MOUNTAIN INFRASTRUCTURE AND TECHNOLOGY

Discussion Paper Series

ENERGY PLANNING AND MANAGEMENT IN DHADING DISTRICT, NEPAL

A CASE STUDY

Agricultural Projects' Services Centre (APROSC)

MIT Series No. 5

1991

International Centre for Integrated Mountain Development

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GPO Box 1440, Ramshah Path
Kathmandu, Nepal

September, 1991

International Centre for Integrated Mountain Development (ICIMOD)

Kathmandu, Nepal

PREFACE

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

This study is one among these six case studies and was conducted in Dhading District, located in the central hills of Nepal. It addresses issues in energy management and planning in Dhading District and assesses existing as well as potential sources of energy.

CONTENTS

List of Abbreviations

Ilaka	=	Sub-district
Village *panchayat*	=	Lowest political unit
Khet	=	Irrigated lowland
Pakho	=	Rainfed upland
MPPU	=	Multi-purpose power unit
LU	=	Livestock unit
Gobar gas	=	Bio-gas
Ghatta	=	Local water mill

Energy Content and Conversion Factors

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

Heat Content of Different Fuel Types

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

Background

An assured supply of energy is essential not only for sustaining day to day life but also for successfully carrying out development projects. However, the mountain region of Nepal is particularly disadvantaged on the energy front. Lack of transport facilities in this region limits the scope for the use of several alternative energy sources. This region is also economically poor, hence the people cannot afford the use of commercial energy sources. Due to these problems, one or two traditional energy sources face tremendous pressure, resulting in environmental problems.

In view of this, it has become a matter of great urgency to plan and manage existing and potential energy resources in the region. In the process of developing such a management plan, three interrelated issues are important: a) availability of alternative energy sources, b) creation of appropriate institutions and c) an information base for planning.

At present, fuelwood continues to be the main source of energy in the mountain regions of developing countries. In view of the rapid depletion of available forests, the continued reliance on the forest as the main source of fuel can be disastrous. Alternative sources must be sought and used. The Hindu Kush-Himalayas is a vast reservoir of hydropower. Only a fraction of the total potential power is tapped at present. Hydropower projects are capital intensive. Hence, rural electrification is an expensive proposal for mountain villages. Heavy reliance on fossil fuels, such as kerosene and diesel, is also not a viable alternative because of problems such as rise in oil prices, high transport costs, etc. However, there is good scope for developing small and micro-hydel projects. These projects have a low gestation period, require relatively low investment, and have potential for local use. Potential use of other sources of energy, such as biogas, geothermal, wind, and solar power, as alternatives is limited in the Hindu Kush-Himalayas. Their use in the future will depend on technological breakthroughs towards cost reduction.

There is a serious lack in the knowledge base in terms of the current status of energy use and management at the local level. Villagers use a number of energy sources simultaneously. There is an element of complementarity and substitutability of energy sources which depends on a large number of economic and non-economic factors. This aspect can be addressed only through studies of all available energy sources in totality.

This study, therefore, addresses issues in energy management and planning in a mountain district of Nepal. Assessment of existing as well as potential sources of energy is made. Based on the comprehensive information thus generated, the discussion is oriented towards local level planning and management. Hopefully, the ultimate use of this work will be to develop energy management and planning guidelines. These guidelines could then be used for training district level officers working in the field of energy-related issues.

Objectives of the Study

The broad objective of the study is to assess the energy situation of Dhading District, located in the central hills of Nepal, in order to provide basic information for the planning and management of energy issues. The study has the following specific objectives.

1. To provide an overview of the energy development policies of the Government.

2. To assess the present energy situation in Dhading District of Nepal.

3. To document the present institutional arrangements for the development of the energy sector.

4. To analyse the possible sources of alternative energy and the prospects of related technology.

Methodology

This study is mainly based on various secondary sources of information. Apart from this, information gathered during an observation tour of the district has also been used extensively. Such information also includes subjective judgement of the district level employees and entrepreneurs involved in this area. Information has also been drawn from the publications of the International Centre for Integrated Mountain Development (ICIMOD), Agricultural Projects' Services Centre (APROSC), Dhading Development Office, and the five year plan documents of His Majesty's Government of Nepal (HMG/N).

Energy Development in Nepal

National Development Planning and Energy Development

Nepal has followed planned economic development since 1956. However, specific policies in energy development were formulated only from the Fifth Five Year Plan. The main thrust of the energy policy is to reduce the dependance on imported oil through the development of water resources and traditional fuel sources. Likewise, research and development of alternative energy sources, such as biogas and solar and wind power, and the development of other natural energy sources are the main areas of focus. Investment in the establishment of small hydropower plants in the private sector through a participatory approach and the mobilisation of local resources are the key features of the energy development policies in Nepal. Other energy policies include the integrated development of irrigation and energy projects, the implementation of small hydropower projects in areas not connected by the electricity grid, and the expansion of rural electrification to support cottage and small scale industries.

