Field Document No. 32

REGIONAL WOOD ENERGY DEVELOPMENT PROGRAMME IN ASIA
GCP/RAS/154/NET

MASTER PLAN FOR FORESTRY DEVELOPMENT IN BHUTAN

WOOD ENERGY SECTORAL ANALYSIS

Ministry of Agriculture
Department of Forestry
Thimphu, Bhutan

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Bangkok, December, 1991

This publication is printed by
the FAO Regional Wood Energy Development Programme in Asia,
Bangkok, Thailand

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FOREWORD

Wood energy is considered crucial for meeting subsistence as well as developmental energy needs of the rural and urban populations in most developing countries in Asia. In mountainous regions in particular, fuelwood energy use has its far reaching socio-economic and environmental implications. Notwithstanding efforts being made in alleviating this problem, there is a widespread ignorance about the functioning of the wood energy systems, in most developing countries. Energy planners are steadfastedly continuing their efforts in developing and improving commercial energy systems; biomass/wood energy problems continue to be left on the back burner. Likewise Forestry Sector plans, in the past have only marginally recognised the problems of fuelwood energy; most approaches to the solutions are based on adhoc assumptions of scarcity.

More recently, the needs of inter-sectoral planning for forestry development are recognised by most countries in this region. TFAP's and Forestry Master Plans are under preparation. The Advisory Committee (PAC) of this project in its first meeting in October, 1989 had emphasised the need for project assistance in wood energy planning under TFAP framework. Accordingly, opportunity was taken to assist the member countries in wood energy sector analysis, within TFAP framework. Guidelines for sectoral analysis were prepared by the FAO for test and application.

On the request of the Royal Government of Bhutan, this project provided assistance for wood energy sector analysis, under Forestry Master Plan. The consultant, Mr. Auke Koopmans has done an excellent job in analzing the existing data. The weakness in database was the main constraint in this study. Yet, using the available data, the consultant has reached some interesting conclusion and made useful follow-up recommendations.

This report highlights the existing patterns of wood energy consumption, projected future demands and supply-demand balance. It also emphasises the need for conservation of resources which are considered adequate at present, but likely to decline with the emerging demands of household, industries and agriculture.

Similar studies have been conducted by this project in Vietnam, under TFAP, applying the guidelnes for wood energy sector analysis and the study report is under publication.

It is hoped that this report will serve as a reference document for similar studies planned in other project member countries.

R.S. Gujral
Chief Technical Advisor

EXECUTIVE SUMMARY

This report focuses on the fuelwood energy demand and supply in Bhutan, and gives a brief overview on the overall energy situation in the country.

The first chapter provides general information on Bhutan, its population, climate, current energy situation and the economy. The second and third chapters describe the biomass energy situation, energy conversion technologies and the equipment used in the country.

By relying on existing information - data collection on energy demand and consumption is still inadequate in Bhutan - an estimate of the total biomass energy consumption in the domestic and industrial sectors was calculated. With regard to the industrial sector, emphasis was given on rural-based industrial activities such as food and agro-processing. Although a large number of industries were identified, only a few could be covered in-depth, due to lacking information on most of these activities.

The domestic sector, together with the industries and other activities are estimated to consume about 0.92 million metric tons of wood per year (in all forms, including charcoal). In addition to wood, other energy sources, for instance fueloil, coal and electricity are used, but the exact amounts cannot be defined on the basis of existing information.

The potential supply of fuelwood is estimated to be far larger than the present demand. It should be noted, however, that accessibility and other factors have not yet been taken into account. There are certain areas, notably in the southern and eastern parts of the country, which already experience fuelwood shortages.

The fourth chapter concentrates on fuelwood supplies, pricing and energy substitution and conservation. It is shown that there is no free fuelwood market system in Bhutan, as the supply and the prices are controlled by the Government. However, this is only valid in urban areas. The rural people collect fuelwood freely from forests, bypassing official channels. Fuelwood trade is practically non-existent in the rural Bhutan.

Due to the costs of commercial energy sources, the options for energy substitution are limited, particularly in rural areas, where biomass energy is considered to be a "free" commodity. In urban areas, where fuelwood is partly monetized, substitution does take place, as fuel costs are competitive and people prefer fuels that are easy and clean to handle, such as gas for cooking and electricity for heating.

With regard to energy savings, the introduction of improved industrial production methods and conservation measures, for example improved stoves, could significantly reduce energy consumption, not only in the industrial, but also in the domestic sector. However, experience with the improved stoves shows that more work has to be done to develop a stove that is not only cheap, clean and efficient, but also acceptable to most users.

Institutional aspects are briefly discussed in chapter 5, which shows that biomass energy has not received appropriate attention in the national energy planning, although biomass energy supplies account for about 88% of the total energy consumption. Data collection on biomass energy consumption has started recently, but this still happens on an *ad-hoc* basis. There should be more coordination and cooperation between departments within ministries, and between various ministries involved in biomass energy matters. Lacking coordination and cooperation may lead to problems in matching the demand and the supply, and hamper the development of this important energy sector.

It is concluded that, as existing data are far from adequate, more efforts have to be put on data collection on biomass energy consumption, availability, pricing, etc. Institutional expertise, however, must be upgraded to achieve this. A reliable database on biomass energy should be established for the use of energy planners to enable sound energy policy planning. These continuous processes of upgrading expertise and data collecting would lead to a better understanding of the importance of biomass energy in the Bhutanese economy. Problem areas could be identified and solutions developed. A project proposal, geared towards the upgrading of institutional capabilities and the establishment of a database on wood energy, is annexed.

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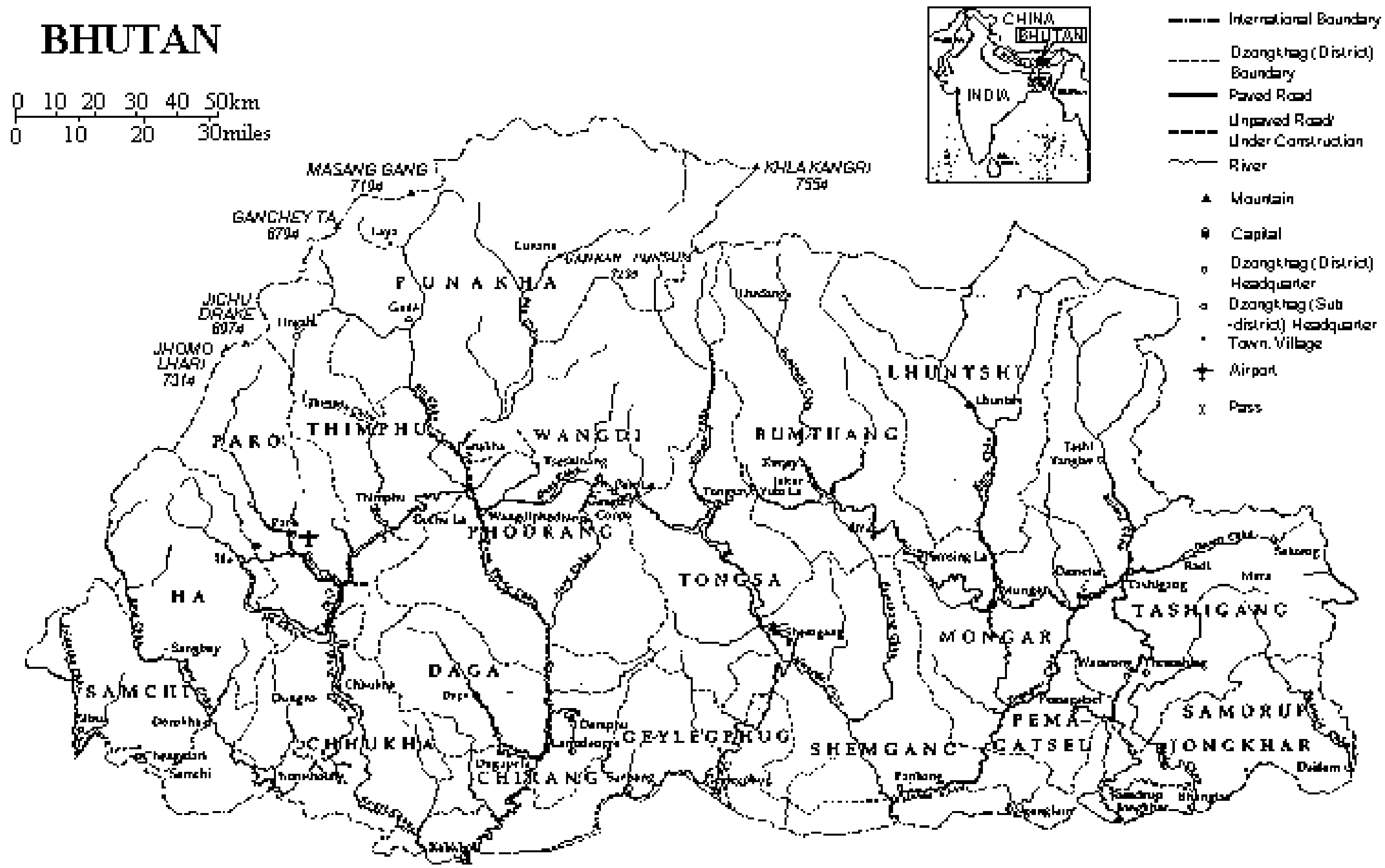
LIST OF ABBREVIATIONS USED

AAC	- Annual Allowable Cut
ADB	- Asian Development Bank
ADT	- Air Dry Ton
BCCL	- Bhutan Carbide and Chemicals Limited
BLC	- Bhutan Logging Corporation
CSO	- Central Statistical Office
DANIDA	- Danish International Development Agency
DOA	- Department of Agriculture
DOF	- Department of Forests
DOP	- Department of Power
DWH	- Department of Works and Housing
Dzongkhag	- Local word for District
FAO	- Food and Agriculture Organization
FYP	- Five Year Plan
Gewog	- Local word for sub-district
HV	- High Variant
ITU	- International Telecommunication Organization
kWh	- Kilo Watt Hour
LV	- Low Variant
MOA	- Ministry of Agriculture
MPFD	- Master Plan for Forestry Development in Bhutan
MPFSP	- Master Plan for the Forestry Sector in Nepal
MTI	- Ministry of Trade and Industries
MW	- Mega Watt
MV	- Medium Variant
NGO	- Non Government organization
Nu	- Ngultrum (Bhutan's currency)
PIS	- Pre Investment Survey
RBA	- Royal Bhutan Army
RBG	- Royal Body Guard
RBP	- Royal Bhutan Police
RED	- Rural Energy Division
RGOB	- Royal Government of Bhutan
STC	- State Trading Corporation
SV	- Standing Volume
TCC	- Tashi Commercial Corporation
UN	- United Nations
UNDP	- United Nations Development Programme
WB	- World Bank



Source: Survey of Bhutan (1989)
The boundaries and names used on this map do not imply official endorsement or acceptance by the United Nation

INTRODUCTION

The Royal Government of Bhutan (RGOB) has long recognized that a large part of the country's population depends on fuelwood as the main source of energy. The supply of fuelwood a cheap and renewable source of energy, which does not drain the national economy as other, imported energy sources do – is therefore important. Sustainable supply, which can be guaranteed by judicious forest management, is paramount to the future welfare of the country and its people.

In 1989, an agreement was reached between RGOB and donor agencies (Asian Development Bank (ADB) and the Danish International Development Agency (DANIDA)), to prepare a Master Plan for Forestry Development (MPFD) in Bhutan. The plan is to be a comprehensive strategy for the forestry sector, and cover the next 20 years. To ensure that the fuelwood needs of the country will be properly taken into account in the MPFD, the Department of Forestry (DOF) requested the Regional Wood Energy Development Programme, a Bangkok-based FAO project, to provide a consultant specializing in fuelwood energy to assist the MPFD team.

The consultant and his counterpart have reviewed and analyzed the available information on current fuelwood use, demand and supply in Bhutan. This work has covered not only the domestic sector, but also other sectors of the economy. Therefore, an estimate of the present energy consumption as well as a projection of the future demand could be calculated. However, only a very limited amount of direct information on fuelwood use could be obtained. Many secondary sources of information, such as departments of forestry, agriculture, animal husbandry, trade and industry, power, health, works and housing, transport and communication, were used to support the effort. The consultant wishes to express his gratitude for the assistance provided by these departments.

The data in this report are provisional and should be updated as more reliable information become available. Although all information has been checked and cross-checked with care, some uncertainties remain, especially with regard to the population size, and *gewog* and district boundaries. This is because official data, although said to be available, could not be supplied to the consultant.

Many people have provided valuable assistance during the time spent in Bhutan, in the office as well as during field trips, and their assistance and advice is hereby acknowledged. The consultant wishes to express a special word of thanks to Mr. Rytkonen of Jaakko Poyry, who provided computing power and the statistical analysis of various information, in particular, on fuelwood consumption and projection, and a preliminary estimate on sustainable wood supply in the form of timber and fuelwood.

This report focuses on fuelwood, and only briefly refers to other issues that are considered relevant, such as fuelwood supplies through social and community forestry. These matters are covered in depth by other consultants. Comments received from concerned and interested parties have been included as far as possible.

1. COUNTRY PROFILE

1.1 Geo-Climatic Conditions

Bhutan, covering an estimated area of about 46,500 square kilometres, is a small landlocked country. It is bordered by the Indian states of Sikkim in the west, West Bengal and Assam in the south, Arunachal Pradesh in the east and by the Tibetan autonomous region of the Peoples Republic of China in the north and northwest. The gateway by road to western Bhutan is Phuntsholing, located about 175 kilometres by road south of the capital Thimphu, while the only gateway by air is Paro, about 55 kilometres to the west of Thimphu. The nearest harbour is Calcutta, India, about 750 kilometres by road south of Phuntsholing. The nearest railway head - there is no railway in Bhutan -is located in India, about 40 kilometres south of Phuntsholing.

Bhutan is a relatively compact country, which measures from east to west about 320 kilometres and from north to south about 170 kilometres. The country is almost entirely mountainous with flat land limited to broader river valleys and some small parts along the southern border. The land rises from about 300 metres above sea level in the south to the towering Himalayan mountains in the north with peaks reaching over 7,000 metres. The main rivers run in general in north-south direction between steep mountains. Figure 1.1 shows the topography of Bhutan.

As an example, to show the difficulties encountered in transport due to the topography, figure 1.2 shows that, although the distance from Thimphu to Tashigang in the eastern Bhutan is only 190 kilometres following a straight line, by road the distance is about 540 kilometres - about two days' travel by car is required to reach Tashigang from Thimphu.

In Bhutan, three main landforms can be distinguished: the southern foothills, the inner Himalayas and the higher Himalayas. The southern foothills rise from the plains to heights of about 1,500 metres extending to the north by about 20 kilometres. The area consists of steep hills covered with forests. The inner Himalayas rise gradually to about 3,000 metres. Here the broader river valleys can be found, e.g. Paro, Thimphu, Punakha, Wangdi Phodrang, Bumthang and Tashigang, which form the economic and cultural heartland of the country. The northern region comprises of the main Himalayan range of snow-capped mountains, which separate Bhutan from Tibet. The Kula Gangri and the Gangkar Punsum (both over 7,500 metres) and the Jomolhari (7,315 metres) are the highest peaks.

The population is concentrated along the southern foothills and in or near river valleys. The northern part is sparsely populated. Out of the total area of about 46,500 square kilometres, it has been estimated that 42.7% is covered with forests with a crown cover of over 40%, while 14.1% is forest-covered but with a crown cover of less than 40%. Alpine areas, grasslands and rivers cover an estimated 25.8%, while the remaining 17.3% comprises of agricultural land and other areas[1]. The distribution is shown in figure 1.3.

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[1] Source: Preliminary results of the landuse mapping exercise carried out by Mr. Gupta within the framework of the Bhutan Master Plan for Forestry Development (ADB/DANIDA/FAO).

Figure 1.1 Topography of Bhutan

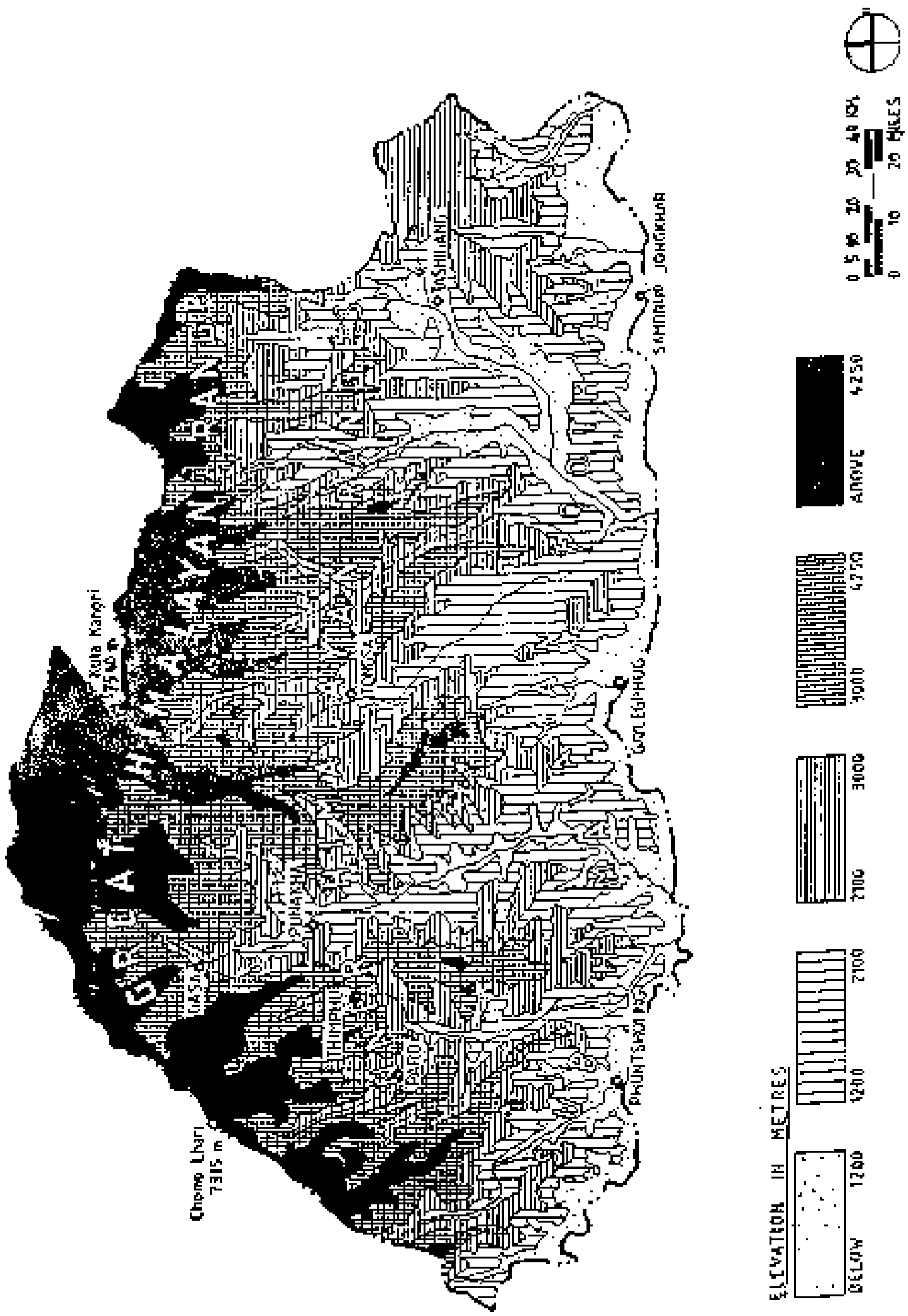


Figure 1.2 East-West Route Profile Thimphu - Tashigang (source MOA, 1991)

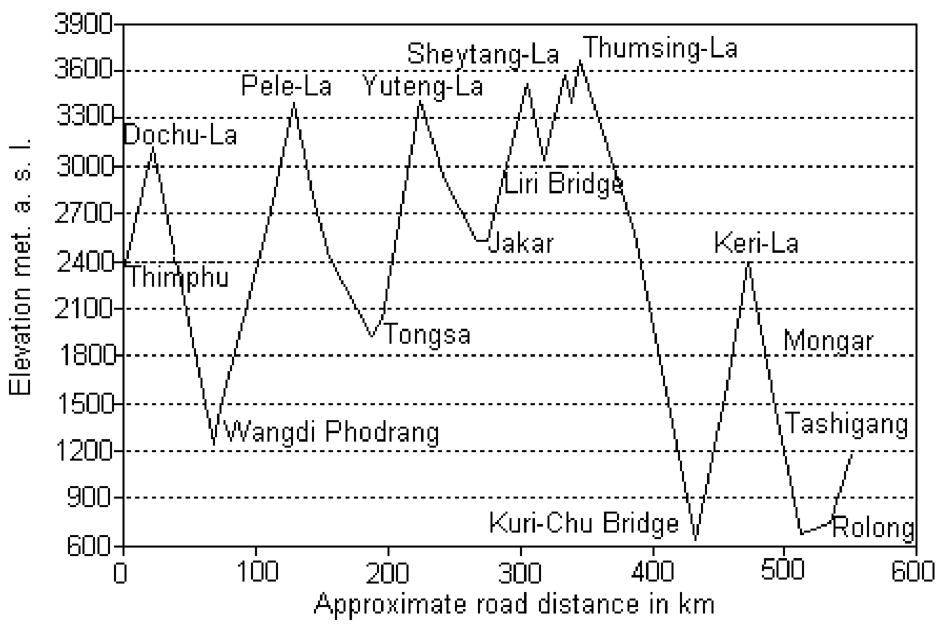
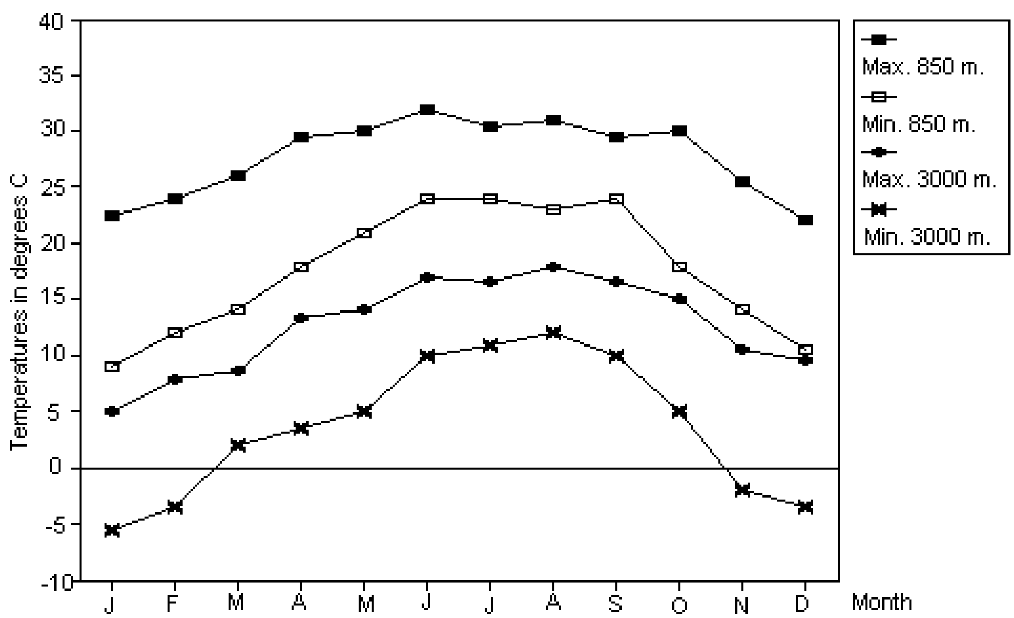


Figure 1.4 Representative Temperature Regime Average Temp. at Low and High Elevation



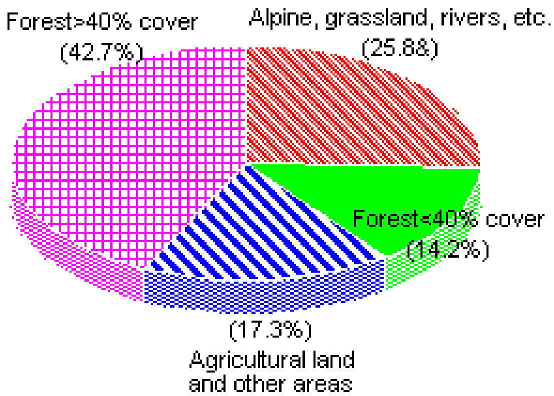


Figure 1.3 Land distribution

The climate in Bhutan is varied. The country can be divided into three distinct climatic zones broadly corresponding to the three main geographical divisions. The southern foothills have a hot humid climate with fairly even temperatures throughout the year (between 15^{o}C and 30^{o}C), and rainfall ranging from 2,500 mm to 5,000 mm in some areas. The central belt (inner Himalayas) has a cool temperate climate with an average annual rainfall of about 1,000 mm - the western part gets a comparatively higher amount. The higher, northern region has a severe alpine climate with an annual rainfall of about 400 mm, 60-90% of which is concentrated during the summer months and south-west monsoon. Figure 1.4 shows average maximum and minimum temperatures at lower and higher elevations.

Substantial variations within these broad ranges are found and climate and rainfall characteristics change dramatically from one valley to another, with consequent changes in the types of crop grown. Widespread rainfall can occur resulting in floods during the monsoon period in the summer inundating plains, fields, bridges and houses, and causing considerable damage to property and crops. Landslides, which can block roads completely for long periods, are also common.

1.2 The People and the Country

Bhutan is a kingdom with His Majesty, Jigme Singey Wangchuk, the present king and fourth of the line. The king is the head of state and the Royal Government. The National Assembly is the main legislative and policy-making body, while the Cabinet is the main executive body. Administratively, the country is divided into 18 districts or *dzonkhags*, headed by the *Dzongdag* or district administrator. Each district is divided into sub-districts or *gewogs*; there are 192 *gewogs* in Bhutan.

The population[2] consists of three main ethnic groups: the *Sharchops*, the *Ngalops* and the *Lhotsams*. The first two groups are collectively known as *Drukpas*, who account for about 65% of

[2]Official statistical information (CSO, 1989) indicates a population size of about 1.375 million in 1988. Preliminary results of the recent census shows that the actual population is about 600,000-700,000 people, with a per capita GNP of about US$425 (Source: Interview with the new chairman of the Planning Commission of Bhutan, Dasho C. Dorji in Kuensle, Vol. VI, No. 23 of June 15, 1991). The too high population estimate of 1960 was used by the National Assembly before the first visit of foreigners to Bhutan, and the population was then set at 700,000 people (14th National Assembly, 13th day of the 4th month of the Iron Mouse Year, Resolution 2-Part VIII). The figure, at an annual increase of 2%, would have increased to about 1.3 million, which is in accordance with the present official population size.

the total population. While the *Drukpas* are Tantric Buddhists by religion and culture, the *Lhotsams* or the southern Bhutanese practice mainly the Hindu religion.

The majority of the population is engaged in agricultural activities, whereas the remainder is engaged in business, government service or other occupations as shown in table 1.1. In addition to the registered occupations and activities, there are also small-scale cottage activities carried out at home, e.g. weaving, cheese and butter making, to name only few.

The official statistics show a birth rate of 39.1 per thousand, while the death rate has been estimated at 19.3 per thousand. The annual population growth rate stood at about 2% in 1984. Life expectancy was estimated at about 45.8 years for males and 49.1 years for females. It is expected that this will considerably improve due to better living conditions and improvements in the health sector.

The Central Statistical Office (CSO) has estimated that the average annual population growth rate from 1986 to the year 2006 will be about 2.3%. Using this assumption, it can be estimated that by the year 2000 Bhutan's population will be about 1.75 million, and that by the year 2020, the population has doubled.

Table 1.1 Percentage of the population according to economic activity (1984)

	All ages			Ages 15 - 64		
	Male	Female	Persons	Male	Female	Persons
Agriculture	52.5	61.5	57.2	78.4	95.4	87.2
Government service	3.9	0.3	2.0	6.5	0.4	3.4
Business	0.9	0.3	0.6	1.4	0.5	0.9
Other occupations	2.8	0.2	1.4	4.0	0.2	2.0
No occupation	39.9	37.8	38.8	9.6	3.6	6.5

Source: Statistical Yearbook of Bhutan 1989 (CSO, May 1990)

About 95% of the total population live in rural areas, and the remaining 5% in urban or semi-urban areas. The largest town and capital, Thimphu, has approximately 25,000 inhabitants. The share of the urban population has increased slightly over the last 30 years from about 2.5% in 1960, to 3.5% in 1975 and about 5.3% in 1990[3]. The same source shows a slight shift in the labour force between 1960 and 1980 from agricultural occupations (95% in 1960; 92% in 1980) to industrial and service-related activities (respectively, 2% and 3% in 1960; 3% and 5% in 1980).

[3] Source: World Resources 1990 - 1991, World Resources Institute.

1.3 National Economy

Bhutan has, besides valuable forests, considerable mineral resources such as coal, copper, dolomite, graphite, gypsum, lead/zinc, limestone, marble, mica, slate, talc, tufa and tungsten.

in mountainous areas making the exploitation economically difficult. Coal, limestone, marble and slate, among others, are mined and used either domestically or exported in raw or processed form. Cement is exported to India, and planned to be exported to Bangladesh and Nepal as well as produced for domestic use. (There are several cement factories in Bhutan; Penden, Yangzom and Namgey factories are located in the southwestern Bhutan; whereas Lhaki factory in southwest and Dongsam factory in southeast, are expected to start production in 1993-94 and 1996-97, respectively).

Cable logging systems are used in difficult terrain

Wood, as logs, timber or coal - at present exported to Bangladesh - are other important products with export prospects. Hydropower-based electricity is one the most important income generators in Bhutan.

The Gross National Product (GNP) has shown a steady increase over the years. It was estimated that the per capita GNP was about US$190[4] in 1990. However, it should be noted that this figure is probably understated, due to difficulties in measuring the output in a rural economy, where barter trade still features strongly. Moreover, the population of Bhutan is much smaller than originally assumed, and a per capita GNP of US$400 is apparently closer to the truth (see also footnote 2).

The economy has been growing in real terms from 1980 to 1987 at an annual rate of 8.8%. As shown in table 1.2, in 1987, the agricultural sector contributed 47% of the total Gross Domestic Product (GDP), followed by electricity production (12%), and community and personal services (10%). The notable increase in the share of electricity production in the GDP reflects the completion and commissioning of the Chhukha hydropower station. Most of the electricity generated at the station is exported to India. The decrease in the volume of the construction sector in 1986 is caused by the completion of the Chhukha hydroelectricity project.

