INTRODUCTION

Biomass fuels are predominant forms of energy sources in the total national energy consumption of Nepal. In 1988/89, 95.1 per cent of the total energy needs were met by biomass fuels (WECS 1989), and, of these, fuelwood, agricultural residue, and animal dung accounted for 75.9, 10.9, and 8.3 per cent of the total biomass fuels respectively. A major proportion of this biomass fuel is consumed by the domestic sector. Out of the total energy consumed, 95 per cent is used for cooking, followed by space-heating, and agro-processing.

Fuelwood

In 1985/86, it was estimated that the supply of accessible fuelwood was 6.27 million tons out of which 5.14 million tons came from the forests and 1.13 million tons from farmlands (WECS 1987b). In the same year, it was estimated that 10.8 million tons of fuelwood were consumed. The excessive and unregulated use of fuelwood for household cooking, space-heating, and wood-based rural industries accelerated destruction of the forests. From the above figure, 181 million GJ of gross energy was obtained which, at 10 per cent, assumed the conversion efficiency of traditional stoves to be 18.1 million net GJ. (It may be noted, however, that the Improved Cooking-Stove (ICS) has a 20 to 30 per cent conversion efficiency). The Master Plan for the Forestry Sector assumed urban household consumption to be 248kg per capita per year, ranging between 548 to 829kg per annum in the mountains and between 474 to 483kg per annum for the *Terai*, whereas it was 176kg for Kathmandu, 144kg for Lalitpur, and 128kg for Bhaktapur on a per capita per annum basis (Shaikh 1989).

Agricultural Residue

It is difficult to estimate what proportion of agricultural residue is used for fuel in the different geographical regions of Nepal. Residues include those from rice, maize, wheat, sugar, millet, and bagasse which can be grown in a number of agro-ecological zones with varying yields and residue/crop ratios (New Era 1990).

It is estimated that 12.47 million tons of agricultural residue were produced in 1985/86 (Table 1).[1] Assuming that one-sixth of the residue (2.1 million tons) was used for fuel, discharging a uniform heat value of 12.6 GJ per ton, the gross energy derived from this source would have been 26.2 million GJ. Assuming only a five per cent efficiency in use, the energy used amounts to 1.3 million GJ.

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1. The latest available statistics on agricultural production are for 1987/88. According to the statistics, 13.46 million tons of agricultural residue were produced. It is assumed that one-sixth of the residue (2.24 million tons) was used for energy purposes.

Table 1: Production of Agricultural Residue

Agricultural Residue	Mountain Region '000 T	Hill Region '000 T	*Terai* Region '000 T	Nepal (Total) '000 T
Rice husk	15.3	146.98	538.85	701.13
Rice straw	183.6	1763.70	6466.20	8413.30
Rice barn	3.1	29.40	107.77	140.23
Maize cobs	21.1	177.57	63.31	262.14
Maize stalks	140.4	1183.80	423.40	1747.60
Wheat straw	51.3	361.38	633.85	1046.50
Bagasse	0.4	9.40	157.71	167.50
Jute stick	0.0	0.00	1.22	1.22
Total	415.2	3672.21	8392.51	12479.62

Source : WECS; Energy Sector Synopsis Report 1985/86, 1987b.

The physiographic distribution of agricultural residue production is 67.2, 29.4, and 3.4 per cent for the *Terai*, hill, and mountain regions respectively. Rice straw accounts for about 67.2 per cent of the total agricultural residue supply (Sharma 1986).

Animal Dung

Animal dung is the third type of indigenous energy source. Based on a study conducted by the Agricultural Statistics' Division of the Ministry of Agriculture there were about 15.5 million livestock units (LSU) in Nepal in 1985/86 (New Era 1990). Dung produced in the hill and mountain regions is mostly used for composting, but in the *Terai* it is used for fuel in the form of dung-cakes and dung-sticks that are made by mixing it with straw and jute sticks. There are estimated to be 4.8 million head of livestock in the *Terai*. Assuming that 45 per cent of the dung production is lost during grazing, only 2.2 million tons of dung are available for fuel in the *Terai* Region (New Era 1990).