Currently, the per capita energy consumption in Nepal is about 224 kg of coal equivalent per annum, 94 per cent of which is met from traditional energy sources and 6 per cent from commercial energy sources. The sources of energy are mainly fuelwood and petroleum products. To conserve and develop forest resources, afforestation programmes are being implemented through community forestry projects and other programmes and improved cooking-stoves are being distributed to economise on the use of fuelwood. Under the Small Farmers' Development Programme, individually-owned and community-owned biogas plants have been constructed and multipurpose water mills and crossflow turbines have also been installed in potential areas. Thus, the Seventh Plan recognises the need for alternative energy sources.

In the Seventh Five Year Plan various programmes for alternative energy development have been identified. Targets and outlays in these programmes, as specified in the plan, are shown in Table 1.

Table 1: Targets and Outlays for Alternative Energy Development in the Seventh Plan Period

Area	Target	Outlay (Million Rs)
Forest and Soil Conservation (afforestation, ha)	1,75,000	1290
Power Development (kW)	1,06,629	4812.7
Alternative Energy Development:	50	
Biogas (No)	4000	
Improved cooking-stoves (No)	1,60,000	
Multipurpose water mills (No)	640	
Crossflow turbines (No)	320	
Water and Power (energy) Development	Comprehensive survey and exploration	5.6
Environment	Environmental impact studies	10.8

Source: The Seventh Plan, 1985-1990, HMG/N, National Planning Commission, Singha Durbar, 1985.

Profile of Dhading District

Dhading is one of the eight districts of the Bagmati Zone that falls in the Central Development Region of Nepal. It lies between 27° 40' to 28° 14' latitude and 84° to 85° 1' longitude. The northern border of the district forms the international boundary with the Tibetan Autonomous Region of China. The district is divided into 9 sub-districts (*Ilakas*) and 50 Village *Panchayats* covering a geographical area of 192,487 hectares, which is 1.3 per cent of the total area of the country.

Its topography is diverse, the elevation ranging from 488m to 7,409m above sea level. The middle hills, mountains, and the high Himalayan region occupy 72, 20, and 8 per cent respectively of the total land area.

The district has alpine, tropical, and temperate climates. The district receives, on an average, an annual precipitation of 2,210 mm, 80 per cent of which is concentrated in the monsoon season, i.e, mid-June to September. The mean temperature varies from 21°C in summer to 6°C in winter. The district enjoys about 300 days of sunshine in a year.

Land Use Pattern

Out of the total geographical area of the district (192,487 ha), about 23 per cent is under cultivation, 48 per cent under forest, 8 per cent under grassland, 15 per cent under non-cultivated or barren land, and the rest consists of rocks, water bodies, and snow-covered land. Table 2 shows the basic land use pattern for different ecological zones of Dhading District.

Table 2: Basic Land Use Patterns in Dhading District

(Area in ha)

	Agriculture		Grazing	Forest	Others	Total
	Cultivated	Non-cultivated*				
High Himalayas	-	-	4,892	2,940	7,840	15,672
High Mountains	3,438	1,534	5,807	26,209	1,053	38,041
Middle Mountains (Hills)	40,945	27,428	5,242	63,707	1,452	138,774
Total	44,383	28,962	15,941	92,856	10,345	192,487

Source: Land Use Plan Study 1985, APROSC.

* Includes area covered by border, terraces, channels, etc that are within the agricultural land area but which are not cultivated.

Population

Dhading had a population of 243,042 in 1981 (Population Census 1981), composed mainly of Tibeto-Burmans and Indo-Aryan groups. The former are setteled in higher alevations (the High Mountains and the Mahabharat Range) and account for 55 per cent of the total population. The average family size in Dhading is 55.5 and the sex ratio marginally favours males. About 15 per cent of the people are literate. The literacy rate is 27.2 per cent for males and 6.8 for females. The population growth rate is 2.25 per cent per annum. This rate is lower than the national average. Population pressure on land is very high with a density of 17 per hectare of cultivated land.

Agriculture

Subsistence agriculture is the main occupation of the majority of the population in the district. The farming system is characterised by close integration between crop and livestock sub-sectors.

Crops. Different cereal and cash crops are grown in the district. The dominant cereal crops are paddy, wheat, millet, and barley. Paddy, maize, wheat, and millet occupied more than 90 per cent of the cropped area in 1983/84. The typical cropping patterns, particularly in the low lands (*khet*) where irrigation facilities are available, are early paddy-late paddy-wheat and maize-paddy-wheat. At the other extreme are the uplands (*Pakho*), with no irrigation facilities. On such land, often, not more than one crop is grown in a single year.

Vegetable and fruit crops are generally grown in kitchen gardens by almost every household. Usually the produce is for home consumption. The production of cash crops such as sugarcane and oilseeds is limited and is concentrated in some pocket areas of the district.

Livestock. Livestock plays an important role in the local economy as a source of draft power, food, skin, manure, and fuel. According to the latest estimate (Agricultural Statistics of Nepal 1983), the livestock population in Dhading District is as stated below.