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[4] Source: Economic Indicators, Asiaweek, May 24, 1991. (based on a population size of 1.5 million).

Table 1.2 Gross Domestic Product in million Ngultrum at 1980 prices

Sector	1980	1984	1985	1986	1987
Agriculture,	309.9	388.3	411.6	436.3	458.1
Livestock	139.2	161.3	168.6	177.4	184.5
Forestry and logging	172.3	256.9	253.7	267.3	283.2
Manufacturing	35.8	67.2	75.4	71.0	105.0
Mining and quarrying	6.8	15.8	12.6	22.2	21.6
Electricity and gas	2.5	5.2	6.0	60.4	229.0
Commerce	121.5	123.4	132.4	143.4	142.4
Transport and Communications	47.9	66.4	79.4	83.9	91.3
Construction	88.5	173.5	169.0	141.8	152.3
Finance, insurance and business services	70.2	109.4	110.1	126.2	135.7
Community, social and personal services (Gov. administration and defense)	120.4	130.3	126.0	168.6	200.0
Less: Imputed bank service charges	-20.0	-32.0	-25.0	-24.0	-30.0
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TOTAL GROSS DOMESTIC PRODUCT	1095.0	1465.7	1519.8	1674.5	1973.1
Annual growth rate in %		7.0	3.7	10.2	17.8

Source: Statistical Yearbook of Bhutan 1989 (CSO, May 1990)

Bhutan's national currency, the *Ngultrum*, is on par with the Indian Rupee and freely interchangeable with it, indicating the importance of India as a trading and aid partner. The official exchange rate is 21 *Ngultrum* or *Rupees* per US$1. However, in July 1991, a devaluation took place in India, which affects Bhutanese economy.

1.4 Current Energy Situation

Bhutan is, at present, a small producer and consumer of energy. Energy consumption per capita and, in particular, the consumption of conventional energy sources, such as oil, is estimated to be among the lowest in the world. The major source of energy in Bhutan is biomass in the form of wood, which is used by the vast majority of the rural and semi-urban population. In urban areas, electricity (hydropower-based and some minor amounts of oil-based), cooking gas, kerosene and fuelwood are also used. Coal, fuel oil and electricity are the dominant sources of energy for industrial sectors.

Bhutan's energy reserves include coal deposits in the southeastern part of the country, a considerable hydropower potential and biomass in the form of fuelwood.

1.4.1 Coal

Coal is found in the southeastern part of Bhutan near Samrang in Samdrup Jongkhar district. Reserves are estimated at about two million tons. The coal has relatively low heating value of about 20-25 MJ/kg, and a high ash content of 20-30% making it less suitable for most industrial purposes. For this reason, the coal is exported to Bangladesh, mainly for brick burning and tea drying. In 1989, about 1,900 metric tons of coal were mined and exported while in 1990, the amount up to May was 6,800 MT[5]. The production capacity of the coal mine in Samdrup Jongkhar is estimated at 30,000-50,000 tons per year.

Considerable amounts of higher grade coal are imported from India and other countries such as Vietnam, mainly for use in the cement and calcium carbide industries and, to a lesser extent, for other industrial purposes.

1.4.2 Oil

All oil products such as kerosene, fuel oil, diesel oil, petrol and cooking gas are imported and distributed by a TCC-owned private company. The total annual consumption of oil products remained fairly stable between 1985-1989, with 21-22 million litres imported per year. The consumption of kerosene, which is included in the above figure, and mainly used for lighting, has shown a steady increase, albeit slightly leveling-off since 1988, from about 2.5 million litres in 1984 to about 4.6 million litres in 1989. Cooking gas consumption - mainly used in urban areas - has also shown a steady increase from about 230 tons in 1984 to about 625 tons in 1989. The stagnation in the use of kerosene is most probably caused by improved electricity supply and enlarged distribution network. Furthermore, the price of electricity was lowered in 1988 from 0.7-0.9 Nu/kWh to 0.4 Nu/kWh. Cooking gas, which is only available in six towns in Bhutan, is preferred by users over fuelwood as an easy-to-use and relatively cheap source of energy.

1.4.3 Electricity

Hydropower is the main source for electricity generation in bhutan. The country's total installed capacity amounts to about 350 megawatt (MW), of which the Chhukha hydropower station accounts for about 340 MW. However, Chhukha station's capacity to generate electricity varies from 100 MW in dry winter months to about 340 MW during the rainy season in the summer. Most of the power generated at the Chhukha station is exported to India, while some electricity is again imported from India for use in the south-central and southeastern parts of the country due to the lack of a national grid.

1.4.4 Biomass

It has been estimated that approximately 98% of the domestic energy consumption is derived from biomass, mainly fuelwood, and to a very limited extent residues, such as straw, stalks and dung. The industrial and agricultural sectors, together with the government sector (e.g. armed forces, monasteries, road construction) use considerable amounts of fuelwood.

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5 Source: State Trading Corporation of Bhutan.

An energy balance was compiled by the consultant as no official energy balance was made available. By using information provided by the Department of Power (DOP, 1990 and 1991), statistical data and consultant's estimates as the basis, the balance shows that biomass energy accounts for about 88% of the total amount of energy consumed in the country. Conventional energy sources (coal, oil, gas and electricity) account for the remaining 12%. The energy balance is attached as Annex 1.

Fuelwood stock for a household sufficient for about one year

Fuelwood is gathered and transported often by female household members

The sustainable wood supply or annual allowable cut (AAC) from forests, plantations, shrubs and fallow lands, etc. has been estimated to be about 7-8 million tons (personal communication Mr. Rytkonen). Some factors, however, such as protected areas and accessibility, have not been taken into account in this figure. In principle, the wood supplies are sufficient to satisfy the demand. Nevertheless, since fuelwood collection can contribute to deforestation, careful planning and monitoring of this important energy source is required in many districts, if not the whole country.

2. BIOMASS ENERGY DEMAND AND SUPPLY

The energy balance (annex 1), shows that biomass fuels play an important role in the national economy, with approximately 88% of the total energy consumption (Total Final Supplies). The remaining 12% are supplied by coal, oil, gas and electricity. Although biomass fuels play a prominent role on the national level, up to recently hardly any information, other than some estimates, has been available about fuelwood consumption.

Fuelwood, for instance dead wood and fallen trees, are collected by rural people - most of them women - from forests. If the supplies from forests are not sufficient, a permit to cut a limited number of trees for fuelwood for family use (maximum 8-10 trees per year) can be obtained from the Forest Department by paying a nominal royalty of 1 Nu per tree.

The Royal Government of Bhutan is the sole owner of all forests, and, in principle, a permit is required for removal of forest products, including fuelwood. However, the Forest Act of 1969 is ambiguous about this[1]. A preliminary inspection of the available Forest Department records on fuelwood supplies indicated that less than 10% of the total fuelwood consumption was covered by permits. Thus, most of the fuelwood has been removed unregistered. Annex 2 gives an overview of the available information on fuelwood supplies covered by permits from the Forest Department.

The fuelwood covered by permits is mainly for urban or industrial use, and for special groups, such as the armed forces and monasteries, whose supplies are handled by the Forest Department or its authorized agents (e.g. Bhutan Logging Corporation). While urban and industrial users pay a nominal royalty, the armed forces and monasteries are supplied free of charge and the transport costs of the fuelwood are covered.

2.1 Available Literature on Fuelwood Use

The available literature on fuelwood shows widely varying figures for fuelwood use in the domestic sector. Very little information is given on how the figures were obtained and what kind of conversion factors were used.

One of the first reports, which includes information on fuelwood consumption in Bhutan was the Pre-Investment Survey carried out by a forestry institute located in Dehradunn, India (PIS, 1980). This report quotes fuelwood consumption on a per capita basis from 1,957 kg (833 kg per cubic metres) in the south, to 2,660 kg in the central and eastern parts, and 3,230 kg in the north-western part of the country. However, it is not indicated, when these figures were obtained. These data, as

[1] Personnel of the Forest Department was divided on the question if a permit was needed to collect firewood in the form of dead and fallen trees from the forests. About 80% of the people interviewed indicated that a permit is required, while the remaining 20% said that there was no need for a permit. However, most interviewed rural people indicated that a permit was required, but in almost all cases they did not bother to obtain it because of the difficulties involved (obtaining a permit means in some cases two days' walking to the local forest department or ranger office). The Bhutan Forest Act of 1991, which is under consideration, states that a permit is required to remove fuelwood from the government's forests.

well as information obtained from other sources, as described in the following paragraphs, should be treated with caution as seasonal variations affect fuelwood consumption considerably.

In and around Radi *gewog* in Tashigang district, a rural development and energy planning exercise was carried out from June to November 1987 (Johnson e.a., 1987). The results showed that on an average each household used 7-9 tons of fuelwood, mainly for cooking and 20-25% for heating. The average household size was 6.6 persons, and the sample size 38 households. In addition, especially at the end of the monsoon period, maize sticks were used up to 450 kg for heating, and 450 kg maize cobs for cooking and heating. No significant differences were found in fuel consumption between the traditional and the improved stoves. (Measurements over one week were carried out with the traditional stove, and they were repeated about two months after the improved stove had been installed.) Although most of the people were satisfied with the improved stove, many added three lumps of clay to raise the pots, as traditional stoves in Bhutan. Fuelwood collection was considered a major problem by one third of the families. This was mainly due to increased collection distances (from one kilometre to four kilometres over a decade). However, three quarters of the households considered agricultural tasks, in particular transplanting of rice, most arduous. Transportation by roads was a big problem. Lack of cash, to purchase cooking oil, kerosene, cotton for clothing, and pay taxes and other expenses, caused difficulties for almost all families.

A baseline survey of four eastern districts (MOA, 1991) confirms these findings. Fuelwood collection times varied between 1-1.5 hours. Forests contributed a major share of fuel requirements, with homesteads and surroundings providing from 10% to 22%. Part of the latter is straw, which one third of the people reported to use in addition to wood. Unfortunately, fuel use was not quantified in this report. About 30% of the edible cereals grown were used for making alcoholic drinks like *ara* and *chang*, produced and consumed mainly within households, but also bartered or sold. Average cash incomes varied from about Nu 200 to Nu 260 per month.

The Save the Children Fund, a US-based NGO active in Shemgang district, found during a survey of 14 villages and 425 households (January-February 1990), that each household used from 8,200 kg to 10,950 kg of fuelwood. Average household size was 7.2 persons. Some villagers faced problems in collecting sufficient amounts of fuelwood, but, in general, did not find this a major problem. Lack of cash income and labour were the most serious obstacles faced by the majority of the population. About 99% of the respondents had a family cash income of 2,000-3,000 Nu or less per year (about 250 Nu or less per month).

An anonymous report, describing results of a fuelwood consumption survey in Thimphu district (sample size of 164 households), indicates that on an average per capita 2.31 M^3 of fuelwood was consumed (excluding Thimphu town). With Thimphu town, the average dropped to 1.23 M^3 per capita. This study also indicated that in districts located at high elevation (Lhingshi, Soy and Naro), considerable amounts of dung were used as additional fuel to wood and twigs.

Although the use of dung as fuel has been questioned by many, the Forest Management and Conservation Project (BHU/85/016), which carried out studies on grazing in mountainous areas, confirmed this practice. Fuelwood, such as shrubs and twigs, are mainly used on special occasions such as cremations. Dung is used almost exclusively for cooking and heating. This practice is not limited to the districts mentioned above, but is reportedly widespread in other districts, such as Lhuntshi, Tashigang, Bhumtang, Punakha, Paro and Haa.

In Thimphu district fuelwood was collected on an average four times per week, with 30% of the people spending less than two hours per trip. The mean average was found to be 3.8 hours and the maximum eight hours per trip. It was found that only the distance from village to forest had impact on the time spent on fuelwood collection, rather than ownership of or access to land.

The Department of Power, which is responsible for energy matters in the country, is concerned with large scale electricity supplies and distribution, such as the Chhukha hydropower station. One of its divisions, the Rural Energy Division or RED, is in charge of rural and renewable energy issues such as biogas, solar and wind energy and micro-hydropower. In 1990, the department carried out a study on fuelwood use in the country. Information on fuelwood consumption was collected by using questionnaires, statistics and other sources. An initial estimate was made of the total fuelwood consumption in the domestic sector (DOP, 1990).

The RED study is up to now the only attempt to collect information nationwide. Questionnaires were sent to 59 schools, and filled in by grade VI students from primary schools and by grade VIII students from junior high schools. Unfortunately, instructions given to students were minimal, and afterwards the accuracy of results was not checked, which makes their reliability questionable. The study seems - accidentally rather than by design - to emphasize urban areas, where electricity and/or cooking gas is available; at least 9 out of the 33 schools, which returned the questionnaires, were located in urban areas. However, the results are the most up-to-date available on a national basis, and have been used as a major source of information in preparing this report.

Apart from the sources mentioned here, some additional sources on fuelwood consumption were used. The various fuelwood consumption figures quoted are shown in table 2.1. The figures as quoted in the available literature (table 2.1) are high, in particular, when compared with fuelwood consumption data from other countries with similar climatic conditions. Table 2.2 shows fuelwood consumption data from Nepal as reported in the Masterplan for the Forestry Sector in Nepal (MPFSP, 1988), as well as some general data on the Himalayan regions of Nepal, Northern India and Pakistan, Afghanistan and presumably also Bhutan (FAO, 1983b).

Comparing the data in tables 2.1 and 2.2, and including fuelwood consumption data for mountainous areas (Nepal and general), fuelwood consumption is found to vary between 700-900 kg per year (on the basis of a cubic metre weight of 500 kg). This is much lower than the average figure for Bhutan, which would, using the PIS data on weight per solid cubic metre, amount to about 800-3,200 kg per capita per year - four times as much as in Nepal.

Table 2.1 : Annual fuelwood consumption as quoted in the literature consulted.

Location	Use	Amount per capita	Source
Bhutan	Domestic	1.55 cum/cap	DOP, 1990
Bhutan	Domestic	3.00 cum/cap	Infras, 1987
Bhutan rural areas	Domestic	2.50 cum/cap	Ryan, 1985
Bhutan urban areas	Domestic	1.00 cum/cap	Ryan, 1985
Bhutan South	Domestic	1,957 kg/cap/year	PIS, 1980
Bhutan North-West	Domestic	3,230 kg/cap/year	PIS, 1980
Bhutan Centr.+East	Domestic	2,660 kg/cap/year	PIS, 1980
Shemgang district	Domestic	1,140 - 1.520 kg/year	Save the Ch., 1991
Radi village (TAS)	Domestic	1,300 - 1,900 kg/year	Johnson e.a., 1987
Thimphu district	Domestic	2.31 cum/cap	Anon.
Thimphu town	Domestic	0.36 cum/cap	Anon.
Thimphu town	Domestic	0.56 cum/cap	DOP, unpublished

Table 2.2 : Annual fuelwood consumption data from other sources.

Location	Use	Amount per capita	Source
NEPAL			
Mountains	Domestic	640 kg. fuelwood/cap. + 96 kg. residues/cap. equivalent to 708 kg. fuelwood/cap.	MPFSP, 1988
Terai	Domestic	479 kg. fuelwood/cap. + 63 kg. residues/cap. + 171 kg. dung/cap. equivalent to 689 kg. fuelwood/cap.	MPFSP,1988
Sindhu Palchok	Domestic	400-500 kg. fuelwood/cap.	Mahat, 1987
Hill areas	Domestic	1.20 cum/cap.	Wyatt-Smith, 1982
Western hills	Domestic	1.02 cum/cap.	Wyatt-Smith, 1982
GENERAL			
High mountains	Domestic	1.25-1.80 cum/cap.	FAO, 1983b
Low lands	Domestic	0.20-0.70 cum/cap.	FAO, 1983b

Main reasons for the significant variation may be found in the differences in forest areas and population densities. Approximately 60% of Bhutan's land area is covered by forests. The country has a population density of about 15 people per square kilometre. The corresponding figures for Nepal are estimated at 37% and 125. These figures equal to approximately four hectares of forested areas per capita in Bhutan, while in Nepal the figure would stand at 0.28 hectare per capita. Moreover, differences in culture and religion - Nepal is predominantly Hindu, while most of the Bhutanese are Buddhists - as well as cooking practices may affect fuelwood consumption.

Given these widely varying data on fuelwood consumption, it was impossible to use one consumption figure for the country, where climatic conditions vary dramatically and have influence on many activities (e.g. need for space heating and drying of agricultural products). Different habits with regard to the preparation and consumption of alcoholic drinks (*ara, chang*), cooking for animals, dyeing of yarn, etc. should also be taken into account. Almost no information on these varying conditions was available, except some indications in a report on an improved stove programme in Bhutan (UNICEF, 1990), described briefly below.

In southern Bhutan no dyeing of yarn and almost no preparation of alcoholic drinks take place. The number of domestic animals is on an average less than five. Cooking times are long, from six to nine hours per day. In the eastern part of the country, the preparation of alcoholic drinks is common: 30% of the grain is used for this purpose (MOA, 1991). The number of domestic animals is about ten, grain requires drying before grinding, and cooking takes from two to three hours per day. Weaving is common, but only a little yarn dyeing takes place, as most of the dyed yarn is bought from the distribution centres in Khaling and other places. The same conditions are more or less valid for the northern, central and western parts of the country, with the exception that yarn dyeing is common in the northeast. Cooking takes about two hours per day, but it is a custom to have always a pot of hot water ready. In the central part of the country, the number of animals is larger than elsewhere in Bhutan. In most parts of the country, space heating is needed, depending on location, climate and altitude. In the northern parts, heating is required during more than six months of the year; in the central part during 3-4 months, while in the south no heating is necessary. Most often only one room, usually the kitchen, is heated by using the heat from the stove.

To help calculate total fuelwood consumption, it was estimated that one solid cubic metre fuelwood per capita would be required for cooking and related activities. This estimate was based on available information as described above. To calculate additional fuelwood use (for space heating, etc.), a figure of 2.5 cubic metres fuelwood per household was taken. Different altitudes were taken into account: areas below 1,000 metres were believed to require 2.5 m3 per household; from 1,000 to 2,000 metres two times this amount; from 2,000 to 3,000 metres three times 2.5 m3, and so on. It can be argued that in lower lying regions, as in the south, no space heating is needed, but, as cooking fires are kept burning for much longer periods than in the other parts of the country, this additional amount was assumed to compensate longer cooking periods.

The results were converted to fuelwood consumption on a per capita basis, which was later used to project fuelwood consumption in the future. The fuelwood consumption per capita was calculated at a *gewog* and district level. If required, it can be easily converted to area or zone levels (e.g. climatic zones) that have similar fuelwood requirements. The results obtained using this method are comparable with the results of the RED study. It is believed that the picture of fuelwood consumption in the domestic sector is reasonably accurate. In urban areas, it can be assumed that fuelwood consumption is one half of the consumption in rural areas.

2.2 Population Size and Population Projections

To calculate the present fuelwood consumption for domestic purposes in Bhutan, the number of households, and the population sizes in each district, or preferably in each *gewog*, were required. This information was obtained from the UNDP/ITU report (1989). The source indicated the number of households for each *gewog*, the average household size in the districts and the population growth rate in each district. Using this information, the number of households and the size of the population in 1989 was calculated[2]. Annex 3 gives an overview of these figures as well as other basic information from each sub-district or *gewog* and districts or *dzongkhag*.

The Central Statistical Office (CSO) has published in its yearbooks data on the population and future forecasts on the basis of demographic assumptions. Three main variants in total fertility rate, with three subdivisions or projections in each (by assuming differences in crude birth and crude death rates) were calculated, resulting in changes in the average population growth rate. All three main variants show a decline in the total fertility rate which in 1984 stood at 5.9 with the high variant (HV) showing a modest decline to 5.8 which would result in annual population growth rates from 2.4% to 2.7%, depending on the crude birth and death rates. The medium variant (MV) and the low variant (LV) use total fertility rates of 5.0 and 4.0 respectively, resulting in population growth rates of 2.1% - 2.4% for MV and 1.9% - 2.2% in LV depending on the projection chosen.

Discussions with CSO, carried out by MPFD staff, indicated that the medium variant (projection E as shown in the CSO yearbooks, reproduced here as table 2.3) would be the most plausible with the average population growth rate of 2.3%. The decline in the total fertility rate from 5.9 to 5.0 will have implications on the household sizes, fuelwood consumption and the need for timber in the future.

At present the average household size is 6.7 (approximately 7.2 for farm households), and it is estimated to drop to 5.68 by the year 2006 (UNDP/ITU, 1989). It has been assumed that the average household size will decline in a regular way (straight line), which results in average household sizes at the beginning of the successive five-year plans as shown in table 2.4. The table also shows the number of households and the estimated population size as calculated by using demographic assumptions on population growth rates and their implications on the average household size.

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[2] The population size was calculated on the basis of the number of households and their average sizes. The result, when compared with statistics, appears to be about half the official size. This incidently comes close to the population size reported in "Kuensel" of June 15, 1991. Fuelwood demand at present and demand projections for the future have been made with this "revised" population size.

Table 2.3 : Demographic assumptions Medium Variant (projection E)

	1984	1991-2006
Total fertility rate	5.90	5.00
Crude birth rate in %	3.91	3.61
Crude death rate in %	1.93	1.38
Life expectancy: Males	45.80	51.80
Females	49.10	55.00
Average annual population growth rate 1986 - 2006	2.0%	2.3%

Source: CSO, 1988, 1989

It should be noted that by using assumptions as advised by CSO (table 2.3), the results will be different when compared with population growth rates of the demographic sample survey carried out in 1984. The main difference is that in the southern districts population growth rates seem to be higher when compared with the north-western districts. This unbalanced population growth would put a higher pressure on the forests in these southern areas, not only for fuelwood but also for agricultural land, thus worsening the already negative demand-supply balance in these areas.

Table 2.4 : Household size and impact on number of households and population

Year Start of Five Year Plan	1989	1992-93 7	1997-98 8	2002-03 9	2007-08 10	2012-13 11
Average household size	6.70	6.52	6.22	5.92	5.62	5.32
No. of households * 1,000	98.5	108.4	127.3	149.8	176.8	209.3
Est. population * 1,000	659.9	706.5	791.6	886.9	993.7	1,113.3

Source: UNDP-ITU and consultants estimates

2.3 Present Fuelwood Consumption in the Domestic Sector

Based on the estimates made on the per capita fuelwood consumption as described in section 2.1, and taking into account the population size (see section 2.2), the total fuelwood consumption was calculated. However, as in several areas other energy sources are used together with fuelwood, an adjustment for these amounts of fuel was made.

In districts with urbanized areas, an adjustment was made to reflect the lower per capita consumption in these areas. Within the framework of this study the towns of Thimphu, Phuntsholing, Geylegphug and Samdrup Jongkhar have been regarded as urban areas. In the last three cases, as the population size is not known, it has been assumed that the entire *gewog* population is urban-based.

In these areas, other fuels, such as cooking gas, electricity and kerosene are available and used by urban population. For Thimphu city RED[3] estimates on the shares of the different energy sources were obtainable. For Phuntsholing, for which no information was available the same 50/50 share has been taken, while for Geylegphug and Samdrup Jongkhar (in Orong *gewog*), a share of 80% fuelwood and 20% other fuels has been taken.

For other fuel types, notably the residues, no information was available. Rough adjustments were made on the use and/or distribution of other fuels, residues such as straw, maize stalks and cobs and dung. It has been assumed that in the high lying mountain areas, above the tree line, dung is used together with fuelwood as domestic fuel.

An analysis was made of the altitude and population size of the *gewogs* in each district. It has been assumed that in these *gewogs* 30% of the population (the remaining 70% presumed to live in lower lying areas) is using 50% fuelwood and 50% dung. In Radi *gewog* (Tashigang district), maize cobs and stalks are used as fuel (Johnson, 1987). However, no information is available on the extent of this practice in other *gewogs*, but it is believed that in Radi 10% of the fuelwood is replaced by residues.

The baseline survey carried out in four eastern districts (MOA, 1991) shows that straw is used in addition to wood. However, the report only indicates that 30% of the households use straw, but does not give figures on fuelwood consumption. A distribution of fuel source is included, but the report uses "forest" and "households" as fuel source, while the questionnaire specifies "forest" and "near the homestead", which apparently also includes wood. For this reason, the share of straw in the overall energy supply of these four eastern districts could not be calculated. It has been assumed that all fuel consists of wood from forests and homesteads.

The results of the calculations are presented in table 2.5. They show that in 1989, an estimated 0.82 million tons of fuelwood and close to 24,000 tons wood equivalent (WE) of other energy sources, such as electricity, cooking gas, kerosene, dung and agricultural residues, were used in Bhutan for various domestic activities including cooking, space heating, distillation and animal feed preparation.

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[3] Unpublished information, supplied by Mr. Hyvonen of RED, show that in Thimphu town in the domestic sector, about 15,000 cubic metres of wood is used. The remainder comprises of other energy sources like cooking gas, electricity and kerosene. The adopted calculation method, when used for Thimphu town, resulted in an amount of about 31,000 cu.m. Therefore about 16,000 cu.m. of fuelwood, equal to about 50% is replaced by other energy sources with the remaining 50% consisting of fuelwood.

Table 2.5: Domestic fuelwood consumption at district level taking into account use of other fuels

District names	1989 No. of house-holds	1989 Populat. size	Mean altitude district in meters	Average fuelwood use in tons per capita	Est. share of fuelwood in % of total consumption	Estimated amount of Fuelwood in tons in 1989	Estimated amount of Other Fuels tons W.E. in 1989
Bumthang	1,880	12,597	3,334	1.92	93.0	22,541	1,694
Chirang	7,669	51,383	1,367	1.25	100.0	64,365	0
Chhukha	8,701	58,296	1,910	1.00	90.7	52,919	5,434
Daga	2,117	14,187	2,124	1.17	100.0	16,571	0
Geyelegphug	9,081	60,841	943	0.93	97.5	55,059	1,385
Ha	1,533	10,270	3,353	1.71	100.0	17,515	0
Lhuntshi	3,141	21,044	3,314	1.66	100.0	34,979	0
Mongar	5,395	36,144	1,732	1.32	100.0	47,808	0
Paro	3,888	26,052	3,757	1.72	99.8	44,718	81
Pemagatsel	3,131	20,980	1,302	1.27	100.0	26,562	0
Punakha	2,335	15,645	4,502	1.56	97.4	23,721	645
Samchi	11,380	76,249	1,538	1.12	100.0	85,479	0
Samdrup Jongkhar	6,942	46,508	1,092	0.96	97.5	43,384	1,127
Shemgang	2,372	15,891	1,584	1.23	100.0	19,619	0
Tashigang	15,534	104,079	2,810	1.47	99.5	151,799	741
Thimphu	7,686	51,494	3,607	1.18	80.2	48,773	12,005
Tongsa	1,887	12,641	2,644	1.62	100.0	20,481	0
Wangdi Phodrang	3,824	25,618	3,265	1.60	98.3	40,346	691
	98,495	659,919		1.27	97.2	816,639	23,804

Source : Annex 3 and Consultants estimates

The term wood equivalent (WE) has been used here, as the shares of the other fuels, consisting of residues, dung, cooking gas, electricity and kerosene are not known. Conversion of the wood equivalent part can be made by taking into account the calorific values of the fuels as well as end-use efficiencies of stoves used. Annex 5 shows the average values.

2.4 Present Fuelwood Consumption in Other Sectors

The Energy Balance (annex 1) shows that the non-domestic sectors, e.g. industry, agriculture and forestry, commercial and government, have a 23% share of the total energy consumption. Agriculture, forest industries and related activities (including plywood and particle board factories) account for a major share. In addition to conventional energy sources, biomass energy in the form of fuelwood and charcoal is used, accounting for about 50% of the total energy used in these sectors. Although there are countless different industrial and village activities, which use energy, not all use fuelwood. Attempts have been made to identify as many different industries using biomass energy as possible, with the emphasis on major consumers. The list of identified industries is not exhaustive, however, since no information on all industries could be obtained. The industries have been divided into six groups as follows:

Food processing. This group includes, among others, bakeries, restaurants, preservation of fruit and vegetables, confectionery and beancurd (tofu) making. Communal kitchens in boarding houses at schools, army camps and monasteries as well as canteens have been included, as far as information has been available, in the Miscellaneous activities sector.

Mineral-based industries or building materials production. This covers brick making, roof tile making, lime burning, refractories, porcelain and pottery making.

Agro- and forestry products processing. This includes the processing of agricultural crops like sugarcane to sugar, cooking oil production, cardamom drying, lemon grass extraction, rosin and turpentine distillation, charcoal production, and others.

Textile industries. This covers e.g. textile weaving, dyeing, silk yarn reeling (sericulture) and other yarn making.

Miscellaneous activities such as road construction (tar melting and asphalt preparation), soap making, paper making, cremations, and communal kitchens.

Metal industries. This group covers foundries (iron, brass, etc.), blacksmiths and jewelry making. This group, although probably using charcoal, has not been further considered as a group as no information on this sector could be obtained.

In general, activities on which no information could be obtained, have been included in the non-specified sector for which the fuel consumption has been estimated on a per capita basis, spread evenly all over the country, using population size as the allocator.

Based on information obtained during field visits in Bhutan, statistics and other information sources, an estimate was made on the fuel use by the mentioned industries. The amount of fuel used by the different sectors, in case no sufficient data were available, was calculated using assumptions (see also chapter 3). The same method was employed to identify the type of fuel used, but here, based on observations and discussions with concerned institutions and people, an estimate on the respective shares could be made. It should be noted that the information provided here are estimates and in many cases only guesstimates, as no information at all was available. The information given on these sectors therefore should be treated with caution.

Only very little information on the food processing sector was acquired. Bakeries and restaurants exist, but their number is not known, nor how much and what type of fuel they use. Fruit and vegetable preserves are produced by Bhutan Fruit Products in a factory located in Samchi district. The factory uses approximately 750 tons coal per year. In Bumthang and possibly also other districts, fruits, e.g. apples, are processed, but no information on these could be obtained. Tofu making is not practiced, but there are plans to popularize soyabean growing and tofu making under the seventh five-year plan (MOA, 1990). Milk is processed into butter and cheese, but usually this is done at home, and the fuel requirements are included under the domestic sector.

Since hardly any information on food processing industries using fuelwood was available, and, as it is known that these industries exist, it was decided to cover their fuelwood requirements in a separate non-specified sector together with other activities as mentioned before.

