thimphu District

Forest Type	Area (in ha)	Growing Stock Vol/ha (in m^3)	Total Growing Stock (in '000m^3)	Annual Yield (in '000m^3)	Log Volume (in '000m^3)	Residue Volume (in '000m^3)
Alpine forests	70,625	-	-	-	-	-
Temperate forests (mostly conifers)	84,100	428	36,017	857	429	150
Subtropical (mostly hard wood)	10,975	214	2,346	85	42	15
All	180,200	642	38,363	942	471	165

Note:

1. The areas of the vegetation types have been calculated from the report on Remote Sensing by Mr. Negi, UNDP Consultant, on the basis of the recently demarcated boundary of Thimphu District.

2. Growing stock per ha is taken from the following Management Plans.

   a) Temperate forest - Management plan for salvage areas of Thimphu, Paro and Haa.

   b) Subtropical forest - Lobesa Management Unit.

   Annual yield is calculated on the basis of pre-investment survey reports.

   a) Conifers 2.38 per cent of growing stock.

   b) Broad leaved 3.62 per cent of growing stock.

   Conversion loss to log volume is taken as 50 per cent.

3. Residual volume is calculated as follows:

   (1/10 of log volume + 25% of log volume).

4. Residual volume is assumed to be used as firewood.

Fuelwood Demand and Supply Projections

The present fuelwood consumption reveals that there is still an excess supply of 35,855 m^3. after meeting the urban and rural demand. It indicates that, at this stage, Thimpu District as a whole does not face any fuelwood shortage and there is sufficient fuelwood for its own use.

The volumes of growing stock, timber, and residual yield of fuelwood by block are shown in Table 8. The demand and supply situation for different blocks is presented in Table 9. This table shows that existing forests can meet the annual requirements of the rural population in all blocks except one. It also indicates that there are sufficient fuelwood resources even in alpine blocks. In reality, however, most forests in these blocks are far off from the habitations and the collection of fuelwood takes considerable time. The people in these areas turn to easily available sources such as scrub of rhododendron, juniper, and other shrubs for domestic cooking and heating. The alpine zones are ecologically fragile and indiscriminate removing of scrub and shrubs in these areas would ultimately bring about a variety of adverse effects such as soil erosion and desertification.

Table 5: Fuelwood* Supplied to Thimphu Township in 1986/87 (softwood and hardwood)

Month	Softwood (in m^3)	Hardwood (in m^3)
April'86	92.5	14.0 m
May	38.0	5.0 m
June	47.0	-
July	167.5	-
August	173.5	-
September	103.0	-
October	168.4	119.5
November	197.5	41.0
December	59.0	45.4
January'87	47.0	38.0
February	198.4	7.0
March	152.8	41.0
	1439.50	311.4
	Total:-	1750.9

Source: Bhutan Logging Corporation.

* Collected from the logging sites and supplied to Thimphu township from the firewood depot in Thimphu.

Table 6: Firewood* Supply to Thimphu Township in 1986/87

(Quantity in m^3)

Name of Organisation	Apr'86	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'87	Feb	Mar	Total
Govt. Agencies (Various Departments)	810	-	-	888	804	258	126	-	1819	-	1549	-	6254
R.B.A.+R.B.G.+R.B.P. +IMTRAT	-	-	-	-	-	120		-	-	-	1549	-	1669
Private Parties	-	-	-	-	552	291	-	-	-	-	-	-	843
Contractors	-	-	-	-	-	390	-	-	270	-	180	-	840
											Grand Total:		10354
											Average Per Month:		780

* Green trees felled after paying royalty and converted to fuelwood and supplied to the urban population.

Table 7: Firewood Supply to the Villagers Around Thimphu Township in 1986/87

(Quantity in m^3)

Name of Organisation	Apr'86	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'87	Feb	Mar	Apr	Total
Villagers	-	867.1	-	241.4	123.6	60	161.9	-	166.7	-	5076	-	-	6696.7
											Grand Total:			6696.7
											Average Per Month:			558

Source: Thimphu Forest Division.

Note:

a) Dead and fallen branches collected by villagers free of cost are not included in the calculation.

b) The above calculation reflects only the volume of green trees, usually of the oak species, extracted for fuelwood.

c) Villages near Thimphu Town are included and remote villages are not included.