Type	Number
1. Oxen	49,880
2. Milch Cows	10,390
3. Milch Buffalo	15,560
4. Sheep	1,398
5. Goats	127,275
6. Pigs	5,920
7. Poultry (Fowl and Ducks)	184,091

Most animals, especially cattle and sheep, belong to the indigenous breeds. The annual production of milk is estimated at 6,025 thousand litres from cows and 16,699 litres from buffalo. The average milk yields of nearly 580 litres per lactation for cows and 1,073 litres per lactation for buffalo are lower than those of other districts of Nepal.

Industries

There are a number of cottage industries in the district. The important ones are cloth weaving, knitting, basket-making, pottery, mat-making, vegetable-drying, rope-making, hosiery, and ghee-making. Except for pottery and ghee-making all other industries are operated on a limited scale, mostly to meet the demand for household consumption. Candles, tools, utensils, furniture making, rice and oil mills, water mills, brick-making, and pharmaceuticals are some of the other industries of Dhading District. These industries are owned and operated by entrepreneurs who may be pursuing farming as a subsidiary activity. The energy sources used by these industries include fuelwood and electricity.

Infrastructure

Parts of the two national highways pass through the southern flank of Dhading District. About 80 km of the Prithivi Highway linking Kathmandu and Pokhara pass through 17 *Panchayats* of the district and about 25km of the Kathmandu-Birgunj all weather road traverse the district. A fair-weather 20km long road connects the district headquarters (Dhading *Besi*) from Malekhu Town to the Kathmandu-Pokhara road. However, the northern part of the district does not have any access to a road. Eight market centres have developed along the Prithivi Highway. The district has 199 schools including 153 primary, 32 lower secondary, and 14 secondary schools.

Energy Resources in Dhading District

Hydropower

Water Sources and Their Nature. About 3.5 per cent of the total geographical area of the district in the north remains under snow all year round. The snow peaks and mountains feed many rivers and rivulets originating from the north and north-west parts of the district.

Of the three major rivers of the district, only the Buri Gandaki and Trishuli have the potential for hydropower generation on a large scale. Their use for irrigation is limited because of the need for high investment. Ankhu Khola is more suited for mini-and micro-hydel plants and for low-cost irrigation schemes.

The Buri Gandaki is the largest river in the district in terms of its annual discharge. The river can be taken as the district boundary with Gorkha in the west. The hydroelectricity potential of the Buri Gandaki is estimated at 220 MW and is not yet exploited.

Perennial tributaries of these three major rivers provide opportunities to implement low-cost schemes for irrigation, mechanical power, and electricity production as they are scattered enough to cover most parts of the district. Numerous rivulets and streams exist in the district that can be harnessed to generate hydropower for various rural applications.

More than 70 per cent of the annual rainfall in the district occurs during the monsoon, i.e., mid-June to September. It is in this period that most of the snow-fed rivers and rivulets are flooded and silted, causing soil erosion. The average monthly rainfall ranges from 8mm in December to a maximum of 344mm during the month of July.

Problems and Prospects of Hydropower. The present pattern of hydropower generation is predominantly in the form of mechanical shaft power. It is produced either from traditional water mills or locally manufactured turbine installations. The local water mills (*Ghattas*) generally produce technical power up to 1kW and are used for agro-processing, principally for grinding. Hundreds of such traditional *ghattas* are operating in the district. These *ghattas* are mostly coupled with small "run-off the river" type gravity irrigation systems. Technological improvements of many of these traditional water mills have been carried out through such measures as the installation of a number of improved water mills, Multipurpose Power Units (MPPUs), and crossflow turbines. These improved models are used for running agro-processing units such as hullers, oil expellers, and grinders. There are 23 crossflow turbines and 13 MPPUs in operation in the district. The MPPUs are capable of generating mechanical energy ranging from 3 kW to 5 kW, while the power from turbines ranges generally from 5 kW to 25 kW. Initial investments required for setting up a micro-hydro turbine plant range from Rs 5,000 to Rs 15,000 per kW of power generation. For generation of electricity from the turbine mills, the cost per kW is in the range of Rs 10,000 to 15,000, depending upon the site condition. The use of electricity generated from the turbine mills is limited to lighting rural households and shops. A list of privately-owned micro-hydro projects and of their applications are given in Tables 3 and 4 respectively.