The Department of Geology and Mines has provided some information on the mineral-based industries. It appears that brick production in factories has ceased, because factories no longer could compete with India, due to the cost of fuel and manpower shortages. To a lesser degree the same is valid for lime burning, which reportedly uses coal as fuel. Several cement factories operate (Penden Cement with 400 tons per day or TPD, Yangzom Cement 30-100 TPD, Namgay Cement 50-100 TPD; Lhaki Cement with 100 TPD and Dongsam Cement with 1,500 TPD are expected to start production respectively in 1992-1993 and 1996-1997). These factories use coal and electricity (0.22 ton coal and 140 kWh per ton cement). One pottery is known to operate; the existence of others could not be confirmed.

Processing of agricultural and forestry products is carried out in Bhutan with cardamom, sugar, lemon grass, resin processing and charcoal, activated carbon being the most important product. Cardamom, which is grown in the forests, is dried with fuelwood as the sole source of energy. The sugar factory requires, in addition to bagasse, a considerable amount of fuelwood. Both activities are concentrated in Geylegphug district, although cardamom is known to grow also in other districts in a belt stretching from east to west along the southern border. Figure 2.1 shows areas, where cardamom could grow (altitude from 5,000-7,000 feet and high rain fall). Figure 2.2 shows areas in the country where chir-pine (*Pinus roxburghii*) forests are located. Lemon grass distillation, which is dominated by TCC, is common in dry chir-pine forests, with processing at present concentrated in Mongar, Lhuntshi and Tashigang districts. Fuelwood is the only energy source although there are plans to use electricity for larger stills. Resin, tapped also from chir-pine, is processed into rosin and turpentine in the TCC-owned factory in Samdrup Jongkhar district, with fuelwood the main source of energy. Charcoal is produced from logging residues for use in the BCCL calcium-carbide factory near Phuntsholing. A small amount, but of a higher grade is delivered to a TCC-owned plant also near Phuntsholing for conversion into high-grade activated carbon for export. Cooking oil is processed on a very small scale using mustard seed and other oil bearing seeds as raw material. Unfortunately, no information could be obtained on this activity, which is therefore included under the non-specified sector.

Within the textile industries, only yarn dyeing has been considered (no information on other textile-based industries such as silk yarn was available). Processing is done at home and has been included in the domestic sector, although it is known that in Tashigang district the yarn distribution centre of the National Women's Association of Bhutan is dyeing yarn on an industrial scale, requiring annually about 50-75 tons fuelwood.

The remaining sector, miscellaneous activities, should cover more industries than have been named and described in this report. Tanning of hides and candle making are only two of those activities on which no information was available. These have been included in a separate non-specified sector, together with other activities about which no information was acquired. It has been assumed that tar melting for road construction and repair work is done with fuelwood only. The road construction staff (mainly from India) require considerable amounts of fuelwood for cooking and heating. In the first case requirements have been estimated using the length of existing road network as a basis for calculation, while for the latter an estimated number of people involved was available (World Bank, 1989).

Figure 2.1 Areas where cardamom possibly can be grown with numbers indicating extent of annual rainfall in meters

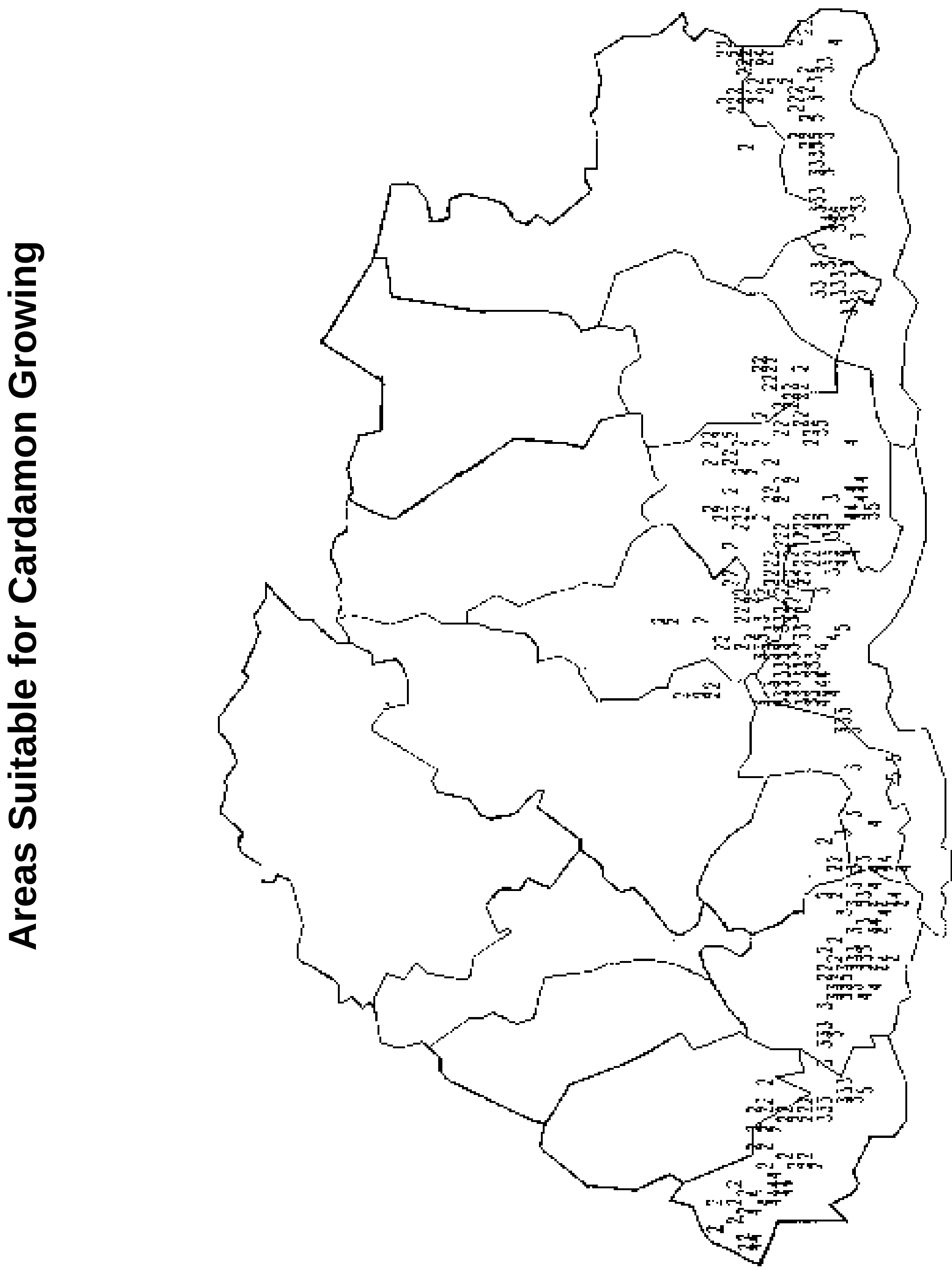


Figure 2.2 Areas predominantly covered by chir pine forests

Distribution of Chir Pine Forest Type

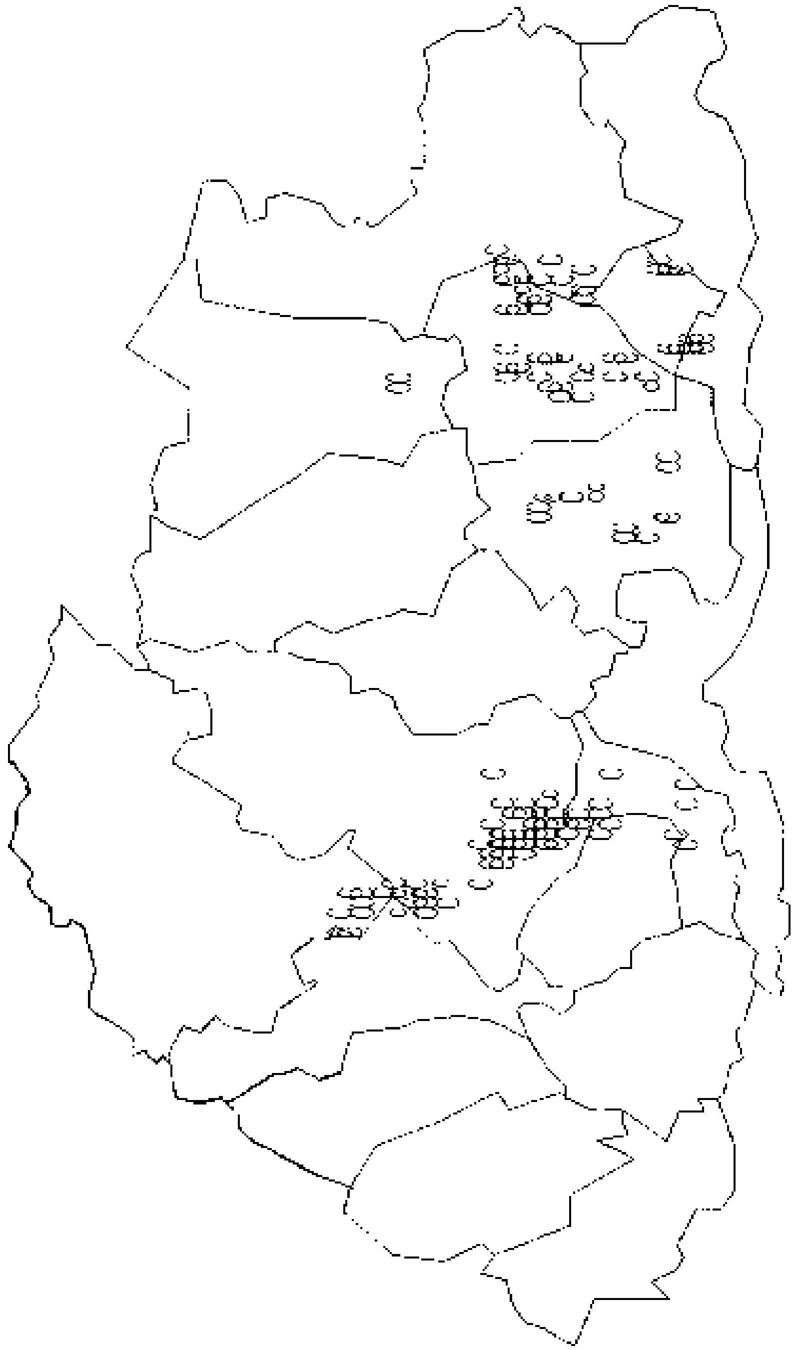


Table 2.6: Fuelwood consumption by industries and other activities estimated at district level

District name or Dzongkhag	AGRICULTURE AND FORESTRY — Use of fuelwood or waste wood in tons: Carda-mom drying	Sugar prod.	Rosin turpent. product.	Lemon grass destil.	Wood ind. and char prod.	MISCELLANEOUS ACTIVITIES — Amount of fuelwood in tons used for: RBA RBG/RBP IMTRAD	Monas-teries	Road con-struc.	Road crews	Crema-tions	UNSPECIFIED — Tons wood: Boardin houses etc.	Calculated on a per cap. basis	TOTAL AMOUNT OF WOOD TONS PER YEAR
Bumthang	0	0	0	0	0	136	77	110	288	57	210	126	1,004
Chirang	1,120	0	0	0	0	792	449	68	180	328	646	513	4,095
Chhukha	0	0	0	0	27,000	774	439	143	375	320	199	621	29,871
Daga	0	0	0	0	0	188	106	82	215	95	73	142	901
Geylegphug	25,146	400	0	0	0	939	532	110	288	321	908	608	29,251
Ha	0	0	0	0	200	111	63	32	83	26	157	103	775
Lhuntshi	0	0	0	253	0	227	129	43	113	84	129	211	1,189
Mongar	0	0	0	1,342	0	478	271	166	436	182	221	361	3,457
Paro	0	0	0	0	2,000	300	170	128	338	43	284	260	3,523
Pemagatsel	0	0	0	0	0	324	183	29	75	84	206	210	1,111
Punakha	0	0	0	0	0	231	131	51	134	39	134	214	935
Samchi	0	0	0	0	4,000	1,087	616	71	186	460	778	758	7,955
Samdrup Jon.	0	0	1,160	0	500	665	377	84	221	313	75	464	3,860
Shemgang	771	0	0	0	0	210	119	107	280	91	255	159	1,992
Tashigang	0	0	0	2,247	0	1,279	725	170	448	391	647	1,041	6,949
Thimphu	0	0	0	0	2,000	1,954	277	91	239	130	1,264	460	6,416
Tongsa	0	0	0	0	0	155	88	122	322	32	172	126	1,018
Wangdi Phod.	0	0	0	0	0	314	178	107	280	50	160	256	1,345
	27,037	400	1,160	3,842	35,700	10,166	4,930	1,710	4,500	3,046	6,520	6,633	105,643

Source : Central Statistical Office and Consultants estimates
File : 006/WOOD-IND-910623

Boarding houses at schools are common, especially at secondary schools. Information concerning their energy consumption is included in this sector, although could have been included in the food processing sector as well. On the basis of the number of students in these schools, a rough estimate was made of the amount of fuel used by assuming that 1.2 kg of fuelwood per person per day is used. Fuelwood requirements of the armed forces (Royal Bhutan Army, Royal Bhutan Police and the Royal Body Guard as well as IMTRAD army personnel from India) are difficult to estimate, as the size of the forces are not known, nor where they are stationed. It has been assumed that all the armed forces are evenly spread (based on the population size) over the country, and that they number about 8,000 and require about 1.1 ton fuelwood per year per person. Monasteries' fuelwood requirements, with an estimated number of 3,400 monks (Pommaret, 1989), have been worked out at about 5,000 tons. Funeral pyres require about 500 kg each time, with the total amount roughly estimated at about 3,000 tons per year.

In order to cover the activities under the title non-specified, on which no information was obtained, it has been estimated, that their fuelwood needs stand at 10 kg per capita, evenly spread over the country.

The total amount used by the industrial sector and other sectors is given in table 2.6. This shows that close to 106,000 tons of fuelwood and residues are consumed per year. Combining the domestic sector with the other sectors, the total amount of fuelwood used rises to about 0.92 million tons. Table 2.7, and the figures 2.3, 2.4 and 2.5 give an overview of the total amount of fuelwood energy consumption. Besides the amounts mentioned, there are also other fuel types used (electricity, cooking gas, kerosene, residues like dung, straw, maize stalks and cobs). This total amount could not be estimated, given the diverse calorific values of the fuels and their combustion efficiencies.

Table 2.7 Estimated total amount of fuelwood used in Bhutan in 1989 in tons

SECTOR	Amount in tons
Domestic sector	816,640
Other sectors	105,643
- Agriculture and forestry	68,139
- Miscellaneous	30,872
- Non-specified	6,633
TOTAL	**922,283**

2.5 Projected Fuelwood Consumption in the Domestic Sector

Using the data obtained from population projections (section 2.2), the total amount of fuelwood, which will be used in the future by this larger population, can be calculated, assuming that the present mix of energy sources (fuelwood, cooking gas, etc.) remains the same. The reason for this assumption is that although improved stoves have been introduced and substituting energy sources are available, their effect on the total present fuelwood consumption is believed to be minimal.

An evaluation of the improved stove programme (UNICEF, 1990) revealed that in six districts, where the stove programme was evaluated, 34% of the stoves worked properly, 35% were used improperly (open pot holes during cooking, damper not used, chimney not cleaned, etc.), while the remaining 31% had been converted either to the traditional type, were damaged or did not have chimney pipes. Due to the use of a chimney (smoke removal for improved health conditions was the main, if not the only, objective of UNICEF, the donor agency of the programme) during cold periods, some extra fuelwood is consumed together with charred wood from the stove, which is then burnt on a metal plate on a sand bed in the living room, or where ever the family congregates. The improved stove is not well suited to boil large quantities of food such as needed, for example, during *puja*'s, labour exchange periods and animal feeding. In many cases, people install an

Figure 2.3 Fuelwood consumption at district level
All sectors

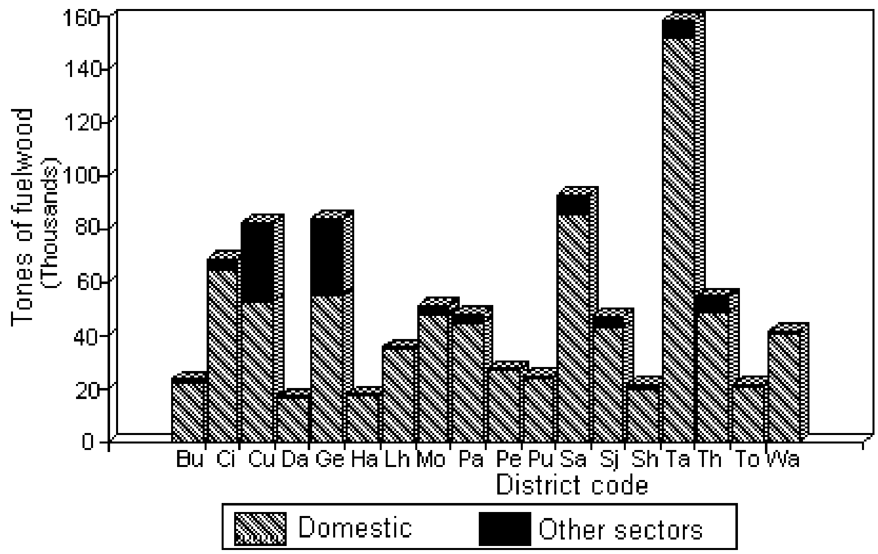


Figure 2.4 Fuelwood consumption
Calculated on per capita basis

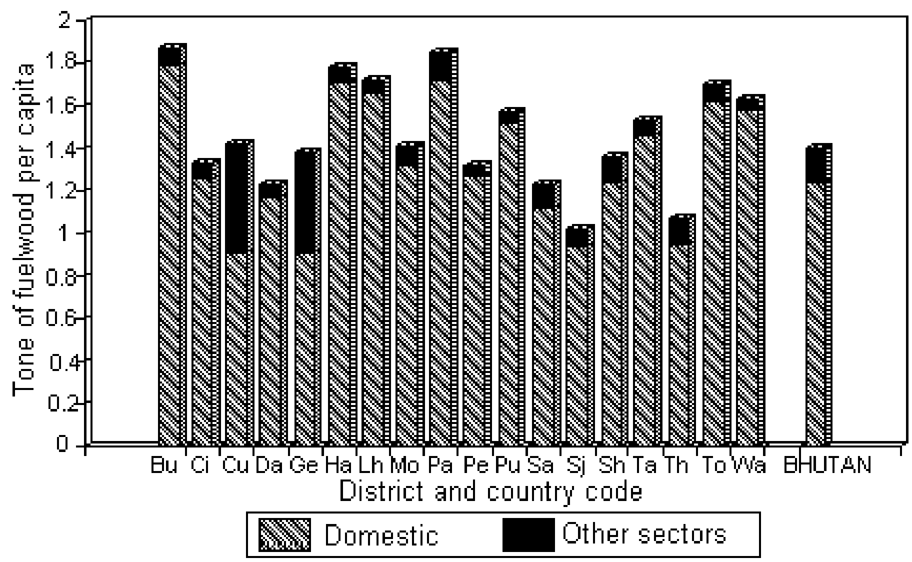


Figure 2.5a Fuelwood consumption in Bhutan
Share in % of total

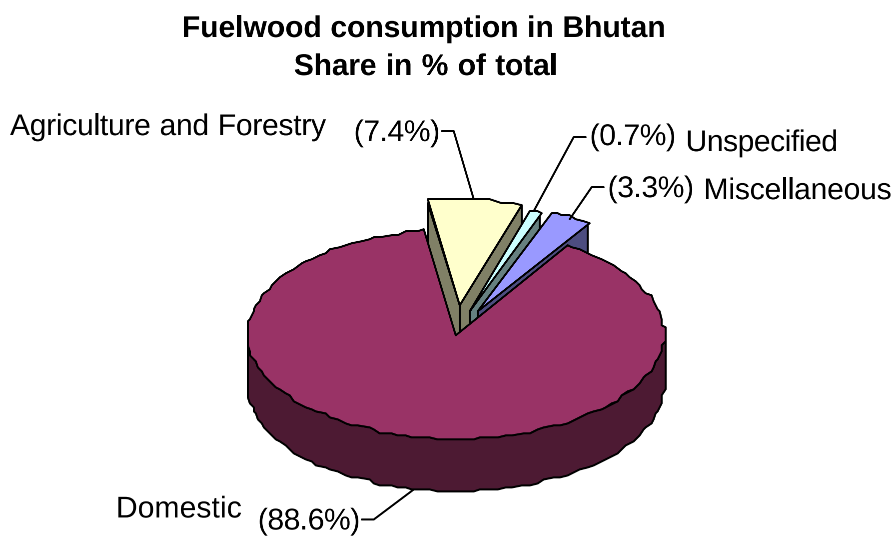
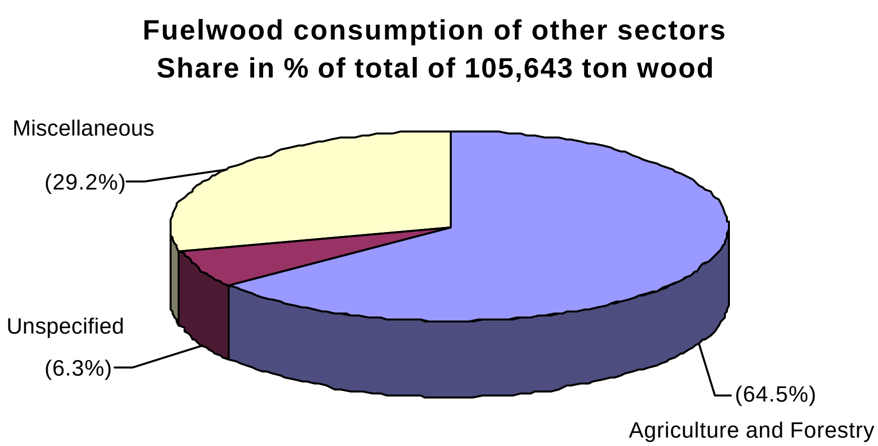


Figure 2.5b Fuelwood consumption of other sectors
Share in % of total of 105,643 ton wood



additional stove, often of the three-stone type, for these occasions. Therefore, although no doubt the improved stove could save fuel, when properly used (tests to compare improved and traditional stoves have not yet been carried out), the net effect on fuelwood consumption is probably minimal or, in some cases, negative.

With regard to fuelwood substitutes, such as kerosene, cooking gas and electricity, it is more difficult to predict what will happen in the future. These substitutes are presently not widely available, possibly with the exception of kerosene, which seems to be used in most of the easily accessible rural areas for lighting and to a limited extent cooking. Electricity is available in larger cities and villages (28 towns and 221 villages electrified with a total of about 16,000 connections, including industry, government, commerce, public lighting, etc. as of June 1990). The domestic use, however, forms only a small part out of the total consumption.

It has been estimated (DOP, 1991a, 1991b) that during the year 1989/90 about 15.7 million kWh was used by the domestic sector in Bhutan, including public lighting and bulk supplies. The domestic sector alone consumed 11.283 million kWh. Out of a total amount of 127.567 million kWh consumed by all sectors, the industries required by far the largest portion, 102.991 million kWh. The 15.7 million kWh (or 11.283 million kWh excluding public lighting) is equal to an annual per capita consumption of about 24 kWh, or 17 kWh excluding public lighting, assuming that the revised population size is about 675,000. The domestic sector in Thimphu and Phuntsholing required during the same period respectively 5.486 and 2.334 million kWh. This leaves for the remaining domestic sector in the rest of the country only 3.463 million kWh, equal to a roughly estimated 5-6 kWh per capita per year. The present annual increase in the per capita consumption of conventional energy sources varies from 0% in the case of kerosene, about 14% in the case of cooking gas and from 15-25% in the case of electricity (see also figures 2.6 and 2.7).

The present low consumption of conventional energy sources is largely due to their limited availability, but also because of lacking cash income in rural areas, where barter trade is common. For instance, cooking gas is only available in six towns. Fuelwood is cheap (see chapter 4) and available almost everywhere. For these reasons, it is not likely that commercial energy sources will replace fuelwood to a large extent. A shift may take place, as indicated by the fall in kerosene consumption and the rise in electricity use, as electricity substitutes kerosene for lighting, whenever electricity becomes available. In the projections on future fuelwood use, it has been assumed that the use of conventional energy sources will, at best, grow annually by 5%. In the "base case" it has been assumed that the use of conventional energy sources stabilizes at present per capita consumption levels.

Fuelwood consumption in the future may be affected by the fact that once fuelwood becomes scarce, people start to economize in an effort to save fuelwood. In most parts of the country, it is expected that in the near future there will be no shortages of fuelwood, except for southern and eastern regions, where the supplies may become sparse (see section 2.7).

With regard to uncertainties concerning the use of improved stoves and the fuelwood supply situation, no analysis of the effect on local shortages on the fuelwood consumption can be given. As a base case, it has been assumed that fuelwood use per capita will remain stable, while in the best case fuelwood consumption will drop by 1% annually. Part of the decrease can be attributed to fuelwood savings through a concerted effort to introduce improved and acceptable stoves, while

Figure 2.6 Commercial energy use
Per capita increase in %

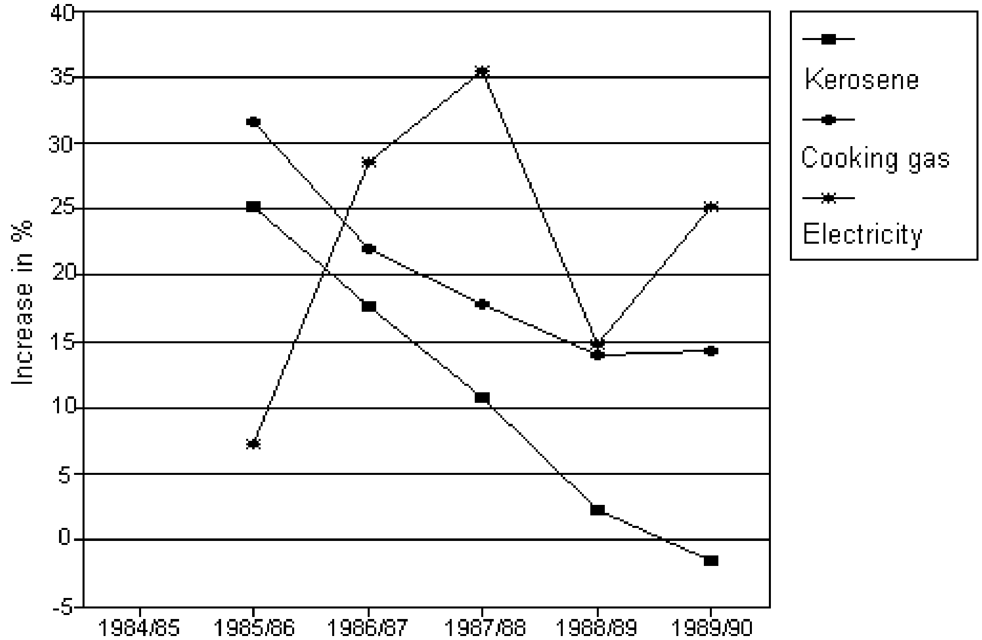
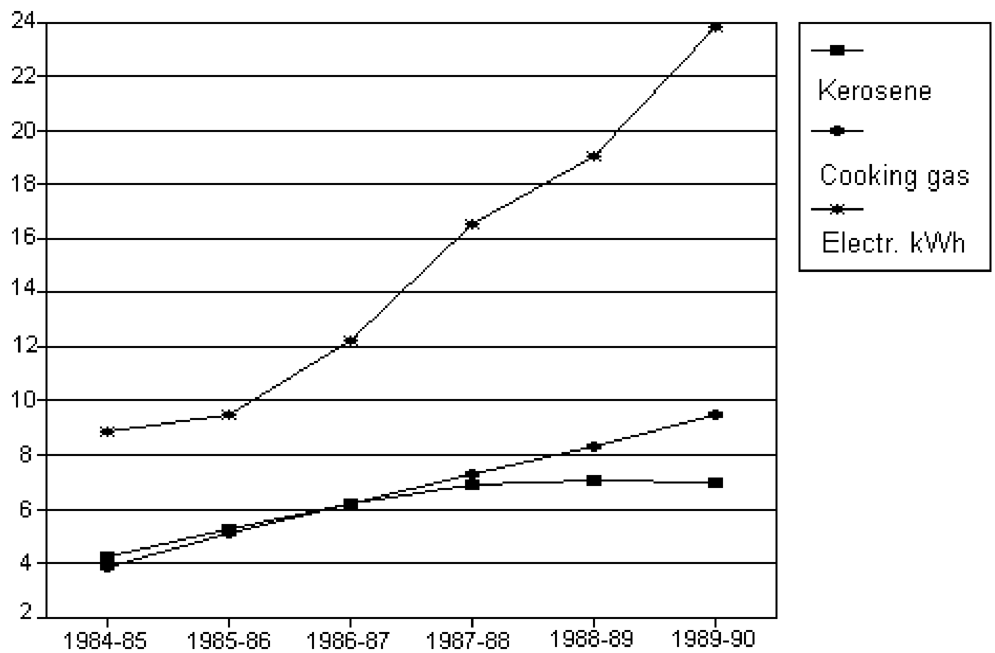


Figure 2.7 Commercial energy use
Consumption per capita



another part may be attributed to shortage-induced economizing in fuelwood, and a switch to other energy sources such as residues, cooking gas, and electricity.

Table 2.8 Fuelwood use projection in thousand tons for the domestic sector

Year	1992/93	1997/98	2002/03	2007/08	2012/13
Start of Five Year Plan	7	8	9	10	11
Est. population * 1,000	706.5	791.6	886.9	993.7	1,113.3
BASE CASE					
-Fuelwood consumption	874.3	979.6	1,097.5	1,229.7	1,377.7
-Residues, etc. in W.E.	4.7	5.3	5.9	6.6	7.4
-Commercial energy sources in W.E.	20.0	22.4	25.1	28.2	31.6
-TOTAL	899.0	1,007.3	1,128.6	1,264.5	1,416.7
BEST CASE					
-Fuelwood consumption	848.3	903.9	963.1	1,026.2	1,093.4
-Residues, etc. in W.E.	4.7	5.3	5.9	6.6	7.4
-Commercial energy sources in W.E.	23.2	33.2	47.4	67.8	97.0
-TOTAL	876.2	942.3	1,016.4	1,100.6	1,197.8

Two cases are presented, firstly the "base case", where it has been assumed that no switch from fuelwood to other energy sources and no fuelwood savings take place, and each energy source maintains its present share. The second case is called the "best case", because it represents maximum fuelwood savings. The best case is based on present information, and the assumption that switching to other energy sources will take place, and fuelwood saving devices, such as improved stoves, will have a positive effect. It has been assumed that fuelwood saving devices, coupled with improved living conditions, increased cash incomes and fuelwood shortages will reduce fuelwood consumption annually by 1%. Part of the decrease may be due to an increased use of commercial energy sources (cooking gas, kerosene and electricity), assumed to grow at an annual rate of 5%. The remaining part of decrease are caused by the introduction of improved stoves, a switch to residues or shortage induced fuelwood savings. However, no prediction can be made on the effect of improved stoves, switch to residues and shortage induced fuelwood savings. For calculation purposes, it has been assumed that the amount of residues consumed will be the same as in the base case. Taking all this into account, a picture as shown in table 2.8 emerges. This table shows the amount of fuelwood required for domestic purposes at the onset of five-year plans (FYP), starting with the seventh five-year plan in 1992/93.