Table 8: Blockwise Growing Stock, Timber, and Residual Yield in Thimphu District

Block	Growing Stock (in 1000T)	Annual Yield* (T)	Log Volume (T)	Residual Volume (T)
Naro	3490.6	83076.7	41538.4	14538.4
Teobesa	8188.3	194882.3	9744.1	3410.4
	2346.1	84929.8	42464.9	14862.7
Kawang	2510.5	597489.0	29874.5	10456.1
Chang	3099.3	73763.8	36881.9	12908.7
Barpa (Babisa)	3293.0	78350.4	39175.2	13711.3
Geyni	2189.3	52104.5	26502.3	9118.3
Mewang	4635.5	110324.6	55612.3	19306.8
Dagala	1361.4	32402.2	16201.1	5670.4
Babesa	738.7	17582.2	8791.2	3076.9
Lingshi	6595.2	156965.9	78482.9	27469.0

Source: Thimphu Forest Division.

Growing Stock	=	Total standing volume in forest
Annual Yield	=	Total annual timber (standing) to be removed (total annual increment)
Log Volume	=	Log (timber)
Residual Volume	=	Residue left after removing prime timber to be used for fuelwood

* Yield calculated on the basis of 2.38 per cent of the growing stock of conifers and 3.62 per cent of the growing stock of broad-leaved species.

Table 9: Blockwise Supply - Demand Projection for Fuelwood in Thimphu District

Block	Population 1987	Consumption Rate m^3	Total Consumption m^3	Fuelwood Availability m^3	Surplus/ Deficit (-) m^3
Babesa	2244	1.01	2486.0	13711.3	11225.4
Chang	3741	2.15	8043.2	12908.7	4865.5
Kawang	8346	1.88	15726.1	40800.4	25074.3
Mewang	8373	2.64	22104.7	19306.8	2797.9
Teobesa	6424	1.77	11370.5	18273.2	6902.7
Dagala	912	4.00	3648.0	5670.4	2022.4
Geyni	1144	4.00	4576.0	9118.3	4542.3
Lingshi	1113	4.00	4452.0	27469.0	23017.0
Naro	525	4.00	2100.0	14537.2	12437.2
Soy	476	4.00	1904.0	3076.9	1172.9

Source: Household Survey by the Author.

Note: Consumption rate of $4m^3$ per year assumed for Alpine *Gewogs*.

The demand for and supply of fuelwood have been projected in Table 10 for the years 1992, 2002, and 2012. Since the per capita fuelwood consumption rate and fuelwood availability are assumed to be constant for all these years in the future, the surplus is projected to decline over time for nine blocks and the deficit to continue to grow in one block. In the year 2012, five out of 10 blocks would have deficits in fuelwood supply.

Energy Supply in the Alpine Zone

The four blocks in the alpine zone are virtually cut off from the rest of the district because these blocks are inaccessible by motorable roads. The people living in these blocks are mostly nomadic and they depend on yaks to earn their living. Winters are very severe in this area and the people need a lot of fuelwood for room heating.

As stated earlier, forests in these blocks are far away from the villages, and this makes it difficult for the people to acquire sufficient fuelwood. The solution to the fuelwood problem in this area is to find alternative energy sources. Photovoltaic systems have been suggested as one of the alternatives for this area. However, the end use is mostly limited to lighting. Moreover, the cost of installing a photovoltaic system is estimated to be Nu. 13,000 which most local people cannot afford. Therefore, installing photovoltaic systems in these areas is not a feasible solution to the energy problem.

Creating village woodlots is another possible alternative for solving the energy problem. However, even this alternative is not very appropriate because villages are small in size and are scattered, the people are nomadic in nature, the number of yaks is high, which makes the protection of plantations difficult, and, since most areas lie above the natural tree line, it is difficult to find suitable tree species for the area.

Strategies to Improve the Fuelwood Supply in Thimpu

It will be hard to find a substitute to fuelwood in Thimpu District for many years to come. Thimpu has sufficient forest resources to meet the current demand for fuelwood. However, with an increase in population, the demand for energy will increase, thus putting more pressure on existing energy resources. Given this situation, the following strategies should be adopted so that the district does not face any energy problem.

Charcoal Production and Use

The best alternative for solving the energy problem in these areas would be to convert the wood into charcoal and distribute it to meet the energy needs for domestic cooking and heating. In addition, the villagers should be trained to use improved cooking-stoves to save energy.

There are large areas of forests in this zone which are located far away from the settlements. Transporting firewood from these forests would be time consuming and cumbersome. Charcoal is easy to handle and can be easily transported over long distances. It has high calorific value and can be stored for a long period. Trees felled on a selection basis and available tops can be converted into charcoal at the forest site. Charcoal can then be transported to the villages by mule. The production of charcoal should be done under the supervision of the forestry staff so that over-extraction of timber is avoided.