Biomass-based Energy Technology

Exploitation of the forests for fuelwood, fodder, and timber, along with the agricultural demands of the growing population have placed forests under heavy pressure, reducing forest cover, and thus damaging the environment. As a result, current rural, household energy supplies and consumption patterns are of serious concern. Lack of fuelwood increases the proportion of crop by-products and animal dung used for fuel, thus constraining their use as fodder and as organic inputs for soil improvement.

In order to overcome scarcity as well as to improve biomass use a change in balance between the biomass energy consumed by the domestic and other productive sectors is essential (Fig. 1). There are three possible approaches to achieving this change in balance.

1. Increasing the domestic and industrial biomass fuel resource base through:

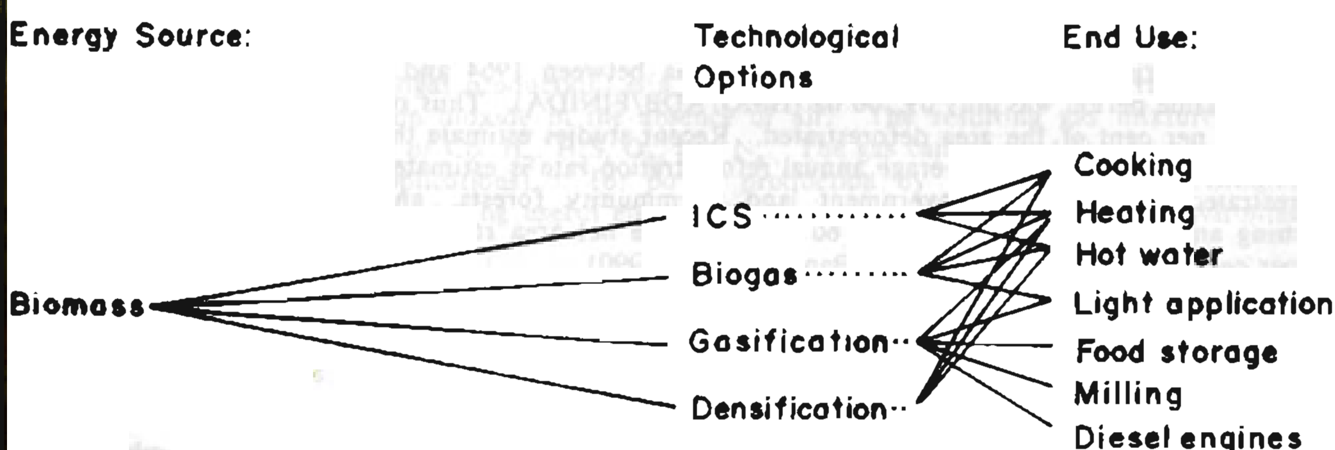
    - o bioenergy plantation programmes and

    - o domestic and industrial use of agricultural residue and animal waste through densification, biogas production, and thermo-chemical gasification processes.

2. Switching to non-biomass fuels.

3. Conservation of biomass through improved cooking-stoves.

Fig. 1: Technological Options and End Use of Biomas



Source: Author's compilation

Bioenergy Plantation Programme

Fuelwood supplies could be increased by efficient management of the existing natural forests, agro-forestry practices, and on-farm plantations. The Master Plan for the Forestry Sector (MPFS) recorded intensive and enriched planting of over nearly 100,000 ha by the end of 1986, half of which were under community forestry projects. However, in the absence of a proper monitoring system, it is difficult to assess the survival rate and the status of growth (New Era 1990). Sagarnath Plantation Project has a target to plant trees on 10,000 ha of land over a period of 10 years on a high, sustained yield basis. The main objective was to plant fast growing exotic species of eucalyptus (*Eucalyptus camaldulensis*) for fuelwood, the indigenous Sissoo (*Dalbergia sisso*) for timber (main stem), and the rest for fuelwood.