2.6 Projected Fuelwood Consumption in the Other Sectors

With regard to other sectors of the Bhutanese economy, very little is known. The Ministry of Trade and Industry plans to carry out, in cooperation with UNIDO, a census of all industries and activities for which a business permit is required, such as bakeries, confectioneries, etc. Once the results are ready in 1992, decisions on the placement of promotional efforts will be made. This may affect energy requirements, due to an expected increase in industrial activities and through the introduction of more efficient technologies and equipment. However, the Ministry of Agriculture has indicated that, for the time being, cardamom growing will not be encouraged and that a switch to another cardamom variety may be considered. Lemongrass extraction will be actively promoted together with the introduction of other essential oil bearing grasses. The production is expected to double in the next ten years (personal communication Mr. Kinley Dorji, Deputy Director Ministry of Agriculture). Better distillation equipment (in terms of high quality output and less contaminated oils, which will have a better price in the export market), will be introduced, and the use of electricity will be encouraged.

The effect of electricity as a replacement for fuelwood, however, may be minimal. Most of the stills are operated in the forests, far away from the power supply system. At present, there is a shortage of electric power supplies in the lemongrass extraction areas, and load shedding in the Tashigang area is common. The 1.1 MW Rangjung hydropower station, which is planned to come on stream in 1993 will provide some relief, but excess power will not be available before the year 2000, as the 45 MW Kuri-chu hydropower station starts deliveries (IFAD, 1991).

In the western part of the country there is no shortage of electric power, with the 360 MW Chhukha hydropower station delivering cheap power to industries (0.2 Nu/kWh valid for the next ten years). Additional cement factories will start operating in the near future, and a new ferro-silicon factory is planned to start production in late 1993. The cement factories will use, in addition to electric power, coal as fuel. The ferro-silicon factory needs also charcoal and/or wood chips as raw material. 4,600 tons wood chips are required annually, according to a feasibility study. However, the BCCL management quoted 4,700 tons of charcoal in addition to 2,300 tons wood chips as being required for the ferro-silicon plant. The difference is probably due to the decision to use Norwegian technology (the furnace) instead of Japanese technology as mentioned in the feasibility study. The latter amounts would require an amount of about 26,000 tons wood annually, in addition to wood for charcoal requirements for the BCCL factory and activated carbon production. In case all these charcoal requirements could be met locally, this would amount to about 60,000 tons wood annually, equal to about 83,000 m^3 solid or 120,000 steres. It has been assumed that improved charcoaling methods are used instead of the present method, which has a recovery rate of only 10%. It is expected that within the next five-year plan all local charcoal requirements are met using local forests as sources, once suitable forest areas have been allocated by the Forest Department for these industries.

With regard to fuelwood requirements for other agricultural and forest-related activities, it is assumed that there will be no additional capacity and their fuelwood requirements will remain stable. Miscellaneous activities, and the non-specified sector have been assumed to grow at the same rate as the population. It is also assumed that switching to other alternatives in these sectors will take place at a rate of 1% per year.

Figure 2.8 Fuelwood use projections all sectors Base Case

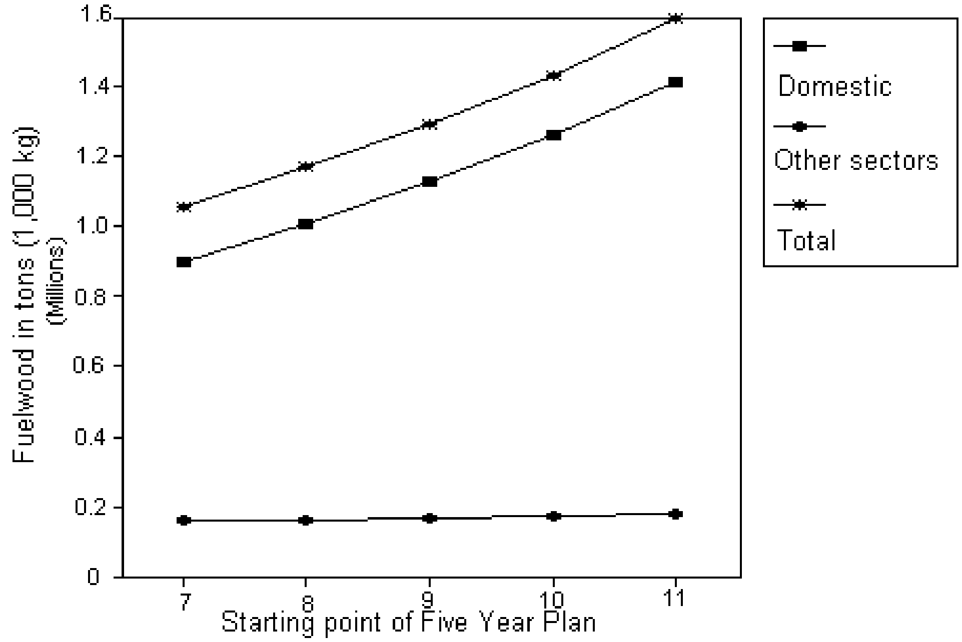


Figure 2.9 Fuelwood use projections all sectors Best Case

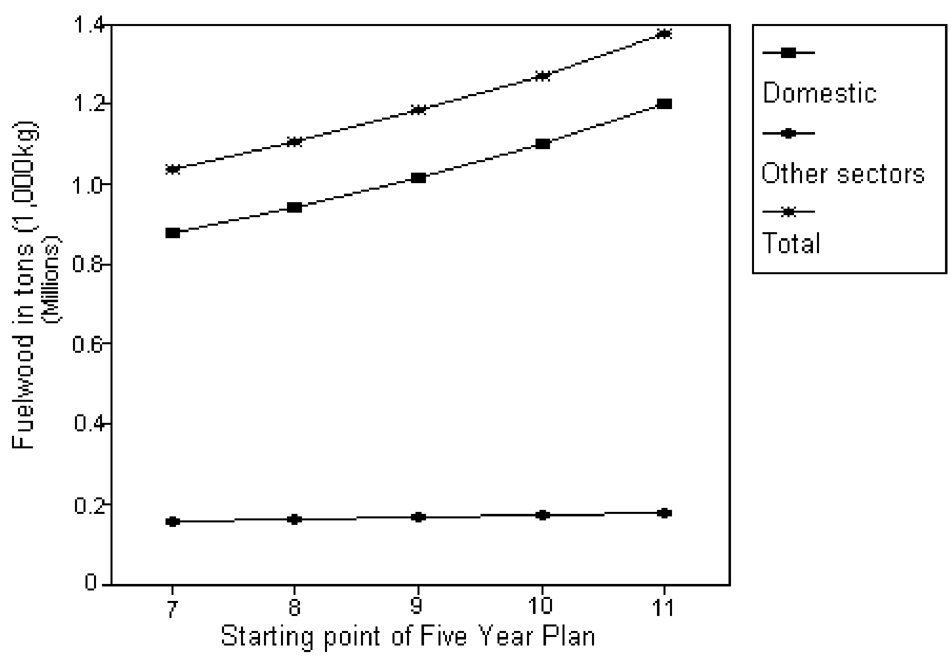


Table 2.9 Fuelwood use projections for non-domestic sectors (1992-2012)

Year	1992/93	1997/98	2002/03	2007/08	2012/13
Start of Five Year Plan	7	8	9	10	11
Est. population * 1,000	706.5	791.6	886.9	993.7	1,113.3
BASE CASE					
-Fuelwood consumption in thousand tons					
-Lemongrass extraction	3.0	4.2	5.9	8.2	11.5
-Wood for charcoal production	62.8	62.8	62.8	62.8	62.8
-Other agri- and forestry activ.	53.8	53.8	53.8	53.8	53.8
-Miscellaneous activities	32.1	34.2	36.4	38.8	41.3
-Unspecified activities	6.9	7.3	7.8	8.3	8.9
	-------	--------	-------	-------	-------
-TOTAL	158.5	162.2	166.6	171.9	178.3

In these sectors only one case, i.e. the "base case" has been considered, since it is difficult to predict future trends. Additional savings, although possible due to the introduction of more efficient equipment, will probably be offset against an increase in such activities. Only in cases, where it is known that additional amounts of fuelwood are required, such amounts have been included. Table 2.9 shows the projection of fuelwood requirements for the non-domestic sector in the next 20 years.

Table 2.10 Fuelwood use projections * 1,000 tons for all sectors (1992-2012)

Year	1992/93	1997/98	2002/03	2007/08	2012/13
Start of Five Year Plan	7	8	9	10	11
Est. population * 1,000	706.5	791.6	886.9	993.7	1,133.3
BASE CASE					
-Domestic sector	899.0	1,007.3	1,128.6	1,264.5	1,416.7
-Other sectors	158.5	162.2	166. 6	171.9	178.3
	-------	-------	-------	-------	-------
-TOTAL	1,057.5	1,169.5	1,295.2	1,436.4	1,595.0
BEST CASE					
-Domestic sector	876.2	942.3	1,016.4	1,100.6	1,197.8
-Other sectors	158.5	162.2	166.6	171.9	178.3
	-------	-------	-------	-------	-------
-TOTAL	1,034.7	1,104.6	1,183.1	1,272.5	1,376.1

Having estimated and projected fuelwood demand for both the domestic and the non-domestic sectors, the total demand for fuelwood in the future can be calculated by combining the results of table 2.8 and 2.9. The results are shown in table 2.10, and graphically presented as figure 2.8 and 2.9. The total estimated demand for fuelwood in the near future stands at 1.058 million tons (base case) or 1.035 million tons (best case) in 1992/93. These amounts are expected to rise to 1.595 million tons (base case) or 1.376 million tons (best case) by 2012/13.

2.7 The Fuelwood Supply and Supply-Demand Balance

Most of the fuelwood used in Bhutan originates from government-owned forests, with a small, unknown amount obtained from private lands, as twigs etc. Almost all of the fuelwood used by the domestic sector is collected by the people themselves. The same applies to the non-domestic sector including large fuelwood users (e.g. cardamom, lemongrass), which obtain their fuelwood supplies largely directly from forests, as most of the processing is done in there. Fuelwood used for road construction is often cut along the road. Charcoal, used at present in the BCCL factory and the activated carbon factory, is derived from logging wastes. The same is true for the plywood and particle board factories, which use most of their own waste wood and processing residues as fuel in boilers, etc., leaving only a very small amount for domestic purposes. Part of the urban supplies are obtained from saw mills in the vicinities of towns. The remaining part comprises of logging wastes or trees cut down for fuelwood.

Most of the fuelwood, perhaps over 90%, is derived from natural forests. Existing plantations are small and too young to supply a significant part of the total fuelwood requirements. Annex 4 shows that plantation areas cover only 31 square kilometres, equal to about 0.08% of Bhutan's land area.

Unfortunately, at the time of writing this report, hardly any information was available on the forest situation in Bhutan, other than the Pre-Investment Survey estimates on areas and growth rates (PIS, 1980). According to this survey, the annual allowable cut (AAC) would be about 13 million solid cubic metres of timber in log form. No estimates were given on fuelwood supplies, but taking logging residues, residues from log conversion to timber, etc. into account, a similar amount might be available. Table 2.11 gives some details of standing stock and growth rates as used in the Pre-Investment Survey and the present forest supply analysis. However, it should be noted, that there are large regional variations, depending on local climatic conditions, watershed areas, crown cover and accessibility. Moreover, it has been assumed that non-forested areas, such as agricultural land, grasslands and rocky areas, supply about 0.2 solid m^3 wood per hectare in the form of brush wood and twigs.

Table 2.11 Some basic parameters of Bhutanese forests

Forest type	Standing volume (SV) Cubic meter timber/ha.	Volume growth rate % of SV
Fir forest	100 - 560	0.5 - 1.5
Mixed conifer forest	100 - 430	0.7 - 2.0
Blue pine	50 - 110	1.0 - 3.0
Chir pine	50 - 130	0.8 - 2.5
Broad leaved with conifers	100 - 380	0.7 - 2.0
Temperate broadleaved	150 - 430	0.8 - 2.5
Trop. & Subtropical hardwoods	200 - 450	0.8 - 2.5

Estimates, based on the recently finalized land use planning exercise by satellite imagery, indicate an AAC of about 10-11 million solid cubic meters. In both cases (PIS and present estimates), accessibility, nor critical watershed areas, forest and wildlife reserves, etc., have been taken into account. If all these factors would have been considered (e.g. areas maximum 20-30 km from existing roads regarded as accessible, no logging in critical watershed areas, forest and wildlife reserves, etc.), the AAC would be much lower and reach only 1 million cubic metres instead of 10-11 million cubic metres (personal communication Mr. Rytkonen).

The 10-11 million cubic metres were determined by using the preliminary results of the photo interpretation (no ground-truthing has been done yet), with areas and land use shown in Annex 4. For each dot of the grid overlaid on the photo, important parameters, such as land use, type of forest and its density (crown cover over or below 40%), climatic conditions, slope and altitude etc. were determined. The AAC was determined by using forest standing stock and average growth rates of the standing stock, as determined during the Pre-Investment Survey (updated where more recent data were available), and correlating these data with each dot.

However, as each dot represents an area of 2.5 by 2.5 km or 625 hectares, the conditions of the surrounding dots were also taken into account by utilizing a computerized statistical analysis programme (SAS) to have a more reliable interpretation. For supply projections, the forest system has been considered as being stable during the next few five-year plan periods, due to that at present there are still so many unknown factors, which may influence the supply. Table 2.12 shows estimated figures for sustainable wood supplies. <u>It should be noted that accessibility has not been taken into account.</u>

Table 2.12 Fuelwood supply and demand balance by district (1992-2012) with the demand shown as a percentage of the potential supply

Year Middle of Five Year Plan	1995 7	2000 8	2005 9	2010 10
Bumthang	4	5	5	6
Chhukha	15	17	19	21
Chirang	44	49	55	62
Daga	6	6	7	8
Geylegphug	24	26	30	33
Ha	3	4	4	4
Lhuntshi	5	6	7	8
Mongar	14	16	18	20
Paro	14	15	17	19
Pemagatsel	27	30	34	38
Punakha	5	6	6	7
Samchi	31	35	39	44
Samdrup Jongkhar	14	16	17	19
Shemgang	6	6	7	8
Tashigang	18	20	23	25
Thimphu	29	32	36	40
Tongsa	4	4	5	5
Wangdi Phodrang	5	6	7	7
BHUTAN	**12**	**14**	**15**	**17**

No information was made available on the road network (in particular concerning future plans), nor where the population is concentrated (other than some general calculations made by the consultant on population density in *gewogs* using unofficial estimates on population sizes and the area covered). Therefore, no reliable analysis on the accessibility of fuelwood can be given.

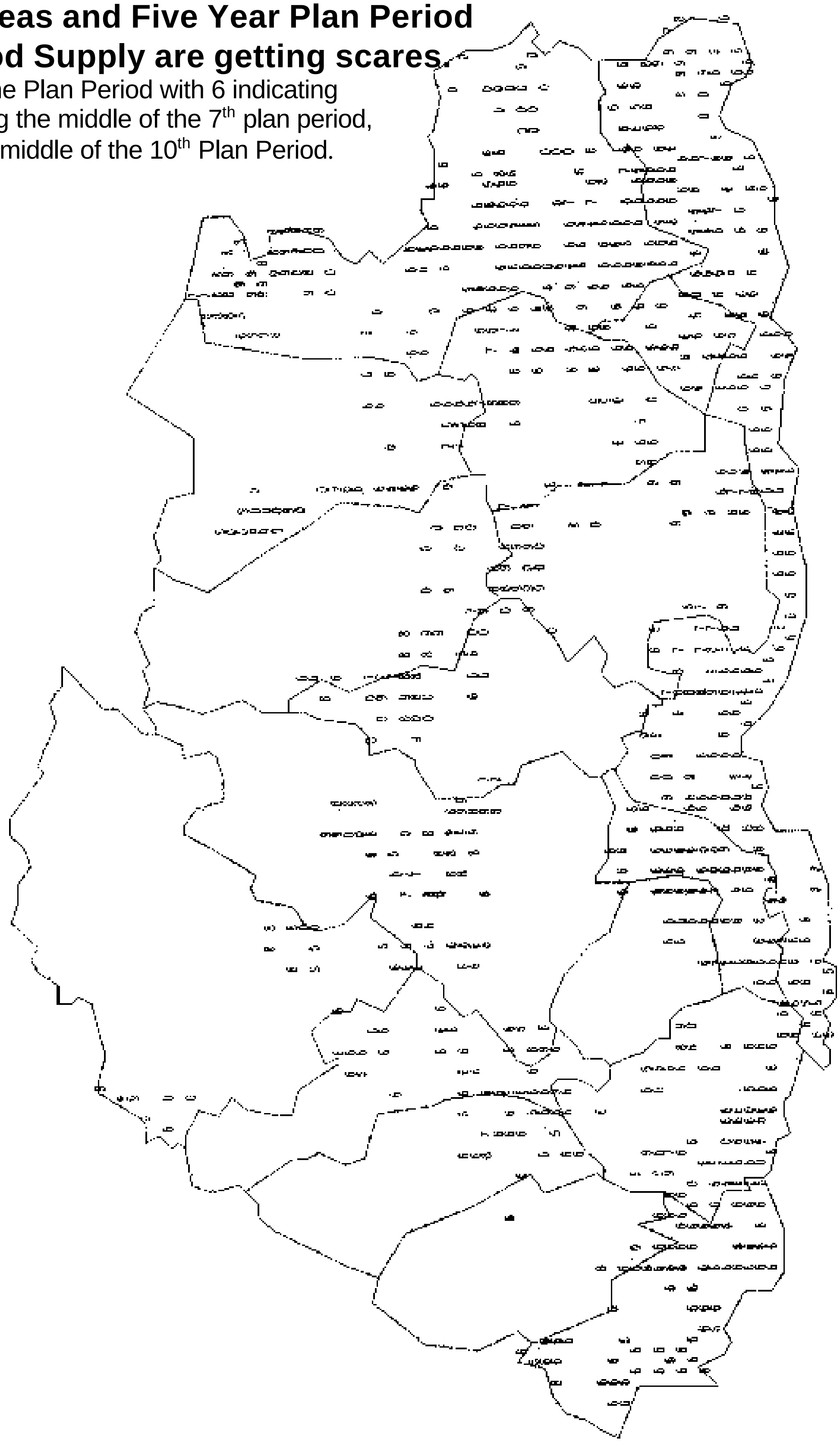
Although table 2.12 indicates that the fuelwood supply seems, on the whole, to be far greater than the demand, there are areas where the demand outstrips the supply. Figure 2.10 shows such areas by indicating by numerals (corresponding to the five-year plans with 0 indicating the 10th five-year plan covering 2007-2012), where and when shortages will occur. Figures 6.1 and 6.2 show respectively the situation at present, and in the middle of the 10th five-year plan.

It should be noted that these indications are only valid for a particular dot on the grid and do not necessarily indicate the conditions of the surroundings. However, it is thought that in this way, a reasonably accurate picture of the fuelwood demand and supply balance is obtained. It should also be noted that the computer analysis and calculations were made using a slightly different database, with regard to district and *gewog* borders and sizes, and using demand in the middle of the five-year plan as opposed to the situation given here (Annex 3 and this chapter), where the situation is shown at the beginning of the five-year plan. Therefore the quantities mentioned might show differences depending on the system used.

Figure 2.10 Areas and Five Year Plan Period when Fuelwood Supply are getting scares.

Numerals indicate the Plan Period with 6 indicating "Present, 7 indicating the middle of the 7th plan period, with 0 indicating the middle of the 10th Plan Period.

Areas and Plan Period Where Fuelwood Supply is Getting Critical



3. WOOD ENERGY CONVERSION AND PROCESSING TECHNOLOGIES

Biomass energy in the form of fuelwood is widely used in the domestic sector and small industries, such as paper making and lemon grass extraction. Agricultural residues, for example straw, stalks and animal dung are also used, but only to a very limited extent and exclusively in areas, where obtaining fuelwood is difficult, for instance in the northern mountainous areas above the tree line. In general, people prefer fuelwood over residues, as they find the handling and storage of residues inconvenient, and because of residues' high ash content.

The following gives a brief overview of energy conversion equipment and technologies used in the domestic and industrial sectors in Bhutan. Specific energy use data, when available, are given, based in most cases on field experiences in Bhutan. However, due to time and other constraints, only a very limited number of industries could be visited. In addition to the on-the-spot collection of information, other sources were used when necessary.

3.1 Domestic Sector

In the domestic sector, a distinction has to be made between stoves used for cooking and devices used for space heating. However, in many cases the stove used for cooking serves at the same time as a heater with people sitting around the stove, in particular in high-lying areas, where fires are maintained throughout the winter.

3.1.1 Stoves used for cooking

Stoves of many different sizes and types are found in Bhutan, but all of them can be categorized under two main groups, e.g. the open fire and shielded fire. Traditional mud stoves, improved mud stoves and the so-called Bumthang stove all fall in the second category. The first category comprises of stoves made of cast iron or metal bars, often circular in shape, or three stones placed in a triangular pattern. The latter are used, in particular in the south for quick cooking or boiling water for tea. These metal bar stoves are simply a support to keep the pots at a certain distance from the floor, on which the fire is set; they do not provide any protection against the air flow. As the sides are not closed, they radiate heat to surroundings, thus serving as space heaters.

A traditional metal tripod stove

The efficiency of these stoves varies, depending on how they are used. Although widely varying figures on their efficiency are found (from 5% to 16%), measurements show an average efficiency of about 12% during actual use in the kitchen. Under laboratory conditions, and with proper tending of the fire, efficiencies of over 20% have been recorded, which shows that these stoves do not have to be fuelwood guzzlers as generally thought. The advantages of these stoves are that they are easy to move, cheap and have a long lifespan. No information on the price of these stoves in Bhutan could be obtained, but from India and Vietnam it is known that these stoves cost about US$0.3-0.5, or about 6-10 Nu.

A traditional mud stove with raised lumps around the potseat

The shielded stoves come in many shapes and sizes. The stove type traditionally used in many Bhutanese households consists of a brick and mud structure with two pot holes and a firebox. These stoves do not have a chimney. The pots are supported by three lumps of clay or stones at the rim of the pot seat on top of the stove. This raises the pot and leaves three small openings, through which flames can leak around the pot. The visible flames are easier to control and help heat the surroundings. The efficiency of these stoves is not known, but again, depending on how they are used and maintained, they can be quite efficient; an efficiency rate of 15-17% is thought to be common. Most of these stoves are built by their owners. The cost of these stoves is not known, but in case the clay, mud, stones and labour would be monetized, the costs would range from US$3-5 (60-100 Nu). In practice, the cost of the stove is thought to be negligible, as all materials are locally available.

Improved stoves are also available and have been promoted by the Agricultural and Mechanical Workshop in Bumthang (now privately-owned, but formerly supported by Helvetas, a Swiss aid organization) and the National Women's Association of Bhutan (NWAB). The latter's activities have now been taken over by the Department of Works and Housing, or DWH (Ministry of Social Services), but still most of the activities are carried out with the assistance of NWAB, as it has a network of women's groups spreading all over the country.

The so-called Bumthang stove has a cast iron top with three potseats, each with several pot seat rings, which can be added or removed to fit the pot. The main firebox is located under the first pot and fitted with a door in order to regulate the flow of combustion air. A brick chimney is added to remove smoke and to provide draft for proper combustion. As far as could be ascertained, no baffles are provided under the other potseats, resulting in that not enough heat is provided under these pots, unless fuelwood is pushed in far enough. Therefore, longer pieces of wood are used. This partly defeats the purpose of the firebox door, as it has to be left open to accommodate the long pieces of fuelwood. The cast iron top serves also as a space heater. Although the people often claim that the stove uses more fuelwood in comparison with the traditional stove, they like the stove. It enables cooking and space heating, the kitchen remains clean, and the smoke is removed. The costs of the stove, made for the most of bricks, cast iron, and cement, are high, reportedly rising to 1,500-3,000 Nu (US$75-150). The efficiency of these stoves is not determined, but it is either better or poorer than that of the traditional stove, depending on how the stove is used. The average efficiency of the traditional stove is about 15-17%.

The improved stove, promoted by DWH/NWAB, resembles the traditional stove. UNICEF, concerned about health risks caused by smoke (e.g. respiratory and eye problems), has provided financial assistance for the project. The improved stove has three potseats instead of two in the traditional one. It is equipped with a cast iron grate and a metal sheet chimney. The three lumps at the circumference of the potseat have been removed to help the chimney function properly. In some cases, an additional large potseat, with a connection to the chimney, is installed for cooking large quantities of cattle feed, during *puja's*, or in case many labourers assist the family (labour exchange system) with transplanting or harvesting, etc.

An impoved stove promoted by DWH/NWAB/UNICEF

Cattle is kept in sheds, and people often build a separate stove, but without a chimney, close to the cattle shed to avoid extra work in preparing cattle feed.

Since 1985-1986, altogether 13,000-14,000 stoves have been installed during the first phase of the UNICEF programme. The second phase at a total cost of about US$600,000 to install additional 4,000 stoves and repair 1,500 stoves, has been approved by UNICEF, with a contribution of US$225,000.

An evaluation carried out at the end of the first phase showed, however, that there were some weaknesses in the stove. Out of the 120 stoves evaluated only 34% were working properly, 35% were malfunctioning, while 31% had either been converted to the traditional type by adding the three lumps around the potseats or had been abandoned due to various reasons. Main reasons for malfunctioning or modified stoves were lack of maintenance, and the fact that the stove was found not suitable for the eastern and southern Bhutan, nor for the high lying areas, where space heating is needed. Dampers, provided to control the flow of air, were rarely used resulting in excessive fuelwood use. Space heating with this stove type is difficult. In many cases the people removed burning pieces of wood or smoldering charcoal and placed them outside the stove for space heating, which counteracts the smoke removal and health objectives.

The stoves have now partly been redesigned. More training is planned to be provided for users in maintenance and the proper use of the stove and dampers. This is necessary as, compared with other countries, the chimneys are oversized ranging from five to nine metres (with a diameter of 12.5 or 15 cm), causing a very high draught in the stove and decreasing the efficiency.

However, the improved stove is still unable to provide space heat. Since imported materials are used (cast iron grate, metal sheets for the chimney, chimney cap, damper and roof plates), the cost of the stove is very high for a stove built out of mud. Prices of the stove ranges from US$63 for the stove suitable for the eastern and southern parts of Bhutan to US$94 for the hill stove. Part of this is subsidized, with UNICEF providing approximately 38% of the including the costs of imported parts. The Government provides skilled labour and covers transport costs (about 27% of the total costs). The remaining 35% is paid by the people themselves, mainly in-kind by providing the soil, unskilled labour and a wooden frame and planks and battens. It is difficult to say, whether this programme will continue, once subsidies will be removed and all costs will be born by the users themselves, keeping also in mind that the users tend to modify the stoves back to the traditional type.

The efficiency of the improved stoves has not been tested. From experience with similar stove types, it is known that the efficiency drops after some time due to lack of maintenance. However, when properly operated and maintained, the efficiency can reach 22-24%, which may result in fuelwood savings of 30-40%. Given the past experiences with the stove, actual savings are lower, and the net effect on the fuelwood consumption in Bhutan most probably is negligible. However, although the stove has also some unwanted effects (more flies in the kitchen as smoke is removed), there is no doubt the stove can have improve the kitchen conditions (cleaner working surroundings).

Stoves used in restaurants and for small- scale food processing, such as pop-rice, etc. are similar to those used by the domestic sector, although their size is larger. The efficiencies of these stoves have not been tested.

3.1.2 Space heating stoves

Specially designed stoves, commonly known in Bhutan as *bukhari's,* are used by many people for space heating. These stoves consist of a double-walled vertical or horizontal cylinder with air circulation holes in the outer wall, provided with a grate and a chimney in which fuelwood is burnt. Combustion products are directly exhausted (straight through principle), which lowers the efficiency considerably. Many users put large stones on top of the stove to heat them and use them as heat storing devices, which improves the situation to a certain extent, but the efficiency still remains low. However, if large houses are heated, the efficiency can improve considerably, as the chimney acts as a heat exchanger. In some case rooms on the top floor are heated by leading the chimney through it. The efficiency can be quite high, but much depends on how the *bukhari* is operated (proper control of primary and secondary air, dampers, etc.). In a few cases imported space heating devices are used (woodfuel, kerosene), but their costs are said to be very high compared with locally made equipment.

3.2 Energy Conversion Technologies Used by Rural-Based Industries

The largest consumers of biomass energy in the rural-based industries sector are the calcium carbide factory, plywood and particle board factories, the extraction of lemongrass oil and the drying of cardamom. There are also other consumers, but the used quantities of biomass fuels are small.

The Bhutan Carbide and Chemicals Ltd. factory (BCCL), of which the Royal Government of Bhutan (RGOB) holds about 37% of the equity, Tashi Commercial Corporation holds 20%, and the remainder 43% by the public, is located near Phunthsholing close to the Indian border. It manufactures calcium carbide by converting limestone (partly imported), and carbon from charcoal (partly imported) and imported coal. The main reason for producing calcium carbide in Bhutan is reportedly the availability of cheap electricity from the Chhukha hydropower station. About 4,000 kWh of electricity is required to produce one ton of calcium carbide in the electric arc furnace.

A bukhari stove

At full capacity the production would be about 22,000 tons calcium carbide (CaC_2) per year. The calcium is derived from limestone, which is burnt at the factory premises, using about 90 litres of fueloil per ton quicklime (CaO). About 25,000 tons of limestone is required annually of which an estimated 10,000 tons is imported, as the local limestone has too high silica content. The carbon is derived from charcoal and coal. Experiments have shown that good results can be obtained using a mix, where about 60-70% charcoal is used, with the balance made up with anthracite and pearl or petroleum coke. As the carbon requirement is about 0.64 tons fixed C per ton, CaC_2 about 12,800 tons of fixed carbon is required to produce 22,000 tons of calcium carbide. Assuming that 65% is derived from charcoal, with a fixed carbon content of 70%, the annual charcoal requirements can be estimated at 12,000 tons.