Table 3: Type and Number of Water Mills Installed in the Dhading District

Type of Water Mill		Year of Installation	Location	Financing Agency	Manufacturer or Installer	Remarks
MPPU	Crossflow Type					
-	1	1978/79	Gajuri	NEC	BYS	Community
-	1	1979/80	Malekhu	ADB/N	BYS	Generating Electricity
-	1	1980/81	Dhading *Besi*	NEC	BYS	
-	1	1981/82	Khaste *Besi*	ADB/N	BYS	
-	1	"	Dhading	ADB/N	BYS	
-	1	"	Maidi	ADB/N	BYS	
			Dhading			
1	-	1982/83	Kali Ban	ADB/N	National	
		"			Structures	
1	-	"	Benighat	ADB/N	Engineering	
1	-	"	Kewalpur	ADB/N	Engineering Structure	
1	-	"	Siuchatar	ADB/N	"	
1	-	"	Mohantar	ADB/N	"	Generating Electricity
-	1	"	Khani *Khola*	Private	"	"
1	-	"	Thakre	ADB/N	"	
1	-	"	Naubise	Private-KMI	"	
-	1	"	Dharko	German N. Help Asso.		
-	1	"	Chainpur	ADB/N	BYS	
-	1	1983/84	Chainpur	ADB/N	BYS	
-	1	"	Chainpur	ADB/N	BYS	
1	-	"	Mahadev	German/N	KMI	Generating Electricity
			Besi	Help Asso.		
-	1	1984/85	Tasarpu	ADB/N	NYS	
-	1	"	Siureni	ADB/N	BYS	
			Dhading			
-	1	"	Naubise	ADB/N	BYS	Generating Electricity
-	1	"	Belkhu	ADB/N	BYS	
-	1	"	Charaudi	ADB/N	NYS	
-	1	1985/86	Kewalpur	ADB/N	NYS	
-	1	"	Bairani	ADB/N	BYS	
1	-	"	Fogarpur	ADB/N	NSE	
			Thakre			
1	-	"	Bairani 4	ADB/N	NSE	
-	1	"	Kumburpurs	ADB/N	TEI	
			Malda			
-	1	"	Jiwanpur	ADB/N	NSE	
-	1	"	Benighat	ADB/N	Km 9	Generating Electricity
1	-	"	Naubise 9	ADB/N	Km 9	
1	-	"	Bhumisthan	ADB/N	Km 9	
-	1	"	Jardu *Khola*	Private	NYS	
1	-	"	Maltar	ADB/N	Km 9	
-	1	1986/87	Pitha-6	ADB/N	NYS	Under Construction
Total 13	23					

Source: Local Development Office, Dhading *Besi*.

Note: The split year generally starts on the 13th of April and ends on the 12th of April of the subsequent year.

Table 4: Potential Application of Micro-Hydropower in Dhading District

	Technologies	Power Range	Application
1.	Traditional *Ghatta*	Up to 1 kW	Grinding of maize and millets.
2.	Improved *Ghatta*	1 - 3 kW	Small rice milling, grinding, and rural lighting.
3.	Multipurpose Power Unit	3 - 8 kW	Agro-processing, rural electrification and water lifting, saw milling.
4.	Crossflow Turbine	8 - 25 kW	As in 3 and operation of heat generator.
5.	Turbine Pump	5 - 30 kW	Generation of mechanical power, water lifting, and rural lighting.
6.	Pelton Turbine		Low flow, high speed power generation, mainly for electric power.
7.	Hydraulic Ram Pump		Small-scale irrigation and drinking water supply (mechanical energy).
8.	Plata Pump		Small-scale irrigation and drinking water supply.
9.	Water Seal (over and under short)		Mechanical-power generation for agro- processing activities.

Source: G.R. Shrestha 1985.

Forest

Fuelwood. Forest biomass is the predominant source of household energy in the district. The average per capita consumption of firewood in the district is estimated at 1.08 m^3, i.e., about 642 kg of wood assuming a density of 595 kg/m^3. The range of firewood consumption varies from 0.91m^3 in areas near roads and away from forests to 1.39 m^3 in areas away from roads and near forests (Agrawal et al. 1986). The microclimate of the area, family size, distance from commercial centres and cultural practices were found to be the major factors affecting firewood consumption.

Apart from areas near the highways and near the district headquarters, firewood is still available as a free commodity. The firewood price decreases as one moves away from the highway towards the north along the Malekhu-Dhading *Besi* road and increases again near the Dhading *Besi* beyond which firewood becomes a free commodity. Along the highway and along the Dhading *Besi* road, many of the rural poor sell firewood to supplement their farm incomes.

It is only along the highways that people use agricultural and animal waste together with firewood to meet their energy needs. In other parts of the district, agricultural waste does not play a major role in meeting the fuel requirements for cooking and heating.

Fodder and Pasture. Fodder and pasture development programmes in the district have not been able to meet the ever increasing demand. As a consequence, the forest is lopped and grazed beyond its regenerative capacity. Such pressure is concentrated mainly in the forests near highways and the forests of the five remote *panchayats* in the north. However, similar pressures, though to a lesser extent, are felt in the central parts of the district as well.

An excessively high number of livestock units (LUs) per household, leading to a decrease in the regenerative capacity of natural forests and pastureland, together with non-adoption of stall-feeding practices are the main factors for negative pressure on the development of forests in the district. Most damaging of all has been the practice of lighting fires in government forests, even though it is illegal, on the part of the people. People perceive two-fold benefits by doing so. Firstly, a forest with a low crown density is less guarded (by government personnel) and generally left open for grazing. Secondly, such a practice causes the sprouting of tender shoots after the monsoon rain and these provide good quality fodder. This also enhances the opportunities for people to cultivate the denuded areas.

Apart from in the High Himalayan Region, farmers have the tradition of growing fodder trees along the boundaries of terraces. However, most of the fodder needs are met by nearby forests.