Table 10: Projection of Population, Fuelwood Consumption, and Fuelwood Availability in Different Blocks of Thimphu District in 1992, 2002, and 2012

Population	Consumption Rate	Total Consumption	Fuelwood Available	Surplus or Deficit (-)
Year: 1992				
2478	1.01	2503	13711	11208
4130	2.15	8880	12908	4029
9215	1.88	17324	40800	23476
9244	2.64	24401	19298	-5098
7093	1.77	12555	18273	5718
1007	4.00	4028	5670	1642
1262	4.00	5052	9118	4066
1226	4.00	4916	27469	22553
580	4.00	2320	14437	12217
526	4.00	2104	3076	972
Year: 2002				
3020	1.01	3050	13711	10661
5035	2.15	10825	12908	2083
11232	1.88	2116	40800	19684
11269	2.64	29750	19306	-10444
8646	1.77	15303	18273	2970
1227	4.00	4908	5670	762
1540	4.00	6160	9118	2958
1498	4.00	5992	27469	21477
707	4.00	2828	14537	11709
641	4.00	2564	3076	512
Year: 2012				
4488	1.01	4533	13711	9178
7482	2.15	16086	12908	-3178
16691	1.88	31379	40800	9421
16745	2.64	44207	19306	-24901
12847	1.77	22739	18273	-4466
1824	3.50	6384	5670	-714
2288	3.50	8008	9118	1110
2226	4.00	8904	27469	18565
1050	4.00	4200	14537	10337
952	3.50	3332	3076	-256

1. Population projection based on a flat 2 per cent per annum growth rate.

2. Fuelwood available (annual increment) assessment assumed to be equal to 1987 availability as the best of all possible supply scenarios.

Efficient Use of Existing Energy Resources. All existing forests should be brought under scientific management so that they can yield timber and fuelwood on a sustained basis. All residues that are not collected for fuelwood should be converted into charcoal and supplied to the users.

Improvement of Degraded Forests. An area of 2,575 ha of forests in various parts of the district is degraded because of the excessive felling of trees for timber and fuelwood in the past. These forests should be included in the afforestation programme.

Establishment of Woodlots on Wasteland. Available wasteland and unproductive land should be planted with fuelwood species in order to supplement the fuelwood supply from the forests. The creation of woodlots is particularly necessary in the fuelwood deficient blocks.

Promotion of Agroforestry and Farm Forestry. Rural households should be encouraged to plant trees on their farm land in order to supplement the fuelwood supply from the forests.

Promotion of Fuel-saving Devices. The average fuelwood consumption in the rural community of Thimpu is $3.3m^3$ per capita per year, and this is much higher than the average consumption of $0.45\ m^3$ per capita per head in the developing countries. Therefore, fuelwood saving methods and devices should be promoted particularly in the fuelwood scarce areas of the district.

Finding Substitutes for Fuelwood. It is difficult to find a perfect substitute for fuelwood. But efforts should be made so that the rural people can have access to electricity, solar power, and kerosene for lighting.

Improvement of the Fuelwood Distribution System. Fuelwood distribution centres are inadequate in Thimpu District. To improve fuelwood supply a fuelwood depot should be located centrally in each block so that the rural people do not have to spend much time in procuring fuelwood.

OPTIONS FOR THE DEVELOPMENT OF RENEWABLE ENERGY RESOURCES

The Department of Science and Technology is responsible for introducing new renewable energy systems and appropriate technologies in the country. The standard approach is to select suitable options from possible alternatives in order to match domestic energy requirements. The appropriate options are selected, based on such criteria as (i) investment requirements, (ii) ease in implementation and maintenance, (iii) intervention requirements, and (iv) suitability for end use requirements.

Being a landlocked and mountainous country, Bhutan faces formidable problems in terms of transportation. The lack of accessibility will continue to be a constraint in locating and constructing energy projects. Other constraints to energy development in Thimpu District relate to manpower, finance, infrastructure, technology, and information.

Use of Appropriate Technologies

The use of appropriate technologies in harnessing the renewable energy resources, mainly solar, wind, and biogas, requires further research and development in Bhutan. The availability of adequate information on district energy needs, constraints, and options is an essential prerequisite for sound energy planning and policy-making. However, technical information regarding various energy options are not readily available in Bhutan. The following paragraphs discuss options for the development of various renewable energy resources in Bhutan in general and in Thimpu in particular.