At the outset it was envisaged that all charcoal requirements would be met by using domestic sources, and contracts with local producers of charcoal were drawn up on that basis. But many problems emerged. The producers were not able to supply required quantities nor quality. The largest amount supplied was 4,278 tons in 1988. Since then supplies have drastically decreased. It has been estimated that in 1991 only about 1,000 tons were derived from domestic sources.

All reasons for the decline in supplies are not known, but transport problems seem to be one of the main reasons. Logging residues and the waste wood obtained from areas, where high tension power lines were newly installed, have been the main raw materials used for charcoal production. As the latter source is exhausted, logging residues are the only remaining source. Another potential source, namely waste wood from the Gedu industrial wood complex, is used mainly for the new particle board factory, but also for steam and power generation. With logging moving further away from the roads, transport costs become prohibitive for the charcoal suppliers (prices mentioned in the contracts include delivery to the factory of BCCL), and they decline to supply. The shortfall is made up by imported supplies coming from as far away as Madras in southern India.

Another reason for the limited local supplies is the conversion method used. The method is wasteful, with recovery rates barely reaching 10%. Each ton of charcoal requires about 10 tons of wood. This low recovery rate is partly caused by the charcoaling method (earthmound), partly by that often green and wet wood is used (m.c. of about 45%), and partly by the

Production of activated carbon from charcoal

insufficient skills of kiln operators. Good practice with earthmound kilns as well as with other charcoal kilns generally requires about four tons of wood to produce one ton of charcoal, while common practice requires about six tons of wood. It is clear that considerable improvements can be made in the charcoaling operations, which would make the production more attractive, and result in a larger supply of domestic charcoal. This, however, will require an efficient organizational set-up to handle the charcoal supply system.

Two other activities using large quantities of fuelwood in Bhutan are the lemongrass extraction and the cardamom drying.

<u>Cardamom</u> is grown in Bhutan covering an area of an estimated 7,500 hectares, located mainly in the southern districts. Cardamom needs a shady place to grow properly; most of it is therefore grown in the forests. The yield per hectare has been estimated to be about 3,000 kg fresh pods or 600 kg of dry cardamom.

Drying of the cardamom pods takes place on the spot using dryers locally known as *bhatti*. The cardamom fruit is harvested just before reaching maturity in August and September. Harvesting takes place with three-week intervals between pickings. The fruit, after picking, are left to mature for 2-4 days before being stripped and dried. Fresh cardamom contains about 80% moisture (wet basis). This has to be reduced to about 10% to bring out the aromatic flavour. Sun drying is normally not practiced, as it bleaches the colour. The bulk of cardamom is dried using direct fired furnaces. In other countries, improved indirect fire-based driers are known to be used, but were not seen in Bhutan.

The traditional driers are constructed of stones or bricks. Their shape is square or rectangular, they measure about 2.5 metres, and are about 1.5-2 metres high. On one wall, depending on the local conditions (prevailing wind direction), an opening of 0.6 by 0.8 metre is made, which becomes the firebox, where the fuel is burnt. The combustion products rise up through a loosely woven bamboo mat fitted about 0.3 metres from the top. A drier of this size can hold about 700 kg of raw cardamom in a 20 cm thick layer. The yield is about 20 - 25%. The drying takes from 48 to 72 hours, during which the cardamom is frequently turned, rubbed together and sprayed with water in order to prevent splitting and get proper colour fixing. The specific fuel consumption in Bhutan is not known, but in Nepal it is normally about 1.5 kg per one kilogramme fresh cardamom or about 6.5-7.5 kg fuelwood per kg dry cardamom, but may go as high as 12 kg per kg.

A cardamom drier or *Bhatta* in the forest

Improved indirect fire-based driers have been developed in Nepal. Their improvements are geared to enhance the quality of cardamom; little or no efforts have been made to reduce fuelwood consumption. Heat exchangers are used, with the combustion products flowing through pipes, which heats the drier to about 60^{o}C. The drying time for a load of 500 kg fresh cardamom is about 17 hours giving a yield of about 20%, while the specific fuelwood consumption is said to be 1.1 kg or 5.6 kg of fuelwood, respectively per kg raw or dry cardamom. In India, where indirect heated dryers are common, the fuel consumption can be as high as 3-4 kg of fuelwood per one kilogramme fresh cardamom, or 15-20 kg fuelwood per one kilogramme dry cardamom.

Lemongrass oil with its active ingredient of "citral" is extracted from lemon grass (*Cymbopogon flexuosus Stapf.*). The species is common ground vegetation in dry chir pine valleys in eastern and central Bhutan. The oil is used in manufacturing of vitamin A, and in the flavour, cosmetics and perfume industry. The industry was, until recently, controlled by Bhutan Aromatics and Phyto-Chemicals (BAP), a Tashi Commercial Corporation -owned industry. Farmers were allowed to sell their oil or grass only to BAP. The Department of Agriculture (DOA), with assistance from FAO, became involved in 1989 in the industry. They operate stainless steel stills, unlike the BAP- and farmer-owned units, which are made from sheet iron. The farmer-owned units are supplied by BAP at a cost of about Nu 2,150 (Nu 1,600 for the still, Nu 400 for the condenser and Nu 150 for transport costs and installation). There are 382 small units in operation. Each unit requires five people (two for grass collection, two for fuelwood collection and one to operate the still). By using stainless steel, although more expensive, a cleaner, higher-grade product is obtained, which sells for US$20 per kg in the European market. The BAP-produced lemongrass oil is sold for US$14 per kg to India. Both prices are valid ex Thimphu.

In addition to lemongrass oil, sofia oil is produced, with about 70% of the small cottage units are devoted to the production of this oil from Sofia grass (*Cymbopogon martinii var. sofia*). However, the producers are paid by BAP only Nu 50 per kg sofia oil as compared to Nu 75/kg lemongrass oil. Sofia oil has the same active ingredient as Palmarosa (*Cymbopogon martinii* *var. motia*), which has a much higher value and could be worth US$ 40/kg in the European market. DOA/FAO is now experimenting at the DOA Essential Oils Research Station in Gyalposhing (Mongar district), whether this grass, which is not native to Bhutan, can be successfully grown in Bhutan.

FAO/DOA has carried out a study of the industry, which revealed that their own units and the small cottage units (BAP-supplied) were more efficient, with an extraction rate of 0.5%, while the large BAP-owned units have a recovery rate of 0.2%. However, with regard to the fuelwood consumption, the large stills are more efficient, when compared with the small cottage units. The large stills require 1 kg of wood per 3 kg grass, whereas the cottage units require 1 kg per 1 kg of grass. It has been estimated that annually about 4,000 tons of fuelwood are needed to operate the units. Most of the fuelwood is acquired from forests (probably without a permit). The grass, after it has been dried, can be used as fuel, but this is not usually done. This can be taken as a sign that the wood supply is not a problem. Improvements in the units should primarily be sought by using more efficient furnaces and high-grade materials to get purer products.

Agro-processing, other than cardamom drying and lemon grass extraction, is practiced on a small scale. Again, not much information is available. Most, if not all of the sugar is processed by a sugar factory located at the premises of the Geylegphug Army Welfare distillery. The cane is crushed, and the juice collected and concentrated in shallow pans placed into a channel leading from the furnace to the chimney. The number of pans, made from cast iron or some other material, varies from three to four. The pans are rectangular in shape. The juice is poured into the pan closest by the firebox and moved progressively, depending on concentration, to pans further to the chimney. The last pan contains syrup of 90% concentration. This syrup is then removed, worked to increase its viscosity and poured into moulds to set. Highly skilled operators are required to ensure the good quality of brown sugar, as the syrup during the concentration process should not burn.

The used fuel is bagasse, which is available on the spot, but has to be dried before use. Efficient operations normally have sufficient amounts of bagasse for production. In this case, in addition to all of the bagasse, one ton of firewood per ton of sugar is used. The operation can be considered inefficient. FAO statistics show that in 1988 approximately 12,000 tons of cane was grown. According to the factory management, over the last few years on an average about 300-400 tons of sugar was produced. This would imply, assuming that all cane is processed in the factory, a sugar recovery rate of only 3-4%, which is extremely low in comparison with international practice, where 10% is considered to be normal. Even when compared with Vietnam, where sugar production is mostly carried out on the same scale, recovery rates of 7% are normal.

It should be noted that of the 12,000 tons of cane grown, some farmers might process sugar by their own, which would improve the situation. As mentioned, farmers have stopped growing sugar cane as it was no longer profitable. Therefore, it can be assumed that all cane is processed at the sugar factory. Further checks will have to be made on the recovery rate, but it appears that the efficiency can be increased considerably by improving the crushing and juice recovery/transport equipment, and by installing more efficient evaporator equipment and furnaces.

Although limekilns, other than the one at BCCL, have been used in Bhutan in the past, none could be located. It is believed that most, if not all, have gone out of business, like the brick factories, as the producers can no longer compete with Indian supplies, where coal and cheap labour are in abundance. This applies to the sector of ceramic and pottery. Only one establishment is in operation producing handicrafts and religious ornaments. Most of the ceramic ware is imported.

***Churpi* for sale in the Thimphu market**

equipment used by the food processing sector, no information at all could be acquired. Few bakeries are known to operate, but these use mainly electricity as energy source. Cheese is produced on a cottage scale. *Churpi*, a very hard variety used as a snack and soft cheese, used extensively in cooking, are the main products. Both are produced on a small scale mostly at home using milk from cattle and yaks. About 20 litres of milk is required to produce about 2 kg of cheese in addition to about 1 kg of butter. Not much fuel is required and although exact figures could not be determined, it has been estimated that about 15 kg of fuelwood per 100 litres of milk is required, but much depends on the scale of operation. The total amount of cheese or butter production is not known. No estimates of the total consumption can be given.

Miscellaneous activities comprise of a large variety of activities: Rosin and turpentine production, dyeing of yarn, road tarring, cremations and paper making are just a few. Unfortunately, not much is known about it, but about a few activities some information could be obtained.

Handwoven fabrics are widely used by the local population for clothing (*kira's, gho's*, etc.), but these fabrics have become much sought-after handicraft products. Wool, cotton and silk yarn are used either alone or combined. Yarn dyeing is practiced at home, or dyed yarn is purchased from yarn distribution centres run by the National Women's Association of Bhutan. Natural dyes are used, and although the colour of the home-dyed yarn might fade, the technique has improved. The yarn at the yarn distribution centres has been dyed at the Khaling Handloom Centre in Tashigang district, and it is said to be non-fading.

Another snack made from rice, often made for own use

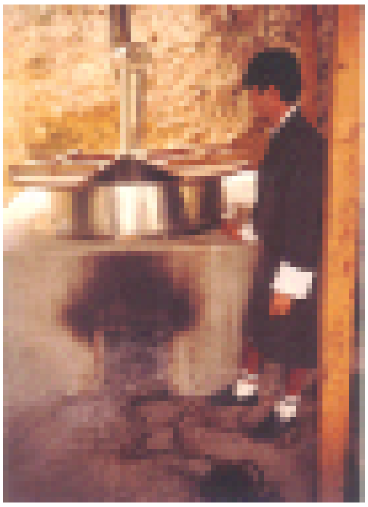
The yarn is dyed in containers which are heated by fuelwood burnt in a circular stove almost the same size as the container. Improvements aimed at increasing the efficiency of the stove can be made, but more in-depth studies would be required to outline specific proposals. The process varies, depending on the required colour. Yarn is steeped and boiled in the dye, whereafter it is left for 1-5 days to soak without heat. Fuelwood consumption at the Khaling Handloom Development Centre was said to be about 100-150 cubic metres annually, but as the total production is not known, no specific nor total fuelwood consumption data can be given. In India, specific fuelwood consumption figures for yarn dyeing on a small scale indicate that about eight kg of fuelwood is used per one kilogramme of yarn.

Road construction and repair are, as in most other countries in the region, labour-intensive activities. The melting of tar is done on a small scale along the roads. Tar in barrels is heated by wood fire, and the molten tar is either poured over the gravel or mixed with sand and fine split gravel for black topping of the roads. The Department of Roads (DOR) of the Public Works Department (PWD), belonging to the Ministry of Social Services, has estimated that about 15 tons of wood are needed for one kilometre of road of about 3-4 metres wide. This equals about 40-50 kg of wood per 10 square metres of road, which is more or less equal to regional practices, where some 50 kg of fuelwood for the same area is used.

No information on road construction activities could be obtained, as this depends on the availability of financial resources. It has been estimated that during the seventh five-year plan about 300-350 km of roads will be constructed, mainly by the Border Road Organization (BRO) of the Indian Ministry of Transport. Some 900 km is planned to be resurfaced by local contractors with bitumen sealing. For this activity DOR proposes to use kerosene-heated bitumen sealing units. One unit is capable of resurfacing 30-40 km of road per year, while DOR intends to acquire another two or three units. However, to calculate fuelwood consumption, it has been assumed that annually new roads and/or repairs will be made on 5% of the existing roads, which is about 114 km per year, and requires estimated 1,700 tons of fuelwood.

Besides direct requirements for tar melting, fuelwood will be needed for domestic purposes for the road construction personnel, estimated to number from 2,000 to 2,500, contracted from India by BRO and PWD. As both husband and wife as well as the elder children are normally employed, it can be assumed that about 3,000 people will have to be provided with fuelwood, requiring about 4,500 tons. Most of the fuelwood for road tarring and domestic use is cut from forests along the roads.

Rosin and turpentine are produced using resin from the chir pine (*Pinus roxburghii*) as raw material. The only factory is located in Samdrup Jongkhar district. It is owned by Tashi Commercial Corporation, the sole license holder to tap resin. The factory processes about 300 tons of resin annually, which would produce an output of 78% rosin, 14% turpentine and about 8% waste. However, in 1990, 363 tons of resin was collected according to the factory management (but, only 272 tons according to the manager of the resin collection centre), with 142 tons of rosin produced and 25 tons of turpentine. This indicates that either large stocks of resin have been built up or that the quality of the resin was low, resulting low recovery rates of 39% and 7%, respectively. The annual fuelwood requirements are said to be 750 stacks, equal to about 1,330 stacked cubic metres. Both the rosin and the turpentine is exported to India at prices ranging from 20-24 Nu/kg for rosin, and 11 Nu/ltr for turpentine (1990 prices).



An improved wood fired bark boiling system imported from Japan

Making paper using a bamboo screen

Hand made paper is widely used in Bhutan for printing of religious and other important documents, painting, packing, etc. Paper is produced on a very small scale, while only one, somewhat larger, factory is located in Thimphu. The bark of *Daphne papyracea* and *Edgeworthia gardneri*, which grow in the eastern and central part of the country, are used for paper making. Approximately three medium-sized trees are required to produce one kilogramme bark.

The dry bark, at a cost of 8 Nu/kg, is softened in water for about 24 hours, and foreign matter is removed. The bark is then boiled for six hours in a closed large container placed on top of the circular stove (diam. about 1.5 m and a height of 70 cm), in which fuelwood is burnt. About 7 kg fuelwood per kg bark is needed. The figure is low, when compared with small scale operations in Nepal, where about 15 kg wood per kg bark is said to be required (Jeanrenaud). The liquid with fibres is then mixed with caustic soda for bleaching for 24 hours. Thereafter the material is beaten for half an hour in an electrically driven disintegrator to separate fibre from pulp. Excess water is removed, and some materials are added to improve the quality and prevent quick settling of the heavier particles. A bamboo screen and frame mold (normally a cloth screen is used) is dipped into the mixture, after which, once the required thickness has been obtained, the formed paper sheet is gently peeled off and deposited on the other sheets. The wet sheets are compressed to remove excess water, and dried either by electrically heated driers or in the sun with the sheets attached to vertical panels. While attaching the sheets, wrinkles are removed carefully to get a smooth sheet of paper.

One kilo of bark is sufficient to produce from 33 to 39 sheets, depending on the size and thickness. Sales prices range from 3-6 Nu per sheet. No figures on the total production in the country are available, but the factory in Thimphu can process under favourable conditions about three batches of 60 kg bark per day. Apart from the factory in Thimphu, small units are located in Tashigang (3 units), Nobding in Wangdi Phodrang (1 unit) and Shemgang (1 unit), each producing on an average 3,000-4,000 sheets per year. It is believed that there are several additional small units operated in homes. The annual fuelwood requirements can not be established, but they are estimated to range from about 400 to 800 tons annually. This would be sufficient to produce about 2-4 million sheets of paper.

Paper sheets being attached to a board for final drying

Cremations are common in Buddhist and Hindu societies and widely practiced also in Bhutan. However, not everyone is cremated. The bodies of small children below the age of nine are disposed off in other ways, such as burial, or they are thrown in rivers, left for vultures, etc. (Pommaret, 1989). An Indian funeral pyre requires 500-600 kg of wood; these figures are believed to stand also in Bhutan. As no figures on the number of deaths in each district are available, a very rough estimate was made by assuming that one third of the population growth rate (crude birth minus crude death rate) would be equal to the number of corpses to be cremated. This probably overestimates the number of cremations, as the infant mortality rate is still quite high at 142 per thousand. Using this method it was estimated that annually about 3,000 tons of fuelwood is used for this purpose.

Several distilleries operate in Bhutan, but most of them do not really distill alcohol, but only blend and bottle alcohol imported from India. A distillery located in Bumthang is said to produce liquor from apples, but no information could be acquired on its output or fuel consumption.

4. FUELWOOD SUPPLY SYSTEM, PRICING AND SUBSTITUTES

In Bhutan, as in most countries in the region, most of the fuelwood used by the rural and a part of urban population, is collected by the people themselves, bypassing fuelwood market systems. Unlike in other countries, where fuelwood is often sold in shops or markets or along the roads, there is no corresponding system in Bhutan.

Fuelwood is "commercially" available in urban areas, but as the forests are government-owned, so is the fuelwood trade: supplies and sales are handled by the Forest Department or its authorized agents. In the last few years, private contractors, appointed by the Forest Department or Bhutan Logging Corporation (BLC), have become involved in fuelwood trade. However, the prices at source are still controlled by the government. Only along the Indian border, a relatively free market system exists. Fuelwood is transported, to both directions between the countries, bypassing official channels. The practice appears to be limited to urban areas such as Geylegphug, Phuntsholing, etc.

The price of fuelwood is largely dependent on transport costs. The cost of wood itself hardly figures in the cost price structure. Table 4.1 shows fuelwood prices as quoted by government sources in Geylegphug area.

Table 4.1 Fuelwood price structure for a truckload of 7 m^3 in Geylegphug area (valid in Nov. 1990 for supply to the Army Welfare Project)

Cutting and collection of fuelwood	Nu. 25.00 per m^3	175.00 Nu.
Loading and unloading of the fuelwood	Nu. 10.00 per m^3	70.00 Nu.
Transportation from cutting area to field depot		190.00 Nu.
Government royalty of fuelwood	Nu. 11.30 per m^3	79.10 Nu.
Establishment and supervision 8% of production costs of Nu 175		14.00 Nu.

Total for one truckload		528.10 Nu.
Price per m^3		75.44 Nu.

Of the total sum of 529 Nu per truckload, at the field depot about 90 Nu (royalty and establishment cost), or about 13 Nu per cubic metre, or 17% of the total, can be considered as the production cost of trees or forest, while over 80% is for harvesting and transport. The same picture emerges from a BLC cost price structure of 1986 for fuelwood sales (World Bank, 1986), shown in table 4.2.

The 1986 price of Nu 100 per m^3 has hardly changed. BLC was selling fuelwood in 1991 at Nu 143 (softwood species) and Nu 215 (hardwood), at a depot in Thimphu. BLC sawmill off-cuts were quoted at Nu 100 per cubic metre in Thimphu. These sawmill offcuts can also be bought by rural people at a price of Nu 20 per cubic metre. For this lower price people need to have a permit from *gewog* and district authorities, certifying that the buyer lives in rural area, and that the fuelwood is for own use. Transport costs have gone up, and transporters quote a price of 1.34 Nu per ton/kilometre on good roads (possibly doubled when off-road transport is used, depending on local conditions). Labour costs are also on the rise. It appears, therefore, that the true cost of growing wood still hardly figures in the overall fuelwood cost price.

Table 4.2 BLC Cost Price Calculation - Firewood Sales

Gross revenue		100.00 Nu/m^3
Less: Royalties 1)	6.00	
Transport to Thimphu 2)	80.00	
Storage/Administration cost depot	1.40	
Collection, cutting and stacking 3)	2.50	
	------	89.90 Nu/m^3

Gross margin		10.10 Nu/m^3

1) Nu. 5/m^3 (Nu. 11.25/m^3 for broadleaf varieties); excise duty 5% and contractor's tax 1% of royalties.
2) Average of 80 km @ Nu. 1 per m^3 per kilometer at transport contract basis.
3) Including all collection, cutting, transport to roadside and stacking cost.

The cost of fuelwood delivered to the consumer by private contractors who obtain fuelwood through BLC or the Forest Department is higher, with prices in 1990 in Thimphu being Nu 2,000-2,500 per truckload of about 7-8 cubic metres, which, after proper stacking, was found to be only five cubic metres. This equals a cubic metre price of Nu 400-500 (approximately Nu 550-700 per ton or about US$27-34 per ton). However, also here the real costs of fuelwood hardly play any role, as the contractors pay only royalty to the Government, with the remainder being transport and labour costs and profit.

Data have not been acquired on the costs of fuelwood in the past, but a project proposal from 1985 (Ryan, 1985) mentions that the establishment of 6,200 hectares of village woodlots for fuel, fodder and poles was expected to cost about US$1.9 million. This included foreign technical assistance and training valued at US$320,000. This report expected that fuelwood would sell for an average price of Nu 172 per air dry ton (about US$13-14 per ADT), Villagers, who would collect wood on the spot, were expected to pay about 20 US$/ADT, which was based on the opportunity cost, i.e. the time saved in fuelwood collection from far away forests. Urban users were expected to pay about US$18 per ADT, but had fuelwood delivered to their doorstep.

Comparing the price of Nu 700 per truckload or US$56 (loaded with three tons air dry wood), or about US$18/ADT, which apparently was based on actual prices at that moment for urban users, and comparing it with the present urban price of about US$27-34 per ton (delivered), it appears that fuelwood prices have gone up considerably, with a rise of 50-90% or annual rises of 7-11%.

The increasing prices of fuelwood, and the convenient use of fuelwood substitutes (no chopping of wood, cooking gas ignites and heats immediately, clean use), have made fuelwood substitutes more popular in urban areas. Table 4.3 gives an overview of actual fuel and energy prices in urban areas, taking into account average end-use efficiencies of stoves used for cooking.

Table 4.3 : Type, price, calorific value, end-use efficiency and cost of cooking energy in urban areas

Energy type	Weight/size per unit	Price in Nu/unit	Cal.val. MJ.	Price per kg or kWh	Price per MJ.	End use effic.	Effective price/MJ
THIMPHU TOWN							
Wood (supplied through F.D.)	100.0 kg.	69.00	15.0	0.69	0.05 Nu	15 %	0.31 Nu
Cooking gas	13.0 kg.	90.74	46.0	6.98	0.15 Nu	46 %	0.33 Nu
Kerosene	1.0 ltr.	2.60	38.0	2.60	0.07 Nu	43 %	0.16 Nu
Electricity	1.0 kWh	0.40	3.6	0.40	0.11 Nu	60 %	0.19 Nu
GEYLEGPHUG TOWN							
Wood (supplied through F.D.)	100.0 kg.	69.00	15.0	0.69	0.05 Nu	15 %	0.31 Nu
Wood (fuelwood from India)	100.0 kg.	27.00	15.0	0.27	0.02 Nu	15 %	0.12 Nu
Cooking gas	13.0 kg.	87.66	46.0	6.74	0.15 Nu	46 %	0.32 Nu
Kerosene	1.0 ltr.	2.80	38.0	2.80	0.07 Nu	43 %	0.17 Nu
Electricity	1.0 kWh	0.40	3.6	0.40	0.11 Nu	60 %	0.19 Nu

These figures for Thimphu and Geylegphug clearly show that cooking gas prices are competitive with fuelwood supplied through the Forest Department. Kerosene and electricity are cheaper in both cases. Only in Geylegphug, where inexpensive fuelwood from India is available, such wood would be the cheapest for cooking. However, imported wood and electricity are not always available (frequent power cuts, not only in the Geylegphug area, but also in other areas not served by the Chhukha power station). For that reason cooking gas and kerosene are preferred.

In rural Bhutan the situation is completely different. Even if opportunity cost for collecting fuelwood (either by families themselves or by hired labour) is taken into account, as shown in table 4.4, fuelwood is here by far the cheapest fuel. Kerosene, in areas at a reasonable distance from main supply points on the southern border, is the next cheapest. If the user lives far from supply points, the price of kerosene rises. Electricity is only available in some areas close to micro-hydropower stations. Even if electricity would be available at urban price (Nu 0.4 per kWh), it still would be more expensive than fuelwood, which in most cases does not require cash.

As mentioned, this calculation does not take into account the convenient use of other fuels, which could prompt a switch to them earlier than otherwise expected. The calculation also does not take into account the availability nor reliability of supply. In both cases, the effect on the switch-over point is at present almost impossible to judge.

Table 4.4 : Type, price, calorific value, end-use efficiency and cost of cooking energy in rural areas

Energy type		Weight/size per unit	Price in Nu/unit	Cal.val. MJ.	Price per kg or kWh	Price per MJ.	End use effic.	Effective price/MJ
Wood (collected)	1)	100.0 kg.	20.00	15.0	0.20	0.01 Nu	15 %	0.09 Nu
Wood (including transport)	2)	100.0 kg.	30.00	15.0	0.30	0.02 Nu	15 %	0.13 Nu
Kerosene (close to supply)	3)	1.0 ltr.	2.60	38.0	2.60	0.07 Nu	43 %	0.16 Nu
Kerosene (far from supply)	3)	1.0 ltr.	6.00	38.0	6.00	0.16 Nu	43 %	0.37 Nu
Electricity (5 Nu/bulb)	4)	1.0 kWh	1.40	3.6	1.40	0.39 Nu	60 %	0.65 Nu

1) Basically free but here an opportunity cost of 20 Nu/100 kg. has been assumed
2) Transport and cutting cost assumed as 30 Nu/100 kg.
3) In principle only used for lighting. Close = Paro town. Far = Lhuntshi town
4) Micro hydro power based. Assumed 40 Watt and 3 hours a day. Basically only used for lighting purposes.

It is apparent that wood is by far the cheapest fuel, and its price or its opportunity cost would have to rise considerably to make other energy sources competitive with it. Assuming that the convenience of other fuels will not affect consumers' choice, it can be shown (table 4.5) that the cost of fuelwood would have to rise from Nu 200 per ton to about Nu 360 per ton in the case of kerosene, or to 1,460 Nu per ton in the case of electricity at rural prices (as experienced in the Shemgang district), to be at par with other fuels.

Table 4.5 Switch-over price of fuelwood to other energy sources in rural areas

Fuel type	Calor. value	End-use effic.	Price factor	Rural price Nu./unit	Wood Price needed to induce switch
Fuelwood	15 MJ/kg	15%	1.00	0.20	0.20 Nu/kg.
Kerosene close	38 MJ/ltr.	43%	7.26	2.60	0.36 Nu/kg.
Kerosene far	38 MJ/ltr.	43%	7.26	6.00	0.83 Nu/kg.
Electricity Urban	3.6 MJ/kWh	60%	0.96	0.40	0.42 Nu/kg.
Electricity Rural	3.6 MJ/kWh	60%	0.96	1.40	1.46 Nu/kg.

In rural areas, a switch from non-monetized wood to monetized conventional fuels will not only require changes in the availability and reliability of supplies, but, more importantly, a change in price, either by subsidizing conventional fuels or by increasing the cost of fuelwood. Lack of cash income to pay for gas and kerosene stoves and gas bottles may form another constraint.

Conventional energy sources, with the exception of a large part of the electricity, are imported using valuable foreign exchange. Subsidizing these energy sources would put an additional burden on the national economy. For this reason, locally grown fuelwood, which is available in abundance, should not be made more expensive. However, as the government is concerned about environmental effects, the increased use of fuelwood on forests will justify conservation efforts and measures, such as improved stoves, space heating devices and improving the efficiency of industrial equipment.

Some work has been done in the past on the use of alternative heating systems as is evident from this house with solar water and solar space heating.

Electricity, generated locally largely exported, is priced at 0.4 Nu per kWh. The price is low in comparison with world market prices, which are around US$0.5-0.7 per kWh, equalling about 1-1.4 Nu/kWh. The reason for the low price is most probably that investment costs of the Chhukha hydropower station were borne by India, which also buys most of the output but at a low price. The micro-hydropower stations in rural areas also sell electricity at a low price, which is given in table 4.4. These prices do not reflect the actual price of electricity. The price paid by consumers is barely sufficient to cover operational costs.

Almost all of the micro-hydropower stations have been supplied on a grant basis by the Japanese Government. Actual investment costs seem to be very high, with a price mentioned of Yen 800 million (about US$5.7 million) for two systems, each having a capacity of 200 kW (installed in Chirang and Daga). The latest unit, also a 200 kW system is alleged to have cost Yen 567 million or about US$4.1 million US$. These prices include everything from design to installation of the system with a distribution network, delivered on a turn-key basis. Another source (IFAD, 1991) quotes a price of Yen 586 million for the two systems (each 200 kW). These figures would result on an average price of about US$11,000 - 13,000 per kW.

Even with cheaper systems (available from India, Nepal, and possibly locally made in Bumthang), it appears that once investment costs are taken into account, the electricity cost price would rise considerably above the 1.4 Nu/kWh now used by the consultant for calculation. Skilled manpower for operation and maintenance is required, which can be a problem due to widespread shortage of labour in the country. If donated equipment are used, problems with imported spare parts may occur.

However, there would be obvious socio-economic benefits in supplying electricity to rural areas. Electricity would increase the quality of life and migration to towns would lessen. Rural people would get opportunities to have additional incomes with the productive use electricity. Home-based activities, such as processing of vegetables and fruit and weaving, would be easier with electricity (power, lighting), so assisting women to improve their living conditions. In some cases, using electricity for cooking could be an option.

Electricity use for cooking will only take place in isolated cases, however. A sufficient spare electric capacity is required, and people should have sufficient cash income to buy electric power. In a recent study (IFAD, 1991), it is proposed that in rural areas small hydropower-based electricity generation units be set up with 50 kW units to serve the needs of 200 households, at a tentative investment cost of US$175,000. This would result in annual capital charges of over 3 Nu per kWh, generated at a load factor of 35%. Even at this low load factor - which is common in the DOP-operated units - there would be only little spare capacity available for cooking with hot plates and cooking plates (on an average requiring from 500 to 4,000 Watt). It is difficult to see that a switch from wood to electricity would take place to a significant extent, in particular, if electricity prices would reflect the actual costs.