Timber. The mining of forests at an unprecedented rate for timber started in the southern part of the district after the opening of the Kathmandu-Pokhara Highway. The road made it easy to transport timber to other parts of the country. In addition, a lot of timber was consumed for the establishment of new settlements and the expansion of old ones along the highway. Consequently, very little timber forest remains along and near the highway. The opening of the Malekhu-Dhading *Besi* road started a similar trend.

Dhading *Besi*, the headquarters of the district, is a relatively new settlement which is expanding rapidly. In this process, a huge amount of timber from the nearby forest is used, as the local houses are constructed by using mainly timber.

Yet another reason for the increased use of timber is the inefficient technology of timber utilisation. More than the necessary quantity of wood is used for a particular purpose and a lot of wood is also wasted between the stages of timber harvesting and timber utilisation.

Other uses of the forests include charcoal-making and the production of traditional wooden utensils. Although only a few households are involved in these activities, the impact on the forests is increasing in areas that have access to markets or roads.

Forest Area and Type

The vast topographical and ecological variations within Dhading have given rise to diverse types of forest vegetation in the district. It is estimated that 48.2 per cent (91,323 ha) of the total geographical area of the district is under forest (CFDP/1984). This level of forest coverage is high compared to the other adjoining districts and to the nation as a whole.

Mid Hills and Valleys. This region, inhabited by a majority of the district population, represents more than 60 per cent of the total geographical area of the district. The highest percentage (69.8%) of the total forest area of the district falls into this region. Ironically, the forest situation in this region is the worst among all other regions as the 68.4 per cent of the total forest area is still too immature to meet the increasing forest demands and 30 per cent of the cover is already under shrubs. Also, only 31 per cent of the total forest area has a crown density of 10 to 40 per cent. This situation, when viewed against the fact that the rate of increase in demand for forest products is highest in this region, makes the picture more gloomy. It is in this region that the Kathmandu-Pokhara Highway passes through rapidly growing trade centres and dense villages.

The Mountain Region. The situation of forests in the mountain region is comparatively better. Twenty-eight per cent of the total forest area of the district falls into this region. Of the total forest area, 45 per cent falls into the matured class and only 18 per cent is under shrubs. Also, 45 per cent of the forest has a better crown density of 40 to 70 per cent, and only 36 per cent has a low crown density of 10 to 40 per cent. With its low population density and a lower rate of increase in the demand for forest products, it seems that the growing demand can be met by better management of the existing forests.

The High Himalayan Region. In the High Himalayan Region, where the population density is very low and the main economic activity is goat and sheep rearing, most of the forest area (56.3%) is under shrubs and 39.3 per cent is of the matured class. Almost all matured forest has a crown density of 40 to 70 per cent. This situation is indicative of the fact that the natural rate of forest regeneration is very low and no effort has been made to rehabilitate the forest once it has degenerated.

Biogas

There are altogether 10 biogas plants in the district out of which 9 are fixed-dome types operating at the household level to meet the family's cooking and lighting needs. A commercial dairy plant near the highway has recently installed a floating-drum type of biogas plant to meet its energy requirements for chilling milk and milk products.

Potential for Biogas Development. A high livestock population in the district offers good prospects for the promotion of biogas technology in Dhading. The animal dung and human excreta of the district could produce 49 to 59 million litres of biogas per day. At 40 per cent, the realistic potential is 19 to 23 million litres per day. Based on these statistics there is scope for installing about 11,000 units of biogas plants in the district.

Agricultural Residue

A large part of the energy consumed in the district comes from two main traditional energy sources, viz; fuelwood (79%) and agricultural residue (18%). Agricultural residue is a traditional fuel source widely used in the district for cooking and heating. It includes hay, husks, crop residue, grass, leaves, sticks, and barks.

As the second major source of traditional fuel, agricultural residue has a great potential for meeting energy requirements. Hence, emphasis needs to be given to the collection of information and to the quality, quantity, and production patterns of residue so as to ensure appropriate planning and management systems for the use of these energy resources.

Owing to the economic, cultural, and geographic variations that exist in the district, it becomes difficult to quantify the use of agricultural residue for various purposes. However, considering the existing trend, it can be said that the increasing population growth may give rise to the increased use of agricultural residue to meet the domestic energy requirements in the rural areas.

The major crops grown in the district, in order of importance, are maize, paddy, wheat, sugarcane, potato, millet, barley, and oilseed. The availability of the residue of these crops is presented in Table 5.

It is estimated that about 18 per cent of the total household energy for cooking and heating comes from agricultural residue (78 kg per person per year). The residue is used as fuel from mid-March to mid-October.

Agricultural residue is not usually marketed. Households along the highways and in Dhading *Besi* use residue for cooking, mostly together with firewood. Agricultural residue is mostly used for purposes other than cooking and heating. A major part of the agricultural residue is used for fodder and compost-making. The per capita consumption of agricultural residue as fodder is estimated to be 344 kg per annum.