Options

Fuelwood. The annual fuelwood production from existing forests is enough to meet the present fuelwood requirements in the district. However, the amount of timber cut for fuelwood purposes may expand and reach alarming proportions with the increasing population and expanding road system. It is now feared that indiscriminate use of this natural resource could lead to large-scale deforestation.

Traditionally, the use of firewood in Bhutan is very wasteful. However, even this wasteful use of firewood seems more economical than electricity use at current prices of these energy sources. In this situation the rural households will continue to use firewood for cooking purpose.

A considerable saving in fuelwood can be achieved by the rural households by using improved smokeless stoves. A national project on smokeless stove has been launched by the National Women's Association of Bhutan. This project envisages producing 60,000 smokeless stoves during the Sixth Five Year Plan. The dissemination of improved cooking stoves should first be done in areas where there is scarcity of fuelwood. Subsidies on these stoves should be given only for an initial period to encourage their use. As women are the main users of stoves, they should be trained on stove maintenance and emphasis should be given to appointing women as stoves promoters. This project should encourage the development of local models of stoves. This is possible if local people and masons are trained as stove-makers.

Biogas Energy. One of the potential new sources of energy is biogas. It is an environmentally clean source of energy. Organic materials, such as animal and agricultural wastes, provide gases that can be easily used for heating and lighting. Biogas plants are technically feasible in the subtropical areas of the district, but they are not feasible in the cool areas because gas production decreases drastically below 10 degrees centigrade. One biogas plant has been tried successfully in a subtropical block of the district. However, economic analysis of biogas production has not been undertaken so far. The Science and Technology Division will also try another biogas plant in Thimpu by constructing a dome type concrete plant to study the effect of temperature on daily and seasonal variations in gas production. This Division is also planning to install individual biogas plants on a trial basis in each block in the subtropical areas.

Solar Energy. No measurements of solar energy insolation are available in Thimpu except "dry shine" data recorded by the Department of Forests. However, according to a rough estimate based on a theoretical calculation the daily insolation in winter months in the wider Valley of Thimpu is in the order of 14 MJ per square meter on a horizontal surface. The solar heating system being proposed now can probably provide sufficient energy for heating water for an average Bhutanese household for bathing and for washing clothes.

The Bhutanese Government has launched a "Rural Housing Project" through the Public Works' Department. The houses built under this project will use solar energy for lighting and heating water. The initial design and planning was done by the National Urban Development Corporation. The aim of the project is to make rural houses comfortable, warm, and clean. According to the Planning Commission, Nu. 800 million has been set aside in the Sixth Plan for subsidies to be given to families to improve rural houses. The subsidies would be in the form of hardware supplies for constructing toilets, smokeless stoves, window panels, and chemicals for treating shingles in order to extend their life from the present five years to about 20 years. Solar power for lighting is also being considered in areas that are inaccessible to hydropower supply. It may be worthwhile and feasible to make use of solar energy in inaccessible alpine areas where grid extension is not possible.

There are several advantages of solar photovoltaics, for example, no maintenance and operation costs, high reliability, long lifespan, etc. However, they also have some disadvantages. Solar panels are still very costly, although their prices are expected to fall substantially in the future. Foreign exchange is required to import these panels from abroad. Moreover, electricity generation from solar panels is very small, thus limiting its application to small individual consumers.

In Bhutan, solar photovoltaic systems have been supplied to almost all wireless stations which require a small but reliable source of electric power to run the transmission sets. Helvetas, a Swiss Agency for Technical Assistance has demonstrated the feasibility of solar generators for certain applications. The Science and Technology Division, with UNICEF participation, proposes to install and demonstrate the use of solar energy in heating, drying, fencing, and in greenhouses.

Wind Energy. Strong winds blow during the winter months in the funnel-shaped Valley of Thimpu. The narrowness of Thimpu Valley can, therefore, provide a higher than average wind condition. A systematic survey of wind patterns and distribution has not been carried out in the district. Wind energy may be useful in isolated areas for generating electricity and for pumping water for irrigation and drinking purposes.

The Science and Technology Division plans to install high-tech windmills for lift irrigation within the country. These mills would be economical because they are practically maintenance free and involve low running costs. If this system is found profitable, the Agricultural Department may find it suitable for its irrigation programme.

Hydropower. It is the government policy to plan future, major water resources' schemes taking into consideration irrigation, flood control, electricity supply for domestic and industrial use, and wildlife development. A very rough estimate shows that about 20,000 MW of hydroelectric power can be harnessed in the country.

In relatively inaccessible areas, the Government plans to carry out detailed investigations and surveys on mini hydroelectric projects. A 30 kW micro-hydel project, constructed with Japanese aid is to be evaluated for economic performance.