On the other hand, fuelwood might become more expensive without any involvement from the Government, as there is shortage of manpower, primarily during agricultural peak periods. Coupled with the labour shortages, distances to forests are increasing (need for more agricultural land, need for grazing pastures, more pressure on the forest due to population growth), and fuelwood might become monetized in some cases. If cash is not sufficient to buy fuelwood, an additional strain is put on women and children, who in most cases collect fuelwood. They would spend more in forests and have less time for income-generating activities at home.

5. ENVIRONMENTAL AND INSTITUTIONAL ASPECTS

5.1 Environmental Aspects

As the energy balance shows, there is an overwhelming dependence on fuelwood the major source for energy, not only in the domestic sector, but, in many cases, also in the industrial sector. Fortunately, Bhutan is endowed with a large forest cover. It has been shown, that in theory, the potential supply of fuelwood is far greater than is required as an energy source. However, it is evident that there are areas, notably along the southern border and in the eastern part of the country, where local shortages of fuelwood already occur or will occur in the near future. Because of a high population pressure in these areas, there is a greater need for fuel for their daily activities, such as cooking, etc. Moreover, there is an increased need for new houses, which in rural areas are made of wood.

The influence of small communities on the forest cover is clearly visible

5-6% of the land area is used for agriculture, there is an obvious need for more land to grow food. This also puts a pressure on forests. A larger population will have more livestock (90% of the rural population owns cattle). Cattle needs areas for grazing, which, as best lands are used for agriculture, will be in forests. Some experts believe that grazing cattle pose the most serious threat on Bhutan's forests. Damages are not only seen on young saplings and trees, but by trampling the soil, cattle can make it prone to erosion (UNDP, 1990). This is a problem especially in areas at an altitude of 3,000-5,000 metres. In the summer cattle graze at these altitudes, while in the winter yaks come down from even higher altitudes to graze in the same areas.

Although it appears that fuelwood collection could escalate local forest degradation, it is not clear, if and to what extent fuelwood needs contribute to forest loss. Further studies on a village level are needed to qualify and quantify this.

The Royal Government of Bhutan has taken interest in environmental preservation. Afforestation and tree planting have become increasingly important activities of the Forest Department. It has been estimated that up to the end of the fifth five-year plan (1987/88), about 11,200 hectares of degraded forests had been planted, mainly with local species. Some 7,360 hectares were planned to be planted during the sixth five-year plan ending in 1992. However, most of these efforts have fallen behind the schedule. Survival rates of trees in the newly afforested areas are said to be rather low. It seems, that more practical experience is needed in nursery management, tree planting and natural regeneration. Legal principles need to be clarified.

The draft of Bhutan Forest Act of 1991 provides no impediment to social forestry. The already approved Social Forestry Rules indicate some restrictions, and require legal steps before user groups can assume management responsibilities. The Private Forest Rules stipulate that farmers still must seek permission to cut and sell trees they have planted as seedling, and there is no guarantee that such permission will be given (personal communication Mr. King, Social Forestry Expert BHU/85/016).

Apart from legal difficulties in relation with social forestry, many people do not see a need to plant trees as forests are plentiful with fuelwood just for the taking. This is also born out in the lemongrass distillation areas, where fuelwood is used extensively, without utilizing processed grass, which, if dry, would form a good source of energy and could substitute fuelwood to a large extent.

However, in some areas people do perceive a need for increased forest resources and farmers have started planting trees for fuelwood and for fodder purposes. In the future, as fuelwood shortages may spread to other areas, afforestation efforts should be stepped up. The local population or community should become involved, either by getting the people to plant trees or by their active involvement in the management of the degraded forests, on which they depend for their livelihood (fuel, fodder, timber, etc.). A report on Social Forestry under the Bhutan Master Plan for Forestry Development (available in 1992), will give clear indications on how to proceed. The executive summary of this report is reproduced here as Annex 6.

In addition to activities to improve forest resources in Bhutan, more efforts will have to be made in conservation by the introduction of fuel-saving stoves, suitable for and accepted by a majority of the users. However, given the diverse needs (cooking, heating, etc.), research in this field will be needed to design a stove which meets major, if not all, user requirements. Also, the industries' possibilities to save energy need scientific attention. Considerable wood savings could be achieved in particular in charcoal making, where improved methods could double the output, when the amount of wood remains the same.

5.2 Institutional Aspects

As mentioned before, wood as an energy source has up to now hardly played any role in the energy planning of Bhutan, probably because it was assumed that it is readily available for everyone. Other conventional energy sources, notably electricity, need planning and feasibility studies before any decision can be made on implementation. With regard to the other conventional energy sources, such as kerosene, diesel oil and petrol, the picture is less clear as imports and sales are handled by the privately-owned Tashi Commercial Corporation. It appears that the Ministry of Trade and Industries has some say in the distribution and pricing as well as in the setting up of new sales points.

Concerning wood fuel and charcoal, only large industrial use seems to be controlled. Charcoal making is allowed, if the owner has a contract with an approved user of charcoal, i.e. the BCCL factory. Only logging and timber processing residues, driftwood from the rivers, etc. are allowed to be used as raw material.

The large users' share forms but a small part of the total fuelwood consumption. On the remaining part, probably over 90-95% of the total consumption, no information is available, and it has been practically ignored in the energy planning process. It seems strange that decisions are made on energy supplies for certain areas, without taking into account alternative and competitive energy sources, especially in areas where cash incomes are low. Unfortunately, no information could be obtained on how the energy planning process works in Bhutan, nor information about surveys on household expenditures in rural areas (available for the Thimphu area and under preparation for some rural areas). This information, together with figures on population size and density, which for this report were obtained only from unofficial sources, are important parameters for all planning and activities concerning energy use.

Energy planning, or maybe better power planning, is at present carried out by the Department of Power (DOP) of the Ministry of Trade and Industries (MTI), in cooperation with the Planning Commission, with little involvement of the Department of Forests (DOF) of the Ministry of Agriculture (MOA). During discussions it was agreed that DOF should have a role, if not the primary role, with regard to energy derived from fuelwood. It was also agreed that fuelwood energy forms a part of the national energy sector, and that policy decisions in any energy field will have implications on other energy planning sectors. In other words, it is essential to develop a national energy policy, which includes all energy sources, and ensures the involvement of all energy producers to enable a rational planning process. The Department of Forestry (with its organizations like BLC) is the primary agency responsible for fuelwood and should be responsible for developing solutions to problems with fuelwood and charcoal scarcity, at present experienced only in limited areas, but foreseen to spread.

However, other departments, such as the Department of Agriculture, which is actively promoting lemongrass extraction (a large fuelwood energy user), and the Ministry of Trade and Industries, which promotes and regulates the industrial sector, with potential large implications on local fuelwood energy demand. The ferro-silicon factory, which is expected to come onstream in 1993, requires from 5,000 to 25,000 tons of fuelwood per year, depending on the process used. The factory will be located in the same area as the BCCL factory, which, if all charcoal needs are met from domestic sources, will consume about 60,000 tons of fuelwood per year. Here, a multi-agency involvement in the energy planning process is necessary, as there will be a large additional strain on the fuelwood supplies in these areas (from about 10,000 tons at present for the BCCL factory to 65,000-85,000 tons, if improved charcoal methods are used, or even up to 170,000 tons with traditional charcoaling methods, if all supplies for the BCCL and ferro-silicon factory are obtained from local sources).

It would be helpful to make one central agency responsible for the coordination of all energy planning activities on the national level, with responsibilities for the other agencies clearly spelled out. However, such a central agency will not only need access to all reliable data, but it should be able to provide advice and inputs for improved data collection on energy consumption and supplies, which is sorely lacking at present. It may make use of specialized planning tools like, for instance, the Long Range Energy Planning model (LEAP) and/or other models.

LEAP is a computer based energy planning model in which, besides energy needs including biomass energy, all sorts of other important data like population size and growth and its effect on land use, land use patterns, economic growth, environmental loadings associated with industries as well as type of energy used, etc. can be part of the input data. Such an introduction would assist with energy as well as forest planning activities. The model can cope with the complexities of energy planning (substitution options, pricing, etc.) as well as uncertainties in the future, in particular with regard to technical, economic and socio-economic change.

The Science and Technology Division was established in 1983 under the then Ministry of Development (MOD), constituting the present Department of Power, Agriculture, Roads, Health and Animal Husbandry. It served as an independent institution till 1988 and was headed by a Joint-Director of MOD. However, the Division was disbanded by the Department of Power, at present part of the Ministry of Trade and Industries, due to budget and staffing problems. The Rural Energy Division of DOP, which has an interest in rural energy technologies and lately also in wood energy, has proposed to revive the activities seen the interest of the Royal Government of Bhutan. This Science and Technology institute could actively provide this central energy planning agency with many types of inputs.

A main function of such an institute would be to provide technical and other assistance to other departments and the private sector on a commercial basis. This could include measurement and testing services, feasibility studies, demand and supply studies, etc. Research and development work could be undertaken, but should be geared towards studying and/or assessing the feasibility of new technologies under the Bhutanese conditions. Basic research should not be encouraged at this stage.

Tasks may also include the setting up and maintenance of a databank on energy supply and demand in the country, environmental and meteorological measurements, assisting industry in solving energy related problems, etc. Other organizations involved with wood energy and in need of specialized inputs, for instance the Department of Works and Housing (DWH), could be assisted with in developing locally acceptable equipment for domestic use, such as cooking stoves and space heating devices.

However, qualified staff, not only for this central energy planning set-up and the support unit for science and technology, but also for other organizations involved with wood energy development, may be difficult to find. Therefore upgrading and training of manpower, either in Bhutan or abroad, may be considered necessary.

The setting up of two new agencies, a planning agency and a supporting science and technology unit, may, seen the wish of the Royal Government of Bhutan to slim down the government size, not be acceptable. Tasks can be combined under one agency or, if forming one agency would not be accepted, spread under several existing agencies, as long as there is a clear commitment by the different agencies to coordinate activities, and share the results or make them available to anyone, who has a legitimate reason to use them.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the information obtained in Bhutan, the main conclusion is that biomass energy (or wood energy, as other biomass energy sources, such as agricultural residues have a minor role) supplies a large part of the total energy consumption in Bhutan. The provisional energy balance for Bhutan (annex 1), indicates that wood energy accounts for 87% of the total amount, residues about 1%, and the conventional energy sources the remaining 12%.

The domestic sector is by far the largest consumer of energy, accounting for about 77% of the total demand in the country. Biomass energy supply over 98% of this demand. The industrial and other sectors account for about 22% of the total energy demand, with biomass energy supplying about 50% of the total sectoral demand (all in terms of energy content).

With regard to other sectors, where biomass is used as an energy source, there are a few activities, notably lemongrass extraction and cardamom drying, which rely at present exclusively on fuelwood. Both activities are important foreign exchange earners, and a notable source of cash income for the rural population.

It should be noted that the amount of energy used by the domestic and other sectors could be under or over estimated, due to limited information available on the consumption and supply of energy sources.

By using the preliminary results of the 1991 land use planning exercise, it appears that the fuelwood supply, when looking at the overall country situation, is positive. However, this statement is based on information, which has not yet been verified in the field. Besides, accessibility has not yet been taken into account due to lacking information. Using information from an earlier land use planning exercise, carried out in 1979-1980 (again without taking accessibility into account), approximately the same result was obtained. A definite conclusion on the supply situation can only be made once reliable land use data are at hand, and accessibility has been taken into account. The information on the supply and demand balance, as given in this report, therefore should be treated with caution.

Based on preliminary calculations using the limited information available (results shown in annex 3), it appears that at present in Chirang district the *gewogs* of Chaunauti, Chirang Dangra, Goseling, Kikhortang, Samjong and Tsokhana experience fuelwood shortages. In Chhukha district this concerns Gengudala *gewog*; in Geylephug the Geylegphug, Sarbhangtar and Sershong *gewog*s; the Shaba in Paro district; Talo or Goen in Punakha; Denchukha, Gumauney, Nainital and Pagli in Samchi district; Bartsam, Bidung, Lumang, Radi, Samkhar and Shongphu *gewogs* in Tashigang district and finally Thimphu in Thimphu district.

As mentioned in the introduction to the report, *gewog* names and areas given here might no longer be accurate, which can affect (positively or negatively) the assessment. Besides the mentioned areas, there are other areas, which are believed to face local fuelwood shortages. Figure

6.1 shows the present situation, with shortages indicated with a - sign, and figure 6.2, which shows the expected situation during the tenth five-year plan (2007-2012). Both figures have their origin in figure 2.10.

Analysis of the opportunities for energy substitution (section 2.5, 2.6 and chapter 4) indicates that wood energy will remain, for the foreseeable future, the most important energy source in Bhutan. Biomass energy has been substituted to a certain extent by other energy sources, such as electricity, cooking gas and kerosene, but mainly in urban areas, where fuel is monetized. In rural Bhutan, where biomass is most often a "free" fuel, options for substitution are limited, due to the costs of commercial energy sources. If a switch takes place, it might be from kerosene to electricity, particularly with regard to lighting. Biogas could be an option, considering the large number of cattle in rural areas, as aptly demonstrated in the Kalikhola *gewog* (Geylegphug district). However, the high price of the equipment and the need for regular maintenance of the system may limit its application, especially for domestic use.

In many cases energy is used in an inefficient way, and there is scope for improvements in the domestic and other sectors. Although the industrial sector, when compared with the domestic sector, uses only a small amount of biomass energy, improvements can be made. This does not necessarily concern only the energy efficiency but, maybe more importantly, the whole production process, which could result in improved quality (cardamom, lemon grass oil), or a larger output (sugar). This, in its turn, could add to the income of the rural producers, and benefit women, in particular in food and agro-processing, which apparently are going to be promoted in the eastern part of the country (IFAD, 1991). In addition to direct benefits, it may have an impact on the regional or national level through an increase in opportunities for economic and other activities, especially in rural areas (e.g. improved housing, health and education).

Another main conclusion, which can be drawn is that, **although biomass energy plays an important role in the overall energy scene in the country, it has not been accorded that importance in energy planning, which places emphasis on commercial energy sources like electricity, kerosene and gas.** This is probably also the reason, why so little is known about wood energy supply and use in Bhutan. All information concerning wood energy was scattered and far from complete. As reference points were also lacking, it could not be confirmed that all information was obtained[1].

To promote much-needed systematic data collection on fuelwood energy in Bhutan, it was fortunate that quite a few people and institutes showing an active interest in biomass energy use, could be identified. These persons and organizations should be relied upon to provide backing in this field in the future, be it in data collection, providing information on available technologies or any other input concerning wood energy.

With regard to rural energy planning expertise, in particular concerning biomass energy, **upgrading of the capabilities of personnel involved in planning technologies and -systems**

[1] It could be that some crucial sources of information have not been approached. For instance, only on the last day of the seven-week consultancy, information on the existence of a base line survey (carried out by the same ministry to which the Forest Department belongs) on four eastern districts was obtained through a fortunate meeting with FAO officers, who also had found the document by accident.

Figure 6.1 Areas which at present are thought to experience localised fuelwood scarcity. The - sign corresponds with dots on the grid overlaid on photographs for the land use planning exercise**.**

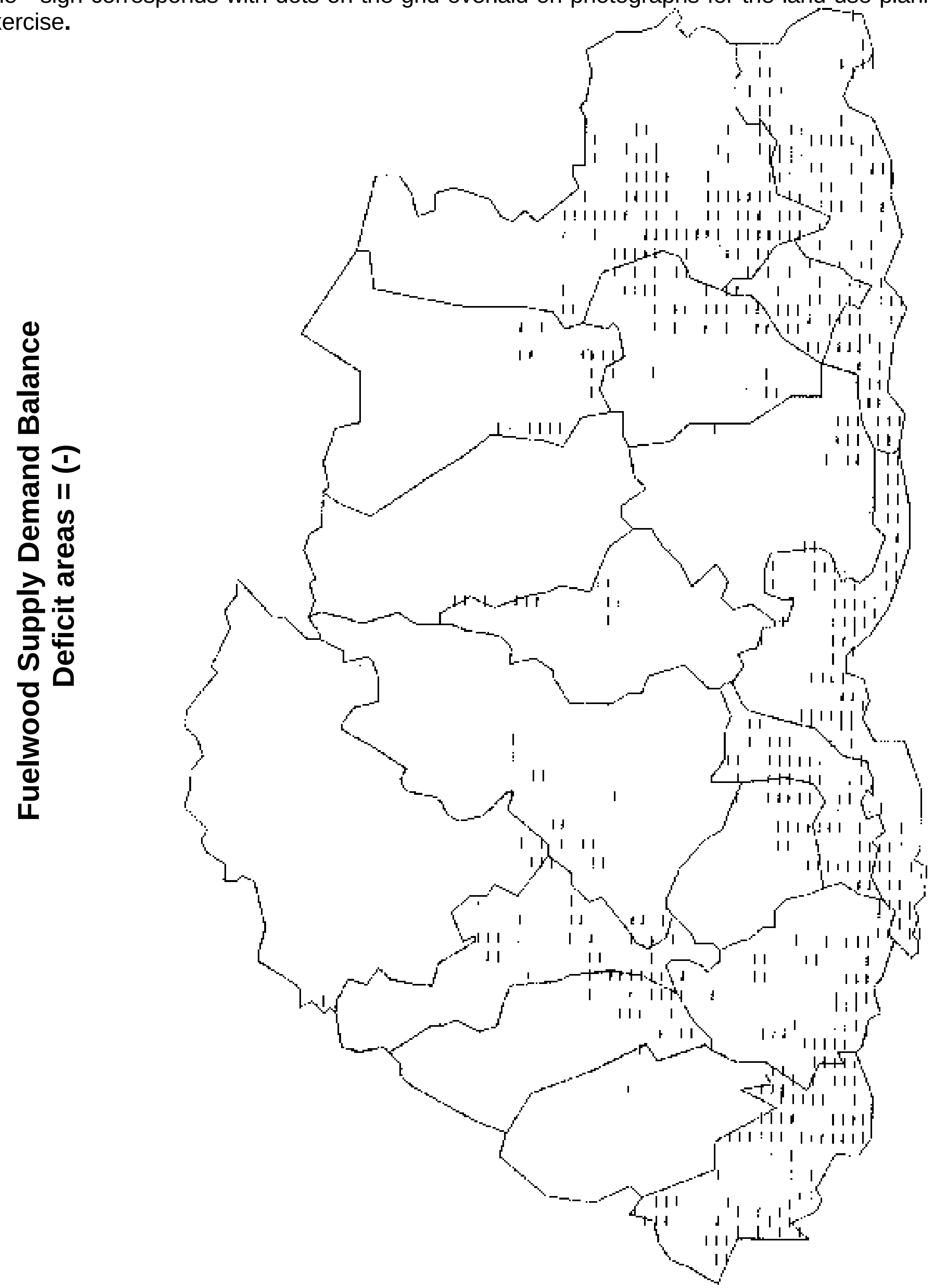
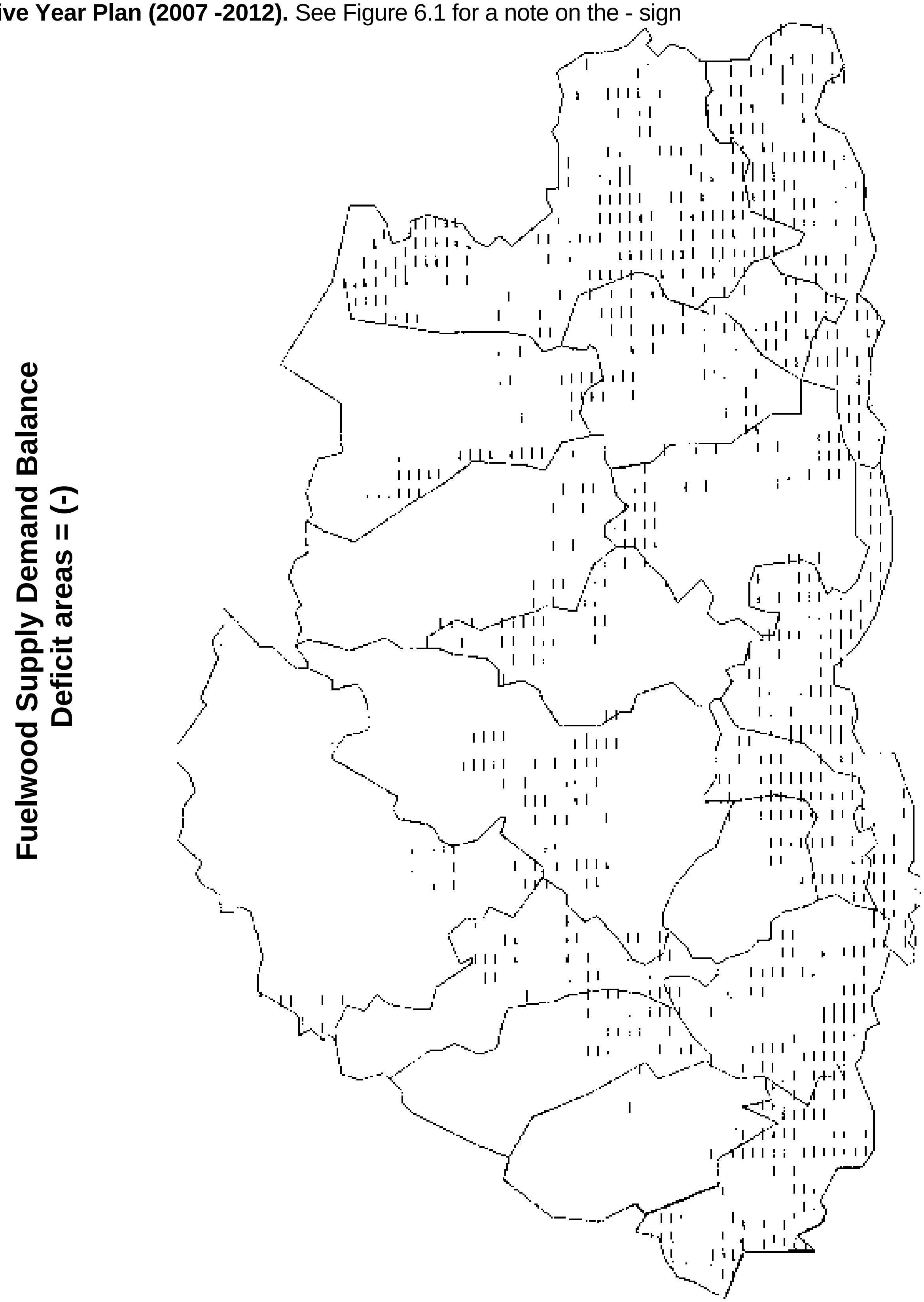


Figure 6.2 Areas which are expected to experience localised fuelwood scarcity in the 10th Five Year Plan (2007 -2012). See Figure 6.1 for a note on the - sign



(such as for instance LEAP, ENERPLAN, MEDEE-S, etc.), energy consumption survey techniques and wood energy flow studies is required.

It should be stressed that **rural energy planning is a dynamic process, which requires updating of planning techniques and -systems coupled with the collection and updating of information on a continuous basis. It should not be an ad-hoc exercise.**

There is at present no institute, other than the Rural Energy Division of DOP, involved in biomass and new and renewable energy planning and development, although there is some expertise in other institutes in this industrial field (furnaces, gasification, small steam power, etc.).

Upgrading of the capabilities (staff and equipment) of the Rural Energy Division and other departments and institutes such as the Department of Forests, in particular in the field of wood energy, will be necessary.

Although a large number of improved stoves have been installed, there is a need for redesigning the stove, the stove programme and strategies in order to better meet the needs of the rural users. The low number of properly used stoves, and the large number of stoves, which have been modified, are a sign that something is wrong, and additional research is needed to redirect the efforts. Also, the quality of the stoves has to be improved. It seems that if less emphasis is put on numbers of stoves installed and more attention is given to get satisfied users, the stove programme can better contribute to energy conservation efforts in the country.

Overall, **a better coordination between departments is be required** in order to prevent problems if the industries, if big fuelwood-consuming establishments are planned to be set up in certain areas. By timely adjustment of the supply of fuelwood, possible problems in matching the demand with the supply can be solved.

6.2 Recommendations

Very little information on wood energy use in Bhutan is available and most of it had to be obtained from many different scattered sources. It is therefore highly recommended that information in whatever form is documented and stored in a retrievable form in one central place, accessible to all institutes or persons who have a need for such information. This data storage and retrieval system should be enlarged and kept updated on a continuous basis. Such a system also could prevent to a large extent the duplication of activities, which might occur.

Given the important role of biomass energy in the overall energy scene, it is imperative that information on energy availability, supply and consumption in all sectors of the economy (domestic, industrial, etc.) is maintained up-to-date in order to ensure the availability of reliable information.

Such information should be used to support policy planning in the energy field, and convince government authorities that biomass energy plays an important role in the national economy and that the country can not afford ignoring this fact. It is recommended that use is made of specialized planning tools like LEAP and/or other models.

This should be acknowledged by the Government by **allocating sufficient resources**, not only to ensure the sustainability of these activities through R&D in energy conservation, tree planting etc. The capabilities in this field could be strengthened by setting up specialized institutes or organizations, which can deal effectively with wood energy and its role in the national economy. This should be done by:

- Strengthening of existing institutes and their personnel or by establishing specialized institutions involved in rural energy planning, biomass energy and related activities (technical capabilities, facilities, etc.) through in-service training, fellowships, etc.

- Seen the large amount of biomass as well as other energy sources used within the country, and often inefficiently, energy conservation measures should be initiated as a part of household energy development and the enhancement of rural industrial productivity. Domestic stoves should be improved in such a way that they will be suitable and acceptable for the majority of the users and, once developed, should be introduced on a priority basis in those areas, which face or will face shortages in the near future. Such areas can in principle be identified from figure 2.10 and from annex 3, as well as information stored in the database at present built up and maintained by the staff of the Master Plan for Forestry Development project in order to facilitate their work.

- Improving the supply situation through afforestation, social forestry projects, management of existing forests by local population, etc. in those areas for which the same database can be used to pinpoint problem areas. Pilot programmes, through which villagers are assisted to manage the forests they use for their supply of fuel, fodder as well as timber needs, should be initiated to find out, how the system traditionally works and in what way the system can be improved.

- Energy audits should be carried out in the industries as well as for other fuelwood using activities to identify wasteful practices, not only with regard to energy, but also with regard to processing in view of improving the quality of the processed goods. An example is the sugar industry which, in the case that processing would be improved, could result in considerably higher yields than the 4% at present (in other countries a yield of 10% of cane to sugar is normal).

- Field research on practical methods in improved charcoal making are highly recommended to enhance fuelwood savings and charcoal quality. An efficient organizational set-up is required to mobilize and supervise charcoal production in the field to ensure efficient practices and the provision of adequate incentives for workers.

- The Department of Forests should make concerted efforts to allocate suitable forest areas to the charcoal using industries to establish new wood raw material areas after logging for timber as well as for charcoal production. These industries are now importing most of their raw material requirements in the form of charcoal and coal using foreign exchange, which has been estimated to amount to US$500,000 per year.

The conclusions and recommendations given here have resulted in a preliminary project proposal on wood energy, such as data base development, the introduction of fuelwood use survey techniques, fuelwood conversion and utilization. The proposal is outlined in annex 8.