Solar Energy

In Nepal, the daily solar radiation on a sunny day is estimated to be between 4.5 to 6 kWh per m^2. Solar radiation data are not available for Dhading District. However, according to the latest agro-climatological record of Gorkha District (the station nearest to Dhading District), the average maximum and minimum sunshine hours per day in the area are 4.6 and 8.5 respectively. The sun shines for a longer duration (6.9 to 8.5 hour/day) from October to May and for a shorter duration (4.6 to 5 hour/day) from June to September (see Table 6).

Solar energy is used in Nepal mainly for heating water for domestic use as well as for commercial and industrial purposes. However, in the rural areas of Dhading, solar water heaters are rarely used. Solar energy is primarily used for drying agricultural and animal products. Solar dries are also used in small industries such as soap-making. In Dhading, solar photovoltaic cells are used at two locations to run communication devices. Although very expensive, these units are functioning well.

Wind Energy

The use of wind energy in Nepal is negligible. Data required to assess the potential for wind energy are not available for Dhading District. However, the data available for Gorkha District (next closest agro-climatological station) are presented in Table 7. The average data of Gorkha District over a period of four years indicate that the wind speed is at a maximum (4 to 4.7 km/hour) between March and May and at a minimum (2.3 to 2.7 km/hour) between June to November. Site-specific data on wind speed, etc will be needed to assess the feasibility of and potential for wind energy development in the district.

Table 5: Dhading District Production of Agricultural Crops and their By-products (1985/86)

Crop			Main Product (MT)	% of By-product	Total Volume of By-product MT	k-cal/kg	By-product (MT) Per capita	By-product (MT) Household
1. Maize								
a)	Grain		22500					
b)	By-product:							
	i)	Cobs		30%	6750	17640	0.03	0.16
	ii)	Stalks		200%	45000	-	0.19	1.04
2. Paddy								
a)	Grain		22750					
b)	By-product:							
	i)	Husk		25%	5688	3340	0.02	0.13
	ii)	Bran		5%	1137.50	-	0.005	-
	iii)	Straw		300%	68250	3000	0.29	1.57
3. Sugarcane								
a)	Main Product		14220					
b)	By-product:							
	i)	Baggage		30%	4266	3860	0.02	0.10
	ii)	Molases		40%	560	-	0.002	0.00
4. Wheat								
a)	Grain		5500					
b)	By-product (Straw)			17%	9625	-	0.04	0.22
5. Potato								
a)	Main Product		7420	70%				
b)	By-product (dried plant)			70%	5194	-	0.022	0.12
6. Millet								
a)	Grain		3300					
b)	By-product (Straw)			180%	5940	-	0.03	0.14
7. Barley								
a)	Grain		290					
b)	By-product			175%	508	-	0.002	0.01
8. Oilseed								
a)	Main Product		180					
b)	By-product			300%*	540	-	0.002	0.012
Total					153467.5			

Source: Compiled from *Feasibility Study of Agricultural Residues' Utilisation in Nepal*. ESCAP,1986.
* Researchers' own estimates.

Table 6: Sunshine Hours/Day in Gorkha District (1983-1986)

(Sunshine hours/day)

Months	1983	1984	1985	1986	Average (1983-86)
January	8.7	8.5	-	9.1	8.1
February	-	8.6	8.4	8.2	8.4
March	8.2	8.5	8.5	8.6	8.5
April	6.7	-	9.2	7.4	7.8
May	7.3	-	7.8	7.9	7.7
June	8.3	-	-	5.7	7.0
July	5.8	-	-	3.4	4.6
August	6.3	-	-	5.5	5.9
September	5.5	-	5.7	4.8	5.3
October	6.4	-	5.8	8.6	6.0
November	8.0	-	8.8	7.8	8.4
December	8.0	-	5.9	7.0	7.0

Source: Department of Hydrology and Meteorology, HMG/N, 1987.

Table 7: Average Daily Wind Speed in Gorkha District (1983-1986)

(Wind Speed km/hour)

Months	1983	1984	1985	1986	4 Years Average
January	-	3.1	3.1	3.5	3.2
February	-	3.7	3.5	4.0	3.7
March	6.1	4.2	3.9	4.6	4.7
April	4.2	5.4	3.7	4.9	4.5
May	3.5	3.1	3.6	5.7	4.0
June	3.0	2.0	2.0	2.9	2.5
July	2.5	2.4	1.7	2.2	2.2
August	2.6	2.8	2.5	2.7	2.6
September	2.9	2.8	2.6	2.7	2.7
October	2.9	4.2	2.9	3.1	3.3
November	3.0	1.7	1.1	3.3	2.3
December	2.9	2.1	3.0	3.5	2.9

Source: Department of Irrigation, Hydrology and Meteorology, HMG/N, 1987.

Management of Energy in Dhading District

Hydropower

A number of private and governmental organisations are actively involved in harnessing water resources in Dhading District. A brief account of their involvement is presented below.