RURAL ENERGY POLICY

The major sources of energy in rural Bhutan are draft power for farming and firewood as fuel for domestic cooking. With the development of the national economy, the availability of new technologies, and complementary qualitative changes in the aspirations of the people, coupled with difficulties in access to and the sustainability of traditional energy sources, the need to harness alternative energy sources has been fully recognised by the Government. As a consequence of this concern, it is the stated objective of the Government to provide reliable, cost effective, and manageable forms of energy to the rural areas where 90 per cent of the total population live.

However, it is obvious from this case study that no deliberate attempt has been made by the Government so far to formulate a unified and comprehensive district energy plan. The review of the issues that hinder systematic rural energy planning in Bhutan indicates that the obstacles are a function of a combination of factors. At the regional level, the economic viability of different options, the cost to individual households, and the manageability of technology by villagers are the crucial factors determining energy planning.

At the national level, the present system of government organisation, with ministries and departments structured along sector-specific hierarchical lines is not conducive to promoting a comprehensive rural energy plan, the components of which cut across various sectors. Therefore, there is an urgent need to review the functional responsibilities of the sectors involved in providing rural energy, such as the Department of Power, the Forest Department, the Public Works' Department, the Science and Technology Division, and the district authorities. The consideration of rural energy within a sectoral context leads to inefficient and piecemeal planning. However, the need is for comprehensive energy planning which takes into account the differential energy requirements of various regions from different sources of energy.

It seems that rural energy planning in Bhutan will continue to be undertaken by different sectoral departments in isolation. Nevertheless, the Government is clearly concerned with improving the supply of various forms of energy in a way that is in tune with local conditions. In most cases the perceptions of local people concerning the priority and relevance of new programmes are not taken into consideration in implementing these programmes. As a result, the fulfilling of physical targets becomes the main concern, with relevance and impact becoming secondary concerns.

Another important feature of rural energy projects implemented in Bhutan is their dependence on foreign assistance. As a result, implementation decisions are sometimes modified to reflect grant conditions, such as location of projects near motor road heads. Even in the implementation of fairly simple programmes such as improved cooking-stoves, reliance on external funding and technical expertise has led to the selection of villages on an ad hoc basis.

While it may be possible to implement rural energy programmes on an ad hoc basis, the advantages of a systematic rural energy plan are numerous. The preparation of a systematic and comprehensive energy plan allows us to identify the needs of different regions for different forms of energy. Once this basic information is available, programmes related to different forms of energy or the introduction of new technologies can be implemented with increased relevance to the region.

SUMMARY AND CONCLUSIONS

More than 90 per cent of the rural population in Bhutan depend on fuelwood as the major source of energy. This case study indicates that the existing forests can supply the annual requirements of fuelwood to the rural population in nine out of ten blocks under study. However, future projections of the fuelwood demand and supply indicate that five out of ten blocks will have a fuelwood deficit in the year 2012 if the fuelwood supply remains the same and the fuelwood demand increases with an increase in population. In the alpine areas of the district, forests are far off from villages and this makes it difficult for villagers to collect fuelwood. The best alternative for solving the energy problem in these areas would be to convert the wood into charcoal and distribute it among the villagers. Efficient use of existing fuelwood resources, improvement of degraded forests, promotion of agroforestry, and promotion of fuel saving devices are some of the measures suggested for improving the fuelwood supply in Thimpu.

Most of the Thimpu Valley is connected to the grid system which receives power from three hydropower projects. Electric power is mostly used for lighting. Since electricity is going to be the cheapest source of energy in the future, its use on a wider scale will depend upon the availability of electric appliances at affordable prices in the rural areas. In inaccessible areas, where grid extension would not be feasible, micro-hydel plants may be an appropriate alternative. Solar photovoltaic systems, biogas plants, and windmills are other alternatives to grid extension which need further research and development.

Although the Bhutanese Government is concerned about improving the rural energy supply, no systematic rural energy planning has been pursued for a variety of reasons. The present system of government organisation, in which a number of government agencies are involved in providing various forms of energy to the rural population, is not conducive to promoting a comprehensive rural energy plan.

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Director: Dr. E.F. Tacke   Deputy Director: Dr. R.P. Yadav

International Centre for Integrated Mountain Development
G.P.O. Box 3226, Kathmandu, Nepal

Telex : 2439 ICIMOD NP   **Cable** : ICIMOD NEPAL
Telephone : (977-1) 525313   **Fax** : (977-1) 524509