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Annex 1: PROVISIONAL ENERGY BALANCE OF BHUTAN (COMPILED FOR 1988/89 FROM AVAILABLE STATISTICAL DATA AND OTHER SOURCES)

	COMMERCIAL ENERGY SOURCES: Coal and Coke	Oil products	LPG / biogas	Electric power	TOTAL commercial energy in PJ	BIOMASS ENERGY: Fuel wood	Resi dues	Char coal	TOTAL biomass energy in PJ	TOTAL amount in PJ	Share in % of total cons.
SUPPLIES											
Primary production	28.5	0.0	0.1	5,605.9	5,634.4	14,415.0	109.4		14,524.4	20,158.9	123.6
Export	(28.5)	0.0		(5,024.1)	(5,052.7)	(6.0)			(6.0)	(5,058.7)	(31.0)
Import	582.5	974.6	28.8	11.9	1,597.8	0.0		247.9	247.9	1,845.7	11.3
Stock +/-	0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0	
ENERGY SUPPLIES	582.5	974.6	28.8	593.6	2,179.6	14,409.0	109.4	247.9	14,766.3	16,945.9	103.9
% of SUPPLIES	3.4	5.8	0.2	3.5	12.9	85.0	0.6	1.5	87.1	100.0	
TRANSFORMATION											
Charcoal production						(607.8)		117.5	(490.3)	(490.3)	(3.0)
Elec. power production	0.0	(10.7)	0.0	3.2	(7.5)					(7.5)	.0
Losses/own use				(137.1)	(137.1)					(137.1)	(0.8)
TOTAL FINAL SUPPLIES	582.5	963.9	28.8	459.8	2,035.0	13,801.2	109.4	365.4	14,276.0	16,311.1	100.0
CONSUMPTION											
Industry	575.0	97.5	0.0	370.8	1,043.3	N.A.	0.0	365.4	365.4	1,408.7	8.6
Agriculture/Forest ind.	N.A.	63.5	0.0	0.0	63.5	989.1	6.8	0.0	995.8	1,059.4	6.5
Transport	0.0	626.7	0.0	0.0	626.7	N.A.	0.0	0.0	0.0	626.7	3.8
Commercial/Un-specified	1.8	N.A.	N.A.	N.A.	1.8	99.5	0.0	0.0	99.5	101.2	0.6
Government	N.A.	15.8	N.A.	32.4	48.2	463.1	0.0	0.0	463.1	511.3	3.1
Domestic use	0.0	160.4	28.8	56.5	245.8	12,249.6	102.6	0.0	12,352.2	12,598.0	77.3
Total Consumption	576.8	963.9	28.8	459.8	2,029.2	13,801.2	109.4	365.4	14,276.1	16,305.3	100.0
Stock +/-	5.8	.0	0.0	.0	5.8	.0	.0	0.0	5.8	5.8	.0
Share in %	3.5	5.9	0.2	2.8	12.4	84.6	0.7	2.2	87.6	100.0	

All energy amounts have been converted to TJ (10^12), using the following conversion factors:

Keros./Diesel 1,000 ltr = 0.035 TJ	LPG gas 1,000 kg. = 0.046 TJ	Coal exp. 1,000 kg. = = 0.015 TJ
Gasoline mot. 1,000 ltr = 0.033 TJ	Biogas 1,000 cu.m. = 0.021 TJ	Coal imp. 1,000 kg. = = 0.025 TJ
Gasoline avi. 1,000 ltr = 0.031 TJ	Electricity 1 GWh. = 3.600 TJ	Charcoal 1,000 kg. = = 0.029 TJ
Furnace oil 1,000 ltr = 0.039 TJ	Residues 1,000 kg. = 0.013 TJ	Fuelwood 1,000 kg. = = 0.015 TJ

Source: Department of Power, RED Publications and estimates made by the consultant
File : 006/ENBAL-911014

Note : Charcoal yield at 10% with 3452 ton local produced for BCCL, 8548 ton import and 600 ton used for activated carbon (BCCL)
The amount of coal approx. 23.300 ton is probably understated as Penden Cement apparently used about 29,000 tons while BCCL imports about 10,000 tons for calcium carbide production as substitute for charcoal

Annex 2 : Fuelwood supplies / disposal at the district level covered by permits

		LOCAL					EXPORT				Remarks
Division	District	87-88	88-89	89-90	90-91		87-88	88-89	89-90	90-91	
FUELWOOD IN TRUCK LOADS											
Chirang	Chirang	0	0	76	0		0	0	0	0	Use not specified
Sarbhang	Chirang	0	7	0			0	0	0	0	Village use (Free grant)
Chirang	Chirang	0	0	3	0		0	0	0	0	RBA/RBG/RBP (Free grant)
Thimphu	Haa	995	894	809	692		0	0	0	0	Use not specified
Mongar	Luntshi	2	2	0	0		0	0	0	0	Gov./Commercial parties
Mongar	Mongar	90	0	0	0		0	0	0	0	Village use (rural rate)
Mongar	Mongar	37	0	20	0		0	0	0	0	Gov./Commercial parties
Mongar	Mongar	15	0	20	0		0	0	0	0	RBA/RBG/RBP (Free grant)
Mongar	Tashigang	81	0	148	91		0	0	0	0	Village use (rural rate)
Mongar	Tashigang	40	41	34	243		0	0	0	0	Gov./Commercial parties
Mongar	Tashigang	20	25	229	73		0	0	0	0	RBA/RBG/RBP (Free grant)
Thimphu	Paro	2,506	1,892	1,777	432		0	0	0	0	Use not specified
Thimphu	Punakha	334	211	117			0	0	0	0	Use not specified
Samdrup.	Samdrup Jongkhar	496	614	443	345		14	0	0	0	Use not specified
Sarbhang	Geylegphug	0	0	1	0		0	0	0	0	RBA/RBG/RBP (Free grant)
Sarbhang	Geylegphug	0	0	0	1		0	0	0	0	Gov. dep.
Sarbhang	Geylegphug	0	0	1	5		0	0	0	0	Village use (Free grant)
Sarbhang	Geylegphug	0	0	0	0		40	0	1	0	Export
Thimphu	Thimphu	2,090	2,227	2,319	2,663		0	0	0	0	Governmental Dep.
Thimphu	Thimphu	387	520	398	236		0	0	0	0	Village use (Free grant)
Thimphu	Thimphu	1,130	1,701	1,076	1,297		0	0	0	0	RBA/RBG/RBP (Free grant)
Thimphu	Wangdi Phodrang	1,962	3,114	2,294			0	0	0	0	Use not specified
		10,185	11,248	9,765	6,078	T/L	54	0	1	0	
FUELWOOD IN HEAD LOADS											
Chirang	Chirang	0	35	0	0		0	0	0	0	Village use (Free grant)
Sarbhang	Chirang	0	1000	0	0		0	0	0	0	Use not specified
Chirang	Dagana	0	0	0	0		0	0	0	0	Use not specified
Mongar	Luntshi	105	0	0	0		0	0	0	0	Village use (rural rate)
Mongar	Mongar	295	400	0	11,520		0	0	0	0	Village use (rural rate)
Mongar	Mongar	60	15	0	0		0	0	0	0	Gov./Commercial parties
Mongar	Mongar	50	0	100	0		0	0	0	0	RBA/RBG/RBP (Free grant)
Mongar	Tashigang	205	900	5,841	0		0	0	0	0	Village use (rural rate)
Mongar	Tashigang	0	0	26	50		0	0	0	0	Gov./Commercial parties
Mongar	Tashigang	200	0	0	0		0	0	0	0	RBA/RBG/RBP (Free grant)
Sarbhang	Geylegphug	0	0	355	35		0	0	0	0	Village use (Free grant)
		915	2,350	6,322	11,605	H/L	0	0	0	0	
SUB-TOTAL WEIGHT IN TONS		55,434	61,260	53,311	33,412		294	0	5	0	

Note: The amount shown under 90-91 covers part of the year and in some cases no information was provided

1 Truck load or T/L assumed as 7.5 cubic meter (cum) stacked wood, equal to 5,440 kg.

1 Head load or H/L has been assumed to weigh 30 kg.

Annex 2 : Fuelwood supplies / disposal at the district level covered by permits Con'd

		LOCAL					EXPORT					Remarks
Division	District	87-88	88-89	89-90	90-91		87-88	88-89	89-90	90-91		
SUB-TOTAL FROM PAGE 1		55,434	61,260	53,311	33,412		294	0	5	0		
FUELWOOD IN STACKS												
Chirang	Chirang	0	0	121	3		0	0	0	0		Use not specified
Mongar	Luntshi	2	0	1	3		0	0	0	0		Village use (rural rate)
Mongar	Luntshi	0	0	0	2		0	0	0	0		Gov./Commercial parties
Mongar	Luntshi	0	5	0	0		0	0	0	0		RBA/RBG/RBP (Free grant)
Mongar	Mongar	4	0	0	0		0	0	0	0		Village use (rural rate)
Mongar	Tashigang	4	0	1	55		0	0	0	0		Village use (rural rate)
Mongar	Tashigang	0	0	0	11		0	0	0	0		Gov./Commercial parties
Samdrup.	Samdrup Jongkhar	21	52	550	90		42	103	0	0		Use not specified
Sarbhang	Geylegphug	0	0	0	23		0	0	0	0		RBA/RBG/RBP (Free grant)
Sarbhang	Geylegphug	0	0	169	45		0	0	0	0		Village use (Free grant)
		31	57	842	232	St.	42	103	0	0		
FUELWOOD IN CUBIC METERS												
Bumthang	Bumthang	2,618	2,618	2,618	0		0	0	0	0		Total 87/88-89/90
Bumthang	Shemgang	133	133	133	0		0	0	0	0		Total 87/88-89/90
Bumthang	Tongsa	0	0	0	0		0	0	0	0		Total 87/88-89/90
Sarbhang	Geylegphug	0	0	0	0		0	783	478	142		Export
		2,751	2,751	2,751	0	CUM	0	0	0	0		
FUELWOOD IN CART LOADS												
Sarbhang	Geylegphug	0	0	6	0		0	0	0	0		Village use (Free grant)
FUELWOOD IN METRIC TONS												
Mongar	Tashigang	1,250	0	0	0		0	0	0	0		Gov./Commerc. parties
TOTAL WEIGHT IN TONS		58,704	63,302	56,010	33,606		329	86	5	0		

Note: The amount shown under 90-91 covers part of the year and in some cases no information was provided

1 Stack assumed measures 1.77 cum and weighs about 835 kg.

1 Cubic meter or CUM assumed to be a solid cubic meter weighing 725 kg.

1 Cartload or C/L has been assumed to be 0.5 cubic meter stacked wood weighing about 235 kg.

OTHER POSSIBLE FUELWOOD SOURCES												
Chirang	Chirang	0	0	428	0		0	0	0	0	Tre	Marked for village use
Sarbhang	Geylegphug	0	0	0	0		1067	0	0	0	Bag	Sawdust
Sarbhang	Geylegphug	0	0	0	0		0	0	15	0	T/L	Sawdust
Thimphu	Thimphu	0	0	159	183		0	0	0	0	Ton	Charcoal (BCCL use ?)
Thimphu	Haa	3	33	44	14		0	0	0	0	Ton	Charcoal (BCCL use ?)

Source : DOF, Management and RAD department

File : 006/FUELWOOD-911012

Annex 3 : Basic data at gewog level (un-official estimates).

No.	GEWOG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	Populat. size	Geographical information Mean alt. in m.	Area in sq.km.	Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989 Total	Per cap.	Estimat. fuelwood share in % of total	timated amount of fuelwood use in ton in 1989	other fuels in ton W.E.	Sustainable supply in tons	Fuelwood balance in tons
1	Chhumi	BUM	1.0313	5.80	457	3,059	3334	387.50	7.89	5,527	1.81	100	5,527	0	101,500	95,973
2	Chokor	BUM	1.0313	5.80	812	5,437	4256	1,500.00	3.62	11,296	2.08	85	9,602	1,694	179,075	169,473
3	Tang	BUM	1.0313	5.80	323	2,167	3728	593.75	3.65	3,915	1.81	100	3,915	0	112,375	108,460
4	Ura	BUM	1.0313	5.80	289	1,935	3328	287.50	6.73	3,497	1.81	100	3,497	0	100,775	97,278
5	Beteni	CHI	1.0310	8.30	464	3,108	1153	93.75	33.15	3,935	1.27	100	3,935	0	15,950	12,015
6	Chaunauti	CHI	1.0310	8.30	325	2,179	1040	31.25	69.72	2,758	1.27	100	2,758	0	725	(2,033)
7	Chirang Dangra	CHI	1.0310	8.30	433	2,900	1133	37.50	77.33	3,671	1.27	100	3,671	0	2,900	(771)
8	Dorona	CHI	1.0310	8.30	298	1,999	1292	81.25	24.60	2,531	1.27	100	2,531	0	15,225	12,694
9	Dunglagang	CHI	1.0310	8.30	351	2,349	2112	50.00	46.99	3,610	1.54	100	3,610	0	13,775	10,165
10	Emiray	CHI	1.0310	8.30	230	1,544	1250	50.00	30.88	1,955	1.27	100	1,955	0	17,400	15,445
11	Gairi Gaon	CHI	1.0310	8.30	265	1,778	600	31.25	56.91	1,771	1.00	100	1,771	0	2,900	1,129
12	Goseling	CHI	1.0310	8.30	505	3,383	1350	25.00	135.32	4,283	1.27	100	4,283	0	2,900	(1,383)
13	Goshi	CHI	1.0310	8.30	471	3,154	1325	25.00	126.14	3,993	1.27	100	3,993	0	8,700	4,707
14	Kikhortang	CHI	1.0310	8.30	1,343	8,998	1500	25.00	359.90	11,391	1.27	100	11,391	0	2,900	(8,491)
15	Lamidangra	CHI	1.0310	8.30	485	3,251	1100	25.00	130.04	4,116	1.27	100	4,116	0	5,800	1,684
16	Patali	CHI	1.0310	8.30	461	3,091	1487	100.00	30.91	3,914	1.27	100	3,914	0	21,025	17,111
17	Phungtenchu	CHI	1.0310	8.30	425	2,845	2241	106.25	26.78	4,372	1.54	100	4,372	0	36,975	32,603
18	Samjong	CHI	1.0310	8.30	332	2,221	1600	18.75	118.47	2,812	1.27	100	2,812	0	725	(2,087)
19	Suntalay	CHI	1.0310	8.30	450	3,018	825	100.00	30.18	3,004	1.00	100	3,004	0	21,025	18,021
20	Tashiding	CHI	1.0310	8.30	439	2,939	833	37.50	78.39	2,926	1.00	100	2,926	0	9,425	6,499
21	Tshokhana	CHI	1.0310	8.30	392	2,626	1675	25.00	105.02	3,324	1.27	100	3,324	0	2,900	(424)
22	Balujora	CHU	1.0310	6.70	547	3,667	809	137.50	26.67	3,650	1.00	100	3,650	0	36,975	33,325
23	Bongo	CHU	1.0310	6.70	598	4,007	1827	231.25	17.33	5,074	1.27	100	5,074	0	85,550	80,476
24	Chapchha	CHU	1.0310	6.70	402	2,691	2975	125.00	21.53	4,135	1.54	100	4,135	0	14,500	10,365
25	Dungna	CHU	1.0310	6.70	208	1,397	2086	175.00	7.98	2,146	1.54	100	2,146	0	47,850	45,704
26	Gengudala	CHU	1.0310	6.70	2,323	15,566	1525	75.00	207.55	19,708	1.27	100	19,708	0	18,850	(858)
27	Getana	CHU	1.0310	6.70	288	1,933	1969	262.50	7.36	2,447	1.27	100	2,447	0	125,425	122,978
28	Geyli	CHU	1.0310	6.70	246	1,651	2244	337.50	4.89	2,536	1.54	100	2,536	0	116,725	114,189
29	Jagchhu	CHU	1.0310	6.70	420	2,817	2725	150.00	18.78	4,328	1.54	100	4,328	0	29,000	24,672
30	Logchina	CHU	1.0310	6.70	287	1,921	1083	75.00	25.61	2,432	1.27	100	2,432	0	11,600	9,168
31	Metab	CHU	1.0310	6.70	121	814	1522	56.25	14.46	1,030	1.27	100	1,030	0	6,525	5,495
32	Puntsholing	CHU	1.0310	6.70	3,259	21,833	860	125.00	174.67	10,868	0.50	50	5,434	5,434	10,150	4,716

(Continued)

No.	GEWOG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	Populat. size	Geographical information Mean alt. in m.	Area in sq.km.	Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989 Total	Per cap.	Estimat. fuelwood share in % of total	mated amount of fuelwood use in ton in 1989	other fuels in ton W.E.	Sustainable supply in ton	Fuelwood balance in ton
33	Drujegang	DAG	1.0380	7.10	277	1,859	814	43.75	42.49	1,851	1.00	100	1,851	0	5,800	3,949
34	Kalizingkha	DAG	1.0380	7.10	567	3,797	1536	106.25	35.73	4,807	1.27	100	4,807	0	63,075	58,268
35	Khibesa	DAG	1.0380	7.10	354	2,374	1650	100.00	23.74	3,005	1.27	100	3,005	0	34,800	31,795
36	Lajab	DAG	1.0380	7.10	201	1,350	1627	93.75	14.40	1,709	1.27	100	1,709	0	26,100	24,391
37	Tsangkha	DAG	1.0380	7.10	604	4,044	969	81.25	49.77	4,026	1.00	100	4,026	0	7,975	3,949
38	Tsezang	DAG	1.0380	7.10	114	764	2640	731.25	1.04	1,174	1.54	100	1,174	0	197,200	196,026
39	Bhur	GEY	1.0256	8.30	410	2,746	545	68.75	39.95	2,734	1.00	100	2,734	0	3,625	891
40	Danabari	GEY	1.0256	8.30	552	3,699	733	75.00	49.32	3,683	1.00	100	3,683	0	5,800	2,117
41	Deorali	GEY	1.0256	8.30	334	2,241	577	106.25	21.09	2,231	1.00	100	2,231	0	13,050	10,819
42	Doban	GEY	1.0256	8.30	262	1,757	1726	256.25	6.86	2,224	1.27	100	2,224	0	62,350	60,126
43	Geylegphug	GEY	1.0256	8.30	2,076	13,909	389	56.25	247.27	6,923	0.50	80	5,539	1,385	1,450	(4,089)
44	Hilay	GEY	1.0256	8.30	706	4,729	1106	100.00	47.29	5,988	1.27	100	5,988	0	15,225	9,237
45	Kalikhola	GEY	1.0256	8.30	612	4,100	575	162.50	25.23	4,081	1.00	100	4,081	0	40,600	36,519
46	Lalai	GEY	1.0256	8.30	577	3,867	743	43.75	88.40	3,850	1.00	100	3,850	0	5,800	1,950
47	Leopani	GEY	1.0256	8.30	505	3,386	673	93.75	36.12	3,371	1.00	100	3,371	0	10,875	7,504
48	Nichula	GEY	1.0256	8.30	430	2,880	519	100.00	28.80	2,867	1.00	100	2,867	0	21,750	18,883
49	Sarbhangtar	GEY	1.0256	8.30	818	5,481	400	31.25	175.40	5,457	1.00	100	5,457	0	725	(4,732)
50	Sershong	GEY	1.0256	8.30	316	2,120	300	12.50	169.58	2,110	1.00	100	2,110	0	0	(2,110)
51	Singye	GEY	1.0256	8.30	408	2,731	650	225.00	12.14	2,718	1.00	100	2,718	0	60,175	57,457
52	Surey	GEY	1.0256	8.30	576	3,859	1464	400.00	9.65	4,886	1.27	100	4,886	0	67,425	62,539
53	Taklai	GEY	1.0256	8.30	498	3,334	529	187.50	17.78	3,319	1.00	100	3,319	0	19,575	16,256
54	Bee	HAA	1.0175	5.80	334	2,240	3936	978.13	2.29	4,049	1.81	100	4,049	0	200,100	196,051
55	Isu	HAA	1.0175	5.80	235	1,575	3361	81.25	19.38	2,846	1.81	100	2,846	0	38,425	35,579
56	Katsho	HAA	1.0175	5.80	546	3,659	3312	100.00	36.59	6,612	1.81	100	6,612	0	34,800	28,188
57	Samar	HAA	1.0175	5.80	259	1,733	2716	650.00	2.67	2,663	1.54	100	2,663	0	190,675	188,012
58	Sangbay	HAA	1.0175	5.80	159	1,062	1731	100.00	10.62	1,345	1.27	100	1,345	0	25,375	24,030
59	Gangzur	LHU	1.0278	5.80	685	4,593	3087	668.75	6.87	8,299	1.81	100	8,299	0	184,150	175,851
60	Jaray	LHU	1.0278	5.80	237	1,586	1957	118.75	13.35	2,008	1.27	100	2,008	0	17,400	15,392
61	Khowa	LHU	1.0278	5.80	423	2,834	3714	706.25	4.01	5,121	1.81	100	5,121	0	135,575	130,454
62	Kurteo	LHU	1.0278	5.80	298	1,995	3894	753.12	2.65	3,605	1.81	100	3,605	0	112,375	108,770
63	Menbi	LHU	1.0278	5.80	469	3,142	2000	87.50	35.91	4,827	1.54	100	4,827	0	18,850	14,023
64	Menji	LHU	1.0278	5.80	289	1,935	3066	75.00	25.80	3,497	1.81	100	3,497	0	42,775	39,278
65	Metsho	LHU	1.0278	5.80	296	1,983	2222	125.00	15.86	3,046	1.54	100	3,046	0	60,900	57,854
66	Tjenkhar	LHU	1.0278	5.80	445	2,978	2805	125.00	23.83	4,576	1.54	100	4,576	0	44,950	40,374

(Continued)

Annex 3 : Basic data at gewog level (un-official estimates).

No.	GEWOG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	1989 Populat. size	Geographical information: Mean alt. in m.	Geographical information: Area in sq.km.	Geographical information: Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989: Total	Amount of energy in ton W.E in 1989: Per cap.	Estimat. fuelwood share in % of total	mated amount of fuelwood use in ton in 1989	mated amount of other fuels in ton W.E.	Sustainable supply in tons	Fuelwood balance in tons
67	Chaskhar	MON	1.0285	7.10	375	2,516	1336	68.75	36.59	3,185	1.27	100	3,185	0	8,700	5,515
68	Dametsi	MON	1.0285	7.10	718	4,814	1700	150.00	32.09	6,094	1.27	100	6,094	0	14,500	8,406
69	Gongdu	MON	1.0285	7.10	348	2,332	936	237.50	9.82	2,322	1.00	100	2,322	0	52,200	49,878
70	Kengkhar	MON	1.0285	7.10	646	4,327	1166	112.50	38.46	5,478	1.27	100	5,478	0	22,475	16,997
71	Mongar	MON	1.0285	7.10	978	6,552	1916	150.00	43.68	8,295	1.27	100	8,295	0	33,350	25,055
72	Ngatsang	MON	1.0285	7.10	565	3,787	2574	325.00	11.65	5,819	1.54	100	5,819	0	97,150	91,331
73	Saleng	MON	1.0285	7.10	323	2,165	2114	468.75	4.62	3,326	1.54	100	3,326	0	88,450	85,124
74	Selambi	MON	1.0285	7.10	362	2,422	1791	143.75	16.85	3,067	1.27	100	3,067	0	36,250	33,183
75	Tangrong	MON	1.0285	7.10	301	2,019	1271	43.75	46.14	2,556	1.27	100	2,556	0	7,250	4,694
76	Tsakaling	MON	1.0285	7.10	590	3,950	2092	81.25	48.62	6,070	1.54	100	6,070	0	17,400	11,330
77	Tsamang	MON	1.0285	7.10	188	1,260	1438	112.50	11.20	1,596	1.27	100	1,596	0	11,600	10,004
78	Dogar	PAR	1.0108	6.20	441	2,957	2662	100.00	29.57	4,543	1.54	100	4,543	0	6,525	1,982
79	Dopshari	PAR	1.0108	6.20	282	1,888	2937	50.00	37.75	2,901	1.54	100	2,901	0	7,975	5,074
80	Doteng	PAR	1.0108	6.20	161	1,077	3942	262.50	4.10	1,946	1.81	100	1,946	0	52,925	50,979
81	Humrel	PAR	1.0108	6.20	568	3,808	3281	131.25	29.02	6,882	1.81	100	6,882	0	36,250	29,368
82	Lamgong	PAR	1.0108	6.20	406	2,719	3383	75.00	36.25	4,914	1.81	100	4,914	0	10,875	5,961
83	Lungni	PAR	1.0108	6.20	240	1,606	3100	43.75	36.70	2,902	1.81	100	2,902	0	10,150	7,248
84	Naja + South	PAR	1.0108	6.20	310	2,079	3042	168.75	12.32	3,757	1.81	100	3,757	0	55,825	52,068
85	Shaba	PAR	1.0108	6.20	533	3,571	3000	37.50	95.24	6,454	1.81	100	6,454	0	5,075	(1,379)
86	Soy	PAR	1.0078	6.20	39	259	4916	443.75	0.58	538	2.08	85	457	81	20,300	19,843
87	Tsento	PAR	1.0108	6.20	335	2,246	3992	553.13	4.06	4,058	1.81	100	4,058	0	98,600	94,542
88	Wangchang	PAR	1.0108	6.20	574	3,843	2825	50.00	76.86	5,905	1.54	100	5,905	0	9,425	3,520
89	Chongshi Borang	PEM	1.0194	8.30	294	1,968	1420	62.50	31.49	2,492	1.27	100	2,492	0	15,950	13,458
90	Dungmed	PEM	1.0194	8.30	426	2,857	1146	81.25	35.17	3,617	1.27	100	3,617	0	19,575	15,958
91	Khangma	PEM	1.0194	8.30	200	1,341	1125	100.00	13.41	1,698	1.27	100	1,698	0	15,950	14,252
92	Khar	PEM	1.0194	8.30	479	3,208	1179	118.75	27.01	4,061	1.27	100	4,061	0	24,650	20,589
93	Shumar	PEM	1.0194	8.30	974	6,528	1494	106.25	61.44	8,264	1.27	100	8,264	0	21,750	13,486
94	Yurung	PEM	1.0194	8.30	418	2,801	1333	56.25	49.79	3,546	1.27	100	3,546	0	5,800	2,254
95	Zobel	PEM	1.0194	8.30	340	2,277	1550	62.50	36.43	2,883	1.27	100	2,883	0	13,775	10,892

(Continued)

Annex 3 : Basic data at gewog level (un-official estimates).

No.	GEWOG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	Populat. size	Geographical information Mean alt. in m.	Area in sq.km.	Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989 Total	Per cap.	Estimat. fuelwood share in % of total	mated amount of fuelwood use in ton in 1989	other fuels in ton W.E.	Sustainable supply in tons	Fuelwood balance in tons
96	Chhubu	PUN	1.0168	5.80	355	2,377	2892	312.50	7.61	3,652	1.54	100	3,652	0	65,250	61,598
97	Geonshari	PUN	1.0168	5.80	82	548	2561	81.25	6.75	843	1.54	100	843	0	18,125	17,282
98	Guma	PUN	1.0168	5.80	414	2,776	2050	50.00	55.52	4,265	1.54	100	4,265	0	16,675	12,410
99	Khamed	PUN	1.0078	5.80	98	657	3076	187.50	3.50	1,188	1.81	100	1,188	0	55,100	53,912
100	Khateo	PUN	1.0078	5.80	167	1,122	3566	275.00	4.08	2,028	1.81	100	2,028	0	60,900	58,872
101	Laya	PUN	1.0078	5.80	130	870	4585	750.00	1.16	1,808	2.08	85	1,537	271	68,150	66,613
102	Lingbukha	PUN	1.0168	5.80	231	1,549	1925	50.00	30.98	1,961	1.27	100	1,961	0	10,875	8,914
103	Lunana	PUN	1.0078	5.80	159	1,062	5062	2,868.75	0.37	2,495	2.35	85	2,120	374	104,400	102,280
104	Shengana	PUN	1.0168	5.80	109	733	2454	68.75	10.67	1,127	1.54	100	1,127	0	18,850	17,723
105	Talo (Goen)	PUN	1.0168	5.80	347	2,324	1500	12.50	185.91	2,942	1.27	100	2,942	0	0	(2,942)
106	Zoma	PUN	1.0168	5.80	243	1,625	1820	62.50	26.01	2,058	1.27	100	2,058	0	13,775	11,717
107	Bangra	SAC	1.0317	7.70	617	4,136	1973	134.38	30.78	5,236	1.27	100	5,236	0	26,100	20,864
108	Biru	SAC	1.0317	7.70	482	3,232	1800	62.50	51.71	4,092	1.27	100	4,092	0	20,300	16,208
109	Chargharey	SAC	1.0317	7.70	656	4,392	500	25.00	175.67	4,372	1.00	100	4,372	0	9,425	5,053
110	Chengmari	SAC	1.0317	7.70	864	5,792	560	31.25	185.34	5,766	1.00	100	5,766	0	9,425	3,659
111	Denchhukha	SAC	1.0317	7.70	302	2,021	1644	56.25	35.93	2,559	1.27	100	2,559	0	1,450	(1,109)
112	Dorokha	SAC	1.0317	7.70	685	4,588	1170	125.00	36.70	5,808	1.27	100	5,808	0	15,950	10,142
113	Dungteo	SAC	1.0317	7.70	310	2,078	1500	143.75	14.46	2,631	1.27	100	2,631	0	50,025	47,394
114	Gumauney	SAC	1.0317	7.70	598	4,008	525	25.00	160.32	3,990	1.00	100	3,990	0	725	(3,265)
115	Lahirini	SAC	1.0317	7.70	537	3,595	2232	175.00	20.54	5,523	1.54	100	5,523	0	58,000	52,477
116	Mayona	SAC	1.0317	7.70	410	2,746	1971	193.75	14.18	3,477	1.27	100	3,477	0	50,750	47,273
117	Nainital	SAC	1.0317	7.70	384	2,572	533	18.75	137.16	2,560	1.00	100	2,560	0	725	(1,835)
118	Pagli	SAC	1.0317	7.70	2,029	13,594	653	106.25	127.94	13,533	1.00	100	13,533	0	7,250	(6,283)
119	Samchi	SAC	1.0317	7.70	1,420	9,515	836	68.75	138.39	9,472	1.00	100	9,472	0	15,225	5,753
120	Sibsu	SAC	1.0317	7.70	771	5,164	738	81.25	63.56	5,141	1.00	100	5,141	0	10,875	5,734
121	Tading	SAC	1.0317	7.70	615	4,121	800	137.50	29.97	4,102	1.00	100	4,102	0	15,950	11,848
122	Tendu	SAC	1.0317	7.70	701	4,696	2603	156.25	30.05	7,216	1.54	100	7,216	0	37,700	30,484

(Continued)

No.	GEWOG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	Populat. size	Geographical information Mean alt. in m.	Area in sq.km.	Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989 Total	Per cap.	Estimat. fuelwood share in % of total	mated amount of fuelwood use in ton in 1989	other fuels in ton W.E.	Sustainable supply in tons	Fuelwood balance in tons
123	Bakuli	SAJ	1.0352	7.70	789	5,286	486	87.50	60.42	5,263	1.00	100	5,263	0	12,325	7,062
124	Dalim	SAJ	1.0352	7.70	512	3,428	422	53.13	64.52	3,413	1.00	100	3,413	0	9,425	6,012
125	Dechhenling	SAJ	1.0352	7.70	497	3,329	1025	125.00	26.64	4,215	1.27	100	4,215	0	29,000	24,785
126	Hastinapur	SAJ	1.0352	7.70	722	4,836	485	168.75	28.66	4,815	1.00	100	4,815	0	43,500	38,685
127	Louri	SAJ	1.0352	7.70	561	3,757	1938	146.75	25.60	4,757	1.27	100	4,757	0	39,150	34,393
128	Martsala	SAJ	1.0352	7.70	587	3,930	1666	331.25	11.86	4,975	1.27	100	4,975	0	33,350	28,375
129	Norbugang	SAJ	1.0352	7.70	697	4,670	672	281.25	16.60	4,649	1.00	100	4,649	0	37,700	33,051
130	Orong	SAJ	1.0352	7.70	1,690	11,325	815	368.75	30.71	5,637	0.50	80	4,510	1,127	104,400	99,890
131	Samrang	SAJ	1.0352	7.70	408	2,737	325	21.87	125.14	2,725	1.00	100	2,725	0	3,625	900
132	Serthig	SAJ	1.0352	7.70	479	3,210	1457	359.37	8.93	4,064	1.27	100	4,064	0	121,800	117,736
133	Bardo	SHE	1.0322	7.10	328	2,200	1947	250.00	8.80	2,786	1.27	100	2,786	0	45,675	42,889
134	Drokar	SHE	1.0322	7.10	195	1,306	866	243.75	5.36	1,300	1.00	100	1,300	0	43,500	42,200
135	Nangkor	SHE	1.0322	7.10	317	2,124	1727	450.00	4.72	2,689	1.27	100	2,689	0	63,800	61,111
136	Ngala	SHE	1.0322	7.10	434	2,905	912	200.00	14.53	2,892	1.00	100	2,892	0	33,350	30,458
137	Pangkhar	SHE	1.0322	7.10	216	1,448	1010	412.50	3.51	1,834	1.27	100	1,834	0	76,850	75,016
138	Shingkhar	SHE	1.0322	7.10	353	2,363	2203	325.00	7.27	3,632	1.54	100	3,632	0	46,400	42,768
139	Tong	SHE	1.0322	7.10	529	3,544	1905	587.50	6.03	4,487	1.27	100	4,487	0	83,375	78,888
140	Bartsam	TAS	1.0229	6.60	950	6,366	1645	68.75	92.60	8,060	1.27	100	8,060	0	5,800	(2,260)
141	Bidung	TAS	1.0229	6.60	577	3,865	1440	31.25	123.67	4,893	1.27	100	4,893	0	725	(4,168)
142	Gomdar	TAS	1.0229	6.60	889	5,954	1573	68.75	86.60	7,538	1.27	100	7,538	0	12,325	4,787
143	Jangphu	TAS	1.0229	6.60	1,253	8,397	2061	112.50	74.64	12,903	1.54	100	12,903	0	15,225	2,322
144	Kanglung	TAS	1.0229	6.60	788	5,278	2307	81.25	64.97	8,111	1.54	100	8,111	0	13,050	4,939
145	Kangpara	TAS	1.0229	6.60	498	3,338	2682	318.75	10.47	5,130	1.54	100	5,130	0	60,900	55,770
146	Khaling	TAS	1.0229	6.60	669	4,481	2400	137.50	32.59	6,885	1.54	100	6,885	0	23,200	16,315
147	Lumang	TAS	1.0229	6.60	858	5,749	1792	81.25	70.76	7,279	1.27	100	7,279	0	5,800	(1,479)
148	Meraksakteng	TAS	1.0229	6.60	827	5,543	3352	978.12	5.67	10,017	1.81	100	10,017	0	216,775	206,758
149	Nanong	TAS	1.0229	6.60	570	3,817	1604	143.75	26.55	4,833	1.27	100	4,833	0	14,500	9,667
150	Phongme	TAS	1.0229	6.60	830	5,563	2582	175.00	31.79	8,548	1.54	100	8,548	0	58,725	50,177
151	Radi	TAS	1.0229	6.60	720	4,824	2350	25.00	192.98	7,413	1.54	90	6,672	741	5,800	(872)
152	Samkhar	TAS	1.0229	6.60	1,098	7,354	2211	56.25	130.73	11,300	1.54	100	11,300	0	8,700	(2,600)
153	Shongphu	TAS	1.0229	6.60	596	3,996	2144	56.25	71.04	6,140	1.54	100	6,140	0	5,800	(340)
154	Tashi Yangtse	TAS	1.0229	6.60	1,073	7,190	3383	1,137.50	6.32	12,992	1.81	100	12,992	0	238,525	225,533
155	Thrimshing	TAS	1.0229	6.60	712	4,773	2160	62.50	76.37	7,335	1.54	100	7,335	0	12,325	4,990
156	Tongma Shangtsen	TAS	1.0229	6.60	644	4,312	1722	112.50	38.33	5,460	1.27	100	5,460	0	31,175	25,715
157	Uzarong	TAS	1.0229	6.60	635	4,252	1571	87.50	48.59	5,383	1.27	100	5,383	0	19,575	14,192
158	Yalang	TAS	1.0229	6.60	495	3,313	2560	93.75	35.34	5,091	1.54	100	5,091	0	34,075	28,984
159	Yangner	TAS	1.0229	6.60	853	5,713	1380	93.76	60.93	7,233	1.27	100	7,233	0	9,425	2,192