Local Groups/Private Entrepreneurs. There are numerous non-formal organisations working in different parts of the district, mainly to facilitate the use of water from nearby rivers and rivulets for irrigation and drinking water. Their activities include the construction of surface diversion schemes for irrigation. Generally such canals also serve water mills. In such cases the owners of water mills take the responsibility for repairing canals and maintaining water supplies for paddy transplantation. Most turbine mills, some with electricity generation systems, are owned and managed by private individuals or groups of entrepreneurs. Most MPPUs and improved *Ghattas* are owned by small farmer groups.

Government Organisations. Nepal Electricity Authority (NEA) is involved in the development of hydropower. Similarly, the Small Hydel Power Development Board (SHDB) is concentrating on the development of mini-hydel plants. Apart from the development of irrigation facilities, the Department of Irrigation is also cooperating with other agencies involved in the development of integrated projects, including those concerned with mills and irrigation.

Non-government Organisations. The Agricultural Development Bank of Nepal (ADB/N), the District Development Committee, and Action Programme are some of the NGOs involved in energy development in Dhading District. ADB/N is involved in disseminating new technology through loan financing for the development of small hydel projects. The District Development Committee and the Dhading District Development Project (DDDP) are also actively participating in the improvement of traditional *Ghattas*.

Problems and Prospects in the Development of Hydropower

The investment cost for the establishment of hydropower is lower for micro-hydro units than for small and large hydro units. The private sector in the country has the technology and skills for the establishment and operation of micro-hydro plants. For larger hydropower projects, the country has to depend on outside agencies. Hence, micro-hydels are appropriate for rural areas in Dhading District. The potentials for diversifying the use of turbines for intensive use, by introducing low power consuming heaters for cooking and for cottage industries, exist.

Given below are some issues involved in the development of micro-hydel technology in the district.

1. Seasonal Fluctuation in River Discharge. The ratio of high flow to low flow is nearly 50 in the case of snow-fed rivers in the district. This creates problems in the context of constructing an optimum design to harness the rivers for power generation. An inventory of the discharge variation of the potential rivers and streams should be prepared. The possible sites of all ranges of hydropower generation should also be identified.

2. Low Utilisation of Load Factor. The load factors for big and small hydropower plants range from 35 per cent and 30 per cent respectively. In micro-hydel plants, the agro-processing units

are operated during the day time and electricity is generated during the evening. This means that the load factor is well above 50 per cent. To increase the load factor, appropriate incentives and measures should be taken to use hydropower for various applications other than agro-processing and electricity generation.

3. Water Rights. There are cases of conflict in the use of water resources for irrigation, water mill operation, and electricity generation. Therefore, there is a need to define water rights as clearly as possible and measures should be taken to maintain operational water rights.

4. Policy and Incentives. There are good prospects for rural electrification through involvement of the private sector, in both the development and management stages. Until now, the participation of the private sector has not been widely successful due to the failure to sufficiently motivate private entrepreneurs, although plan and policy documents have emphasised people's participation in energy development and management. Even the stated incentive measures, such as 50 per cent subsidy for rural electrification, are not being implemented.

5. Research and Development. Private manufacturers are involved in various research programmes to improve the design of turbines by making them cost effective and efficient. The lack of adequate facilities, manpower, and finance are some of the major constraints faced by manufacturers in these research programmes.

6. Institutional Arrangement. The Agricultural Development Bank has been a catalyst in promoting and disseminating water turbines/MPPU for micro-hydropower generation through its district level branch offices and the SFDP network. Due to the very nature of its functions, the Bank has found it difficult ro expand rapidly in this field. Hence, other agencies also need to be involved in the planning and implementation of hydro schemes.

Forests

Almost all natural forests with good crown density in the district are under government ownership. Private forests, on the other hand, include *Panchayat* forests, *Panchayat* protected forests, private forests and lease-hold forests.

The District Forest Controller's Office (DFCO) is the main government body working in forest development in the district. The entire government forest area of the district is divided into three *Ilaka* or ranges. Each of the three range offices supervises the forest development activities of the four sub-areas under it.

Major activities undertaken by the DFCO and its branches include the planning and implementation of forest-related activities and the promotion of improved stoves. But in *panchayats* not covered by the Community Forest Development Programme, its activities are limited to the protection of government forest areas and the regulation of use.

Carrying out forest promotion and conservation activities in difficult terrain with a limited number of ill-equipped personnel is a tremendous responsibility for the DFCO. This, coupled with data deficiency, has caused the DFCO to operate far below the desired level of efficiency in implementing its programme.

In order to aid the activities of DFCO in promoting and conserving forests, several community-based programmes are being implemented, for example, the Community Forestry Development Programme (CFDP), the Small Farmers' Development Project (SFDP), the Dhading Integrated Rural Development Project (DIRDP), and the Participatory Action Research Programme (PARP). In addition, the local leaders themselves have initiated an innovative reforestation programme in their villages and this has gained a fair amount of popularity.

Issues in the Organisation and Management of Forests

1. Ineffective Institutional Support. The existing institutions involved in forestry development have taken a piece-meal approach because of their own limitations which include a rigid institutional framework for operations, and limited budgets, manpower, and data. Delays in releasing budgets from the Centre, the frequent transfer of technicians, the lack of follow-up programmes, and inadequate logistics' support are some of the other reasons which have led to ineffective programme implementation.

2. Inadequate Information for the Planning Process. Various institutions in the district, that are involved in forest development activities, do not have enough resources to collect or gain access to forest-related information. As a result, a comprehensive plan for long-term forestry development could never be prepared. In addition, frequently changing government policies have hindered programme implementation.

3. Lack of Coordination. There are several government and non-government organisations working in the district. In the absence of clearly defined aims, objectives, and standards for forestry development, each organisation is contributing in its own way to the amelioration of the problems of deforestation in general. Consequently, there is a lack of communication and coordination among the institutions involved in forestry activities.

Biogas

The *Gobar Gas Tatha Yantra Bikas Company* (GCTYBC) and the Agricultural Development Bank are the public sector undertakings involved in the promotion of biogas in the district. In addition, there are several private and non-government institutions that are assisting in the promotion of biogas technology. The Department of Agriculture is also involved in propagating this technology.

Issues in the Development of Biogas Plants

1. Initial Cost of Establishment. The installation of a small-sized dome type biogas plant (6 cm) costs about Rs 10,000. Given the low income of the people, this is beyond the reach of many families in the district. Although ADB/N provides loans for installation, many farmers have not been able to meet the financial commitments. Ironically, the families living near the forests or pasture lands keep greater numbers of livestock but have a comparatively lower income than the families along the highway with fewer livestock. Such a distribution of livestock is a constraint to the promotion of biogas technology.

2. Temperature. Biogas technology is ideally suited for tropical and subtropical regions where the temperature for most part of the year remains between 30° to 40° C. In most parts of Dhading, many installations cease to produce gas during the winter months. Hence, it is only in a few of the valley pockets of Dhading where biogas plants can meet the energy requirements of a farm family throughout the year.

3. Technical Knowhow. In spite of more than a decade of development in biogas technology, the technical knowhow required to reduce investment cost is still in its infancy. This has been a major handicap in the promotion of this technology.

Agricultural Residue

In most parts of the district, agricultural residue is valued more for its non-energy uses such as manure, than its use as a substitute for fuelwood. Only families severely affected by the declining availability of firewood are using agricultural residue to meet their energy needs for cooking and heating. Therefore, these wastes are burned in traditional stoves in a very inefficient manner. This situation calls for the promotion of heating and cooking devices that are specially designed for the use of agricultural waste.

Programmes to organise farmers and to assist them in collecting, storing, processing, and selling agricultural residue should be implemented along with the promotion of suitable devices.

Solar and Wind Energy

The issues outlined below are considered important in the effective promotion and management of solar and wind energy.

1. Research to design suitable solar and wind devices should be carried out to meet the needs of small farmers and rural communities. The devices must be manufactured with indigenously available materials.

2. Efforts should be focussed upon reducing the cost of devices in order to make them acceptable by a large number of farmer communities.

3. There should be some focus on the application of the technology in economically beneficial activities such as agro-processing.

Summary and Conclusions

Forest biomass is the predominant source of household energy in the Dhading District of Nepal. The average per capita consumption of firewood in the district is estimated to be 1.08 m^3. Microclimate, family size, distance from a commercial centre, and cultural practices are the major factors affecting firewood consumption. A dense population of livestock has led to the exploitation of forests and grazing land beyond their regenerative capacity.

The generation of hydropower in the district is mainly through the installation of traditional water mills (*ghattas*) and locally manufactured turbines. Multipurpose power units and crossflow turbines are being popularised in the district to run agro-processing units such as hullers, oil expellers, and grinders. The potentials for diversifying the use of turbines, through the introduction of low power-consuming heaters for cooking and for cottage industries, exist. There are good prospects for rapid rural electrification in the district through the involvement of the private sector, in both the planning and the implementation stages. The participation of the private sector could not be enlisted in the past due to the lack of incentives.

Agricultural residue, a traditional source of energy widely used for cooking and heating, contributes about 18 per cent of the total energy requirements. However, agricultural residue is burned in traditional stoves in an inefficient manner. There is, thus, a need for improving heating and cooking devices.

The district also has a good potential for using biogas energy because of the dense population of livestock and the favourable climates in the tropical and subtropical areas. More research and development is needed in the field of solar and wind energy.

ICIMOD is the first international centre in the field of mountain development. Founded out of widespread recognition of environmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

The Centre was established in 1983, and commenced professional activities in 1984. Though international in its concerns, ICIMOD focuses on the specific, complex, and practical problems of the Hindu Kush-Himalayan region which covers all or part of eight Sovereign States.

ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

Mountain Infrastructure and Technology constitutes one of the four thematic research and development programmes at ICIMOD. The programme aims at achieving environmentally sound infrastructural development practices as well as the use of innovative technologies for alleviating drudgery and improving the living conditions of mountain inhabitants. This is carried out through state-of-the-art reviews, field studies, pilot training, and applied research. Currently, the main focus of the programme is on mountain risk engineering with special reference to hill road construction, decentralised district energy planning and management, as well as appropriate mountain technologies.

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