(Continued)

No.	GEWOG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	Populat. size	Geographical information Mean alt. in m.	Area in sq.km.	Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989 Total	Per cap.	Estimat. fuelwood share in % of total	Estimated amount of fuelwood use in ton in 1989	other fuels in ton W.E.	Sustainable supply in tons	Fuelwood balance in tons
160	Babesa	THI	1.0200	5.70	450	3,013	3036	68.75	43.82	5,445	1.81	100	5,445	0	17,400	11,955
161	Chang	THI	1.0200	5.70	293	1,965	2990	68.75	28.58	3,020	1.54	100	3,020	0	12,325	9,305
162	Dagala	THI	1.0200	5.70	75	503	3768	100.00	5.03	909	1.81	100	909	0	5,075	4,166
163	Gaynikha	THI	1.0200	5.70	76	508	3068	137.50	3.69	918	1.81	100	918	0	26,100	25,182
164	Jemena	THI	1.0200	5.70	170	1,137	4981	206.25	5.51	2,361	2.08	85	2,007	354	12,325	10,318
165	Kabisa	THI	1.0200	5.70	439	2,940	3657	131.25	22.40	5,314	1.81	100	5,314	0	46,400	41,086
166	Kawang	THI	1.0200	5.70	470	3,150	2980	31.25	100.80	4,840	1.54	100	4,840	0	26,825	21,985
167	Lingshi	THI	1.0078	5.70	137	921	4560	350.00	2.63	1,914	2.08	85	1,627	287	30,450	28,823
168	Mewang	THI	1.0200	5.70	553	3,704	3175	100.00	37.04	6,693	1.81	100	6,693	0	19,575	12,882
169	Naro	THI	1.0078	5.70	49	328	4500	312.50	1.05	682	2.08	85	579	102	24,650	24,071
170	Teobesa	THI	1.0200	5.70	347	2,328	2681	137.50	16.93	3,577	1.54	100	3,577	0	34,800	31,223
171	Teowang	THI	1.0200	5.70	251	1,682	2988	56.25	29.90	2,584	1.54	100	2,584	0	13,050	10,466
172	Thimphu	THI	1.0200	5.70	4,376	29,316	2960	31.25	938.11	22,523	0.77	50	11,261	11,261	2,175	(9,086)
173	Dragteng	TON	1.0156	6.60	405	2,716	2646	81.25	33.42	4,173	1.54	100	4,173	0	10,150	5,977
174	Korphu	TON	1.0156	6.60	245	1,641	2056	500.00	3.28	2,521	1.54	100	2,521	0	158,775	156,254
175	Namther Langthel	TON	1.0156	6.60	377	2,527	2662	381.25	6.63	3,882	1.54	100	3,882	0	79,750	75,868
176	Nubi	TON	1.0156	6.60	583	3,906	3039	481.25	8.12	7,059	1.81	100	7,059	0	124,700	117,641
177	Tangsibi	TON	1.0156	6.60	276	1,852	2870	425.00	4.36	2,845	1.54	100	2,845	0	131,225	128,380
178	Athang	WAN	1.0118	6.60	167	1,117	2434	781.25	1.43	1,716	1.54	100	1,716	0	203,000	201,284
179	Daga	WAN	1.0118	6.60	160	1,074	1936	375.00	2.86	1,360	1.27	100	1,360	0	108,750	107,390
180	Dangchu	WAN	1.0118	6.60	214	1,436	3330	206.25	6.96	2,595	1.81	100	2,595	0	18,850	16,255
181	Ganteo	WAN	1.0118	6.60	284	1,905	3818	100.00	19.05	3,442	1.81	100	3,442	0	10,150	6,708
182	Gase Tshowog	WAN	1.0118	6.60	122	819	2653	162.50	5.04	1,258	1.54	100	1,258	0	36,656	35,398
183	Gase Tsogong	WAN	1.0118	6.60	170	1,137	1982	106.25	10.70	1,439	1.27	100	1,439	0	20,619	19,180
184	Jena	WAN	1.0118	6.60	327	2,193	3102	281.25	7.80	3,963	1.81	100	3,963	0	41,325	37,362
185	Kashi	WAN	1.0118	6.60	266	1,780	3784	593.75	3.00	3,216	1.81	100	3,216	0	61,625	58,409
186	Nawi	WAN	1.0118	6.60	161	1,081	2710	62.50	17.30	1,661	1.54	100	1,661	0	14,500	12,839
187	Nisho	WAN	1.0118	6.60	316	2,115	2550	200.00	10.57	3,249	1.54	100	3,249	0	32,625	29,376
188	Phangyul	WAN	1.0118	6.60	232	1,555	1792	81.25	19.14	1,969	1.27	100	1,969	0	10,150	8,181
189	Phobji	WAN	1.0118	6.60	227	1,520	3443	200.00	7.60	2,748	1.81	100	2,748	0	42,050	39,302
190	Rubisa	WAN	1.0118	6.60	352	2,355	2404	156.25	15.07	3,619	1.54	100	3,619	0	29,000	25,381
191	Sephu	WAN	1.0118	6.60	331	2,216	4362	1,268.75	1.75	4,605	2.08	85	3,914	691	124,700	120,786
192	Thetsho	WAN	1.0118	6.60	495	3,315	1637	50.00	66.30	4,197	1.27	100	4,197	0	6,525	2,328

(Continued)

Annex 3 : Basic data at district level calculated from gewog data (un-official estimates).

No.	DZONGKHAG NAMES	Dzon-khag code	Pop. growth rate 1984	Farmer h.h. size 1984	1989 No. of households	Populat. size	Geographical information Mean alt. in m.	Area in sq.km.	Pop.dens. cap/sqkm	Amount of energy in ton W.E in 1989 Total	Per cap.	Estimat. fuelwood share in % of total	mated amount of fuelwood use in ton in 1989	other fuels in ton W.E.	Sustainable supply in tons	Fuelwood balance in tons
1	BHUMTHANG	BUM	1.0313	5.80	1,880	12,597	3,334	2,769	4.55	24,235	1.92	0.93	22,541	1,694	493,725	471,184
2	CHIRANG	CHI	1.0310	8.30	7,669	51,383	1,367	863	59.57	64,365	1.25	1.00	64,365	0	181,250	116,885
3	CHUKHA	CHU	1.0310	6.70	8,701	58,296	1,910	1,750	33.31	58,353	1.00	0.91	52,919	5,434	503,150	450,231
4	DAGA	DAG	1.0380	7.10	2,117	14,187	2,124	1,156	12.27	16,571	1.17	1.00	16,571	0	334,950	318,379
5	GEYLEGPHUG	GEY	1.0256	8.30	9,081	60,841	943	1,919	31.71	56,444	0.93	0.98	55,059	1,385	328,425	273,366
6	HA	HA	1.0175	5.80	1,533	10,270	3,353	1,909	5.38	17,515	1.71	1.00	17,515	0	489,375	471,860
7	LHUNTSHI	LHU	1.0278	5.80	3,141	21,044	3,314	2,659	7.91	34,979	1.66	1.00	34,979	0	616,975	581,996
8	MONGAR	MON	1.0285	7.10	5,395	36,144	1,732	1,894	19.09	47,808	1.32	1.00	47,808	0	389,325	341,517
9	PARO	PAR	1.0108	6.20	3,888	26,052	3,757	1,916	13.60	44,799	1.72	1.00	44,718	81	313,925	269,207
10	PEMAGATSHEL	PEM	1.0194	8.30	3,131	20,980	1,302	588	35.71	26,562	1.27	1.00	26,562	0	117,450	90,888
11	PUNAKHA	PUN	1.0168	5.80	2,335	15,645	4,502	4,719	3.32	24,366	1.56	0.97	23,721	645	432,100	408,379
12	SAMCHI	SAC	1.0317	7.70	11,380	76,249	1,538	1,541	49.49	85,479	1.12	1.00	85,479	0	329,875	244,396
13	SAMDRUP JONGKHAR	SAJ	1.0352	7.70	6,942	46,508	1,092	1,944	23.93	44,511	0.96	0.97	43,384	1,127	434,275	390,891
14	SHEMGANG	SHE	1.0323	7.10	2,372	15,891	1,584	2,469	6.44	19,619	1.23	1.00	19,619	0	392,950	373,331
15	TASHIGANG	TAS	1.0229	6.60	15,534	104,079	2,810	3,922	26.54	152,541	1.47	1.00	151,799	741	792,425	640,626
16	THIMPHU	THI	1.0200	5.70	7,686	51,494	3,607	1,731	29.74	60,778	1.18	0.80	48,773	12,005	271,150	222,377
17	TONGSA	TON	1.0156	6.60	1,887	12,641	2,644	1,869	6.76	20,481	1.62	1.00	20,481	0	504,600	484,119
18	WANGDI PHODRANG	WAN	1.0118	6.60	3,824	25,618	3,265	4,625	5.54	41,037	1.60	0.98	40,346	691	760,525	720,179
					98,495	659,919		40,240	16.40	840,443	1.27	0.97	816,639	23,804	7,686,450	6,869,811

File : 006/GEWOG-911012

Source : See note in the introduction to the report

Annex 4 : Land area and land use in Bhutan

	TOTAL AREA In Sq. Km.	In %
- Perpetual snow and glaciers	3,615.63	8.96
- Exposed and rocky areas	1,425.00	3.53
- Alpine pasture and meadows	1,043.75	2.59
- Alpine scrub	3,690.63	9.14
- Grassland and scrubs	434.37	1.08
- River beds	168.75	0.42
- Water bodies and lakes	18.75	0.05
TOTAL ALPINE, GRASS AND WATER	10,396.87	25.75
- Fir	2,662.50	6.59
- Fir, low density	456.25	1.13
- Mixed conifers	2,506.25	6.21
- Mixed conifer, low density	565.62	1.40
- Broad leaved with conifers	1,718.75	4.26
- Broad leaved with conifers, low density	362.50	0.90
- Temperate broad leaved	4,450.00	11.02
- Temperate broad leaved, low density	743.75	1.84
- Tropical & Subtropical hardwoods	4,412.50	10.93
- Tropical & Subtropical hardwoods, low density	956.25	2.37
- Blue pine	850.00	2.11
- Blue pine, low density	143.75	0.36
- Chir pine	662.50	1.64
- Chir pine, low density	131.25	0.33
- Plantations	31.25	0.08
- Degraded forests	2,315.63	5.74
TOTAL FORESTS	22,968.75	56.89
- Valley cultivation	456.25	1.13
- Terraced cultivation	2,043.75	5.06
- Unterraced cultivation	3,037.50	7.52
- Shifting cultivation	750.00	1.86
- Orchards	187.50	0.46
- Habitation	18.75	0.05
- Un-interpreted	512.50	1.27
TOTAL AGRICULTURE AND OTHERS	7,006.25	17.35
TOTAL LAND AREA BHUTAN	40,371.87	100.00

Source : Report on "Land Use Mapping by Master Plan for Forestry Development in Bhutan"

File : 006/LAND-USE-911012

Annex 5

CONVERSION TABLES

Wood conversion factors:

1 cubic meter wood (solid) equals about 1.50 stere or stacked cubic meter
1 cubic meter wood (solid) weighs about 725 kg. (depending upon specie)
1 stere equals about 0.65 cubic meter (solid)
1 stere weighs approximately 475 kg. (depending upon specie)
1 ton wood equals about 2 steres or 1.4 cubic meters wood (solid)

Calorific values of different fuels:

1 kg. wood	= 15.0 MJ	1 kg. charcoal	= 29.0 MJ
1 kg. residues	= 13.0 MJ	1 kg. kerosene	= 42.7 MJ
1 kg. coal (exp.)	= 20.0 MJ	1 ltr kerosene	= 35.0 MJ
1 kg. coal (imp.)	= 25.0 MJ	1 kWh electricity	= 3.6 MJ

Average end-use efficiencies taken into account for domestic stoves:

Fuelwood burning stoves	15%	Gas stoves	45%
Residue burning stoves	12%	Electric stoves	60%
Charcoal stoves	22%	Kerosene stoves	43%

Conversion factors of different fuels to tons wood equivalent (TWE) *)

1 ton residues	= 0.70 TWE	1 TWE	= 1.42 ton residues
1 MWh electricity	= 0.98 TWE	1 TWE	= 1.02 MHh electricity
1 ton cooking gas	= 9.37 TWE	1 TWE	= 0.11 ton cooking gas
1000 ltr. kerosene	= 6.81 TWE	1 TWE	= 150 ltr. kerosene

Conversion factors of different fuels to other fuels *)

1 kg. cooking gas	= 1.38 ltr. kerosene	= 9.58 kWh electricity
1 kWh electricity	= 0.10 kg. cooking gas	= 0.15 ltr. kerosene
1 ltr. kerosene	= 0.72 kg. cooking gas	= 6.97 kWh electricity

*) Taking into account end-use efficiency for domestic stoves.

Conversion factors of fuels for industrial purposes

1 ton wood	= 0.71 ton coal	= 0.35 ton oil
1 ton coal	= 1.40 ton wood	= 0.49 ton oil
1 ton oil	= 2.03 ton coal	= 2.85 ton wood

Annex 6

REPRINT OF EXECUTIVE SUMMARY OF THE REPORT BY MR. G.C. KING, THE CONSULTANT ON SOCIAL FORESTRY FOR THE "MASTER PLAN FOR FORESTRY DEVELOPMENT IN BHUTAN"

Social forestry commenced by Royal Decree in Bhutan in 1979. In the early years seedlings were distributed free of charge to interested farmers. In 1985 Social Forestry Day commenced as an annual event with school children planting trees. Active involvement of communities in social forestry did not commence until 1987 in Chirang (Chirang Hill Irrigation Project) and in 1988 at Phuntsholing (FAO Forest Management and Conservation Project). The latter project was seen as a pilot trial for the implementation of both private forestry and community forestry in Bhutan.

The approaches used to date in the implementation of social forestry were examined and some deficiencies identified. Firstly there has been no assessment of priority areas for social forestry across Bhutan. This is important because where there are large areas of forest remaining in Bhutan there is no urgency to implement social forestry. Future implementation efforts should focus on those areas where villagers are experiencing difficulties obtaining forest products essential to the maintenance of their domestic and farming welfare.

Secondly, while the enthusiasm of involved Forestry Department staff is to be commended, the implementation process has generally been too top down and too fast. This has led to Forestry Department staff having an inadequate understanding of the local forest usage patterns and social organization and the villagers having insufficient understanding of the social forestry program and their responsibilities as participants of the program. Information collection was primarily restricted to village meetings which limited the scope of information obtained often due to the dominance of meetings by the more influential villagers.

Thirdly the use of large subsidies to foster the program was considered inappropriate. The payment of subsidies cannot be sustained as the program expands. It also makes it difficult to assess the villagers commitment to the program. If the villagers have a real need for an improved supply of forest products then the perceived future benefits of the program should be sufficient incentive. In some areas visited villagers had already responded to perceived forest product deficiency by implementing their own initiatives to overcome their problem.

Finally a lack of training in social forestry extension techniques and their implementation was evident. This made it very difficult for staff to function effectively and know whether the path they were following was appropriate or otherwise.

The approved Forest Policy of Bhutan, 1991 proposal and the draft Bhutan Forest Act, 1991 provide no impediment to the development of the social forestry program. Clause 12 of the draft Act states "The Department may issue social forestry and community forestry rules, which shall govern in case of conflict with any other provisions of this chapter." This clause clearly allows for periodic amendment of the Social Forestry Rules to facilitate the implementation of the social forestry program.

An examination of the Social Forestry Rules has shown them to be restrictive in their controls and implementation procedures. For example, under the Community Forest Rules it takes at least thirteen bureaucratic steps for the user group to assume management responsibility for a few hectares of plantation. Under the Private Forest Rules a farmer has to obtain permission from the Divisional Forest Officer to cut or cut and sell trees that he has planted as seedlings and protected and furthermore he has no guarantee that approval will be given. These measures are a disincentive to become involved in the social forestry program and recommendations for amendment are included in the report.

While the government has approved three social forestry rules being the Private Forest Rules, the Community Forest Rules and the Lease Forest Rules it has yet to approve the most significant of the proposed rules being the Community Protected Forest Rules. This latter set of rules relates to community management of existing natural forest traditionally used by local communities. The implementation of community management over areas of natural forest traditionally used by local communities should be the first priority in the social forestry program. Apart from best meeting the forest product needs of the villagers the implementation of sound silvicultural based management, following advice from Forestry Departmental staff, will result in a halt to the degradation process and a gradual improvement in forest condition. It is recommended in this report to facilitate this process that the Community Forest Rules and the Community Protected Forest Rules be amalgamated. This would allow all the forest area traditionally used by a user group or village to be placed under the one simple management plan. The rules would then allow highly degraded areas, often close to villages, to be planted, less degraded areas to be protected and well stocked areas to be judiciously harvested using silviculturally sound prescriptions.

The implementation of the Lease Forest Rules needs to be monitored to ensure that traditional users are not alienated and disadvantaged while an individual or small group gain control of a degraded forest area. The criteria applicable to lease forest establishment would be equally applicable to community forest. It should be ascertained from the local users whether there are any objections to the proposed lease before it is approved. There are two land categories of potential for lease forest and one is degraded areas away from the village and not required for government afforestation projects. The second category is small areas of often cleared land close to villages that have reverted to the government following cadastral survey. As one objective of lease forestry is aimed at assisting the land poor farmers it should be trialled but carefully monitored.

The current extension network in the Department of Forestry is virtually non existent. Only four ranger level staff have any suitable training and only one of these staff is working in social forestry. Consideration was given to involving the forestry sector in an integrated extension package together with agriculture and animal husbandry. The Departments representing the latter two sectors both have well established extension networks. Due to the lack of forestry extension to date and the intensive field investigation necessary to determine the forestry extension needs, particularly in the area of social forestry, it was concluded that initially a line agency approach would be most successful. It was further concluded that the extension duties could not be undertaken by the territorial staff due to their policing function conflicting with the nature of extension duties. As a result an additional cadre of trained extension staff is required. It is proposed that field based extension units be established in each of the eighteen districts progressively on an as needs basis with a coordinating executive headed by a Divisional Forest Officer in Thimphu. The coordinating executive would be called the Social Forestry and Extension Division and would replace the present

Afforestation Division with the new name more truly reflecting the Divisions principal function. The field extension units would be staffed by a ranger in charge assisted by one or more foresters depending upon the workload. The field extension unit would be administratively responsible to the Divisional Forest Officer in whose division the unit was located and technically responsible to the Social Forestry and Extension Division in Thimphu.

Before any extension units are established training in forestry extension applicable to social forestry is an essential prerequisite. Training is required at all levels from senior staff through to those staff who will man the proposed field extension units. Senior staff should fully understand the extension process for social forestry that their staff will be expected to implement. A three day workshop is proposed for senior staff (Divisional Forest Officer and above) using some expert lecturers from outside Bhutan. Due to a general lack of understanding amongst field staff of the social forestry program it is proposed that following the senior level workshop Divisional Forest Officers be required to conduct Divisional level workshops to inform their staff. Those staff to be stationed in the field extension units will have more intensive training. It is proposed that rangers continue to undertake appropriate overseas short courses and then be deployed in a position where they can utilise their acquired knowledge on their return. A two week intensive course based on a successful course used for community forestry extension training in Nepal is proposed for forester level staff.

The preparation locally of visual aids applicable to the implementation of the social forestry in Bhutan is recommended. To illustrate simple silvicultural techniques that could be of value to users groups the establishment of a demonstration trial would also be beneficial. It is suggested that study tours, both for users groups and for extension staff should be part of the program.

Following establishment of a field extension unit it will be necessary for the forestry extension agent to have discussions with his agricultural and animal husbandry counterparts. These meetings should be on regular basis to ensure that farmers are not given conflicting information from the different line agencies.

It is recommended that the village-centred approach to social forestry extension detailed in this report be used as a starting point to the extension process in Bhutan and modified where necessary to suit the local situation. When the Department of Forestry has developed what it believes to be the appropriate extension strategy for social forestry in Bhutan then the possibility of an integrated extension strategy with its sister departments in the Ministry of Agriculture could be reconsidered. This time is probably several years into the future.

The two local non government organizations (NGOs), the National Womens Association and the Royal Society for the Protection of Nature are not expected to play a major role in the development of the social forestry program. Both are supportive but have limited resources at their disposal. Save the Children Federation USA, an international NGO, is likely to implement a farm productivity and resource conservation project in two gewogs in Shemgang District in 1992. It has a social forestry component and due to the concentrated nature of the project in a small area it should be monitored as it could provide some useful learning experiences.

The first step required for future implementation of social forestry in Bhutan is determine the priority areas for implementation. This should be done on a gewog and district basis and will allow the Department of Forestry to establish extension units progressively where they are most needed.

Priority gewogs can be determined using two methods. The first is a rapid appraisal using local knowledge of staff in district and range offices. The second is more objective and uses the Land Use Mapping Report (Gupta,1991), verified by aerial photographs (1990) and the new gewog boundary map. After the determination of priorities the extension agents will know which gewogs have priority for field investigation with a view to future social forestry implementation.

Studies in Nepal have indicated that it takes from 1.3 - 2.8 ha of forest to support 1 ha of agricultural land. No similar studies have been carried out in Bhutan. Nevertheless it is likely to take at least 1 ha of forest to support 1 ha of agricultural land as the situation although slightly different is not dissimilar. In the absence of any definitive study it is recommended that the area traditionally used by villagers to cut, collect and gather their forest products is the best guideline in determining the boundaries of areas of forest to be placed under community management. The establishment of small community woodlots will not satisfy the forest product requirements of villages due to the limited range of species established and the lag time to first harvest. It will at best improve their supply situation by supplementing their needs in due course. It is clear that the first priority in the social forestry program should be directed to local community management of the existing natural forest traditionally used by them.

It is considered that the next five years should continue to be thought of as the learning phase in the implementation of social forestry in Bhutan. Intervention and implementation should commence in a few areas and the approach modified if necessary in the light of experiences gained. Guidelines for a village-centred approach that has been successful elsewhere are provided in the report. The approach emphasises that the approach cannot be rushed as a relationship of trust has to develop between the extension agent and the forest users. In addition the farmers have to be given time to consider the available options and if they decide to participate in the program they must be directly involved in determination of their management needs and the preparation of a simple management plan. The extension agent facilitates this development process by being available to provide advice and assistance when required. It is unwise to target the implementation of the program as each case will be different with varying problems and needs and the user group requiring different time periods to develop an understanding of the program and make the necessary decisions.

Assuming a successful approach is developed during the next five years and trained human resources are available then the program can be expanded to encompass other areas potentially suitable for social forestry implementation during the subsequent fifteen years.

Annex 7

TERMS OF REFERENCE CONSULTANT ON WOOD ENERGY MASTER PLAN FOR FORESTRY DEVELOPMENT, BHUTAN

Under the overall supervision of the Director, Forestry Operations Services (FODO) and technical guidance of the Director Forest Products Division, Forestry Department, FAO, and direct guidance of the Chief Technical Advisor of GCP/RAS/131/NET, and in close cooperation with the MPFD team in Bhutan the incumbent will be responsible for :

1. Review the energy situation of Bhutan from the point of view of fuelwood. Evaluate existing information and suggest methods of generating additional needs.

2. Assess the wood energy supply, conversion techniques and fuelwood and charcoal production and distribution techniques. Identify deficit situations and suggest methods for alleviating them.

3. Identify main trends in underlying forces of fuelwood consumption. Estimate together with resource economist the levels and developments of fuelwood demand over 20 year period, by districts.

4. Analyse the trend in increase of fuelwood prices and collection efforts. Coordinate with community forestry expert the analysis of forest areas and management principles needed to meet the needs.

5. Analyse the socio-economic implications of fuelwood situation. Investigate potential for peoples participation. Coordinate with community forestry expert the extension programmes needed.

6. Suggest improvements in industrial fuelwood systems, institutions, human resources and training. Suggest development programmes and indicate levels of funding needed.

7. Write a report and present main findings, conclusions and suggestions in a workshop.

Duty Station	:	Thimphu
EOD	:	April, 21,1991
Duration	:	Two months split in 2 parts with 1.5 weeks in Thailand for report writing First visit : - 20.4.91 to 20.5.91 Second visit : - 9.6.91 to 30.6.91
Language	:	English.

Annex 8

PROJECT PROFILE

Project Title: Wood Energy Planning, Conversion and Utilization

Donor Input: US$ 1,100,000

Duration: 3 years

Background and Justification

Bhutan with a population of about 0.7 million is an agrarian society with an estimated 87% of the people engaged in farming. The amount of agricultural land per capita is very low when compared with the forested areas, resulting in a pressure on the forests, mainly for agricultural as well as grazing purposes, orchards, etc. The demand for fuelwood in the country is estimated to be about 0.92 million tons which is expected to increase to about 1.37 - 1.60 million tons by the year 2012. Much depends on how the economy develops and in how far fuel switching will take place while population growth and other factors such as the development of the industrial sector will also exert an influence on the demand for fuelwood. With this background, the implementation of energy and fuelwood conservation measures is considered essential in particular in rural areas so as to curb domestic as well as industrial demand.

Objectives

- To strengthen the role of wood energy in a sustained national energy and economic development plan;
- To promote the development of manpower and expertise for programme planning, management and field implementation of wood energy conversion devices and energy conservation programmes;
- To promote the setting up and improvement of wood energy information systems (resources, use, etc.), required for development planning and intervention;
- To promote the efficient use of wood energy and forestry development activities for rural and industrial development;
- To initiate R&D activities on wood energy conversion, utilization and conservation technologies;
- To demonstrate and assess selected and potentially high impact technologies for rural applications for domestic, agricultural and industrial purposes;
- To disseminate improved wood energy conversion systems and technologies through training, extension and technical assistance.

Proposed Activities

- Wood energy planning activities which will require reliable information (both available and to be collected), methodologies and techniques for data collection, processing and interpretation and setting up of an institutional framework to cope with the intersectoral nature of wood energy planning and its dynamism;

- Establishment of a computer based wood energy information and processing system (equipped with well trained staff and necessary facilities). The integrated wood energy data-base should cover national, regional and district levels of wood fuel resources and production, trade, consumption and information on end-users;

- Institutional strengthening or the setting up of key institutes involved in wood energy development (manpower strengthening, facilities, etc.);

- Manpower development and training to be carried out at lead regional and international training institutes on direct or indirect related wood energy development and technologies. This could include Khon Kaen University in Thailand for RRA tools and techniques, AIT in Thailand for wood/biomass energy technologies, IIT Delhi and Punjab University in India for improved wood and biomass cooking stoves, Twente University in the Netherlands for Rural Energy Matters, etc.

- Support to research and pilot projects on wood energy and related systems in the following areas: Fuelwood/wood energy flow studies, wood/biomass energy conservation in the domestic sector for cooking and heating (in cold districts), wood energy conservation in rural industries with emphasis on agro processing, food processing, etc., charcoal production development and systems for specific types of users and wood sources, etc., R&D on briquetting of charcoal fines, etc., studies on economic, socio-economic and cultural issues and their impacts on the adoption of alternative energy sources and equipment;

- Special studies related to national level policy issues and strategies in wood energy development (parallel with other energy sources).

Estimated Inputs

-	Fellowships (40 m/m), In service training, workshops, etc.	125,000
-	Equipment, vehicles, miscellaneous, etc.	250,000
-	International personnel (CTA and 2 project specialists in data collection, processing and rural energy planning, cookstove development and energy conservation in rural industries and commercial applications, charcoal production (total 60 m/m)	420,000
-	Field pilots and demonstration activities	125,000
-	Extension and dissemination	100,000
-	Other (local travel, administrative support, contingencies, etc.)	80,000
	TOTAL	US$ 1,100,000

Counterpart Organizations: Ministry of Agriculture, Department of Forests
Ministry of Trade and Industry, Department of Power
Planning Commission

Proposed Starting Date: As soon as possible