In view of the rapid deterioration of forest resources and the scarcity of fuelwood, bioenergy plantation programmes should be given prime importance. This type of activity generates local labour employment. Its main objective should be to produce bioenergy rather than industrial wood. Therefore, the selection of species is significant and the species should have the following characteristics:

- o high biomass yield,
- o high calorific value,
- o rapid growth,
- o good copiccing (regeneration after harvest),
- o easy to establish,
- o high adaptability,
- o need for little aftercare, and
- o nitrogen-fixing ability as well as the ability to provide steady fuelwood supplies.

There is also a lot of scope for producing charcoal which can replace fossil fuel. It is observed that, in Thailand, the regeneration of forests resulted from increased plantation to obtain raw material for charcoal. This type of plantation helps to increase domestic and industrial biomass fuel.

The area of natural forest decreased by 570,000 ha between 1964 and 1985. Reforestration during the same period was only 69,200 ha (HMG/ADB/FINIDA). Thus reforestation took place on only 12 per cent of the area deforestrated. Recent studies estimate the annual deforestation rate as 44,000 ha whereas the average annual reforestration rate is estimated to be only 7,900 ha. Reforestrated areas include government land, community forests, and private plantations. Assuming an effective survival rate of 60 per cent, the net area reforestrated amounts to only 10.7 per cent of the deforestrated area (Banskota et al. 1990).

Densification of Biomass Residue

Large amounts of biomass residue are produced in Nepal as a result of forestry activities, timber production, and agro-industrial processes. These residues (sawdust, rice husks, straw, wild bushes, bagasse, maize stalks, etc) are available in a form that makes them unsuitable (because of their combustible characteristics) or impractical (because of transport costs) for domestic and/or commercial use.

Residue can be converted into briquettes or pellets of different shapes and sizes by densification processes and can then be used as fuel in various end use devices. In processing, a homogeneous material with a real density of approximately 1,000 - 1,400 kg/m^3 and a bulk density of 500 to 800 kg/m^3 is produced. Ideally, the briquettes are not hygroscopic, do not swell in water, and do not crumble during combustion or gasification.

Briquettes are made by simple densification or by a partial pyrolysis-cum-densification process. The partial pyrolysis-cum-densification process is neither technically sound nor viable from an economic and financial point of view (WECS 1988). Most entrepreneurs in Nepal have ceased to produce briquettes by the partial pyrolysis-cum-densification method, because the dies and extruders are subject to wear and the pyrolyser needs repairing about once a month. This is because the pyrolyser is continually subjected to a temperature of 300°C. Because of reaction to the friction of internal husks and to direct external heat, the pyrolyser is subject to continual deterioration. Production of tar inside the pyrolyser also creates problems, and breakages in the power transfer chain are common (WECS 1988). Also some consumers in Kathmandu complained that these briquettes crumbled during transportation. Based on a patent from the Indian Institute of Technology (IIT) Delhi, two licensees constructed a total of 70 carbonised briquetting plants throughout India; most of which were privately funded. After sixty of these plants ceased to operate, IIT withdrew the licensing rights from these manufacturers (University of Twente 1990).

It is clear from Table 1 that apart from maize cobs and stalks, the maximum quantity of agricultural residue is produced in the *Terai*. Sharma (1986) estimated that the Central Development Region was where the maximum amount of all types of residue, apart from jute sticks, were produced. Data from the Ministry of Industry show that there are about 27 briquetting factories registered for installation in Nepal. Of these, 13 are to be located in the Central Development Region, while seven are to be located in the Western Development Region (WECS 1988). According to the Eighth Plan, Energy Resource Development Section (WECS) Report, 7 rice husk densification plants were installed by the private sector. Their annual production was about 3,500 tons. These are located in the *Terai* and in the Kathmandu Valley.

Biogas

Anaerobic digestion (biogas production) is a process through which organic matter is converted into methane and carbon dioxide in the absence of air. The resulting gas mixture may also contain small quantities of Co, H_2, H_2S, O_2, and N_2. The gas can be used for direct combustion (cooking or heating applications) or for power production by means of internal combustion engines. Apart from producing useful energy, the system can also contribute to environmental hygiene.

Compared to other sources of bioenergy, the anaerobic digestion method has three advantages.

- It converts wet organic substances into useful energy,
- produces biogas from all types of organic waste (with the exception of lignin), and
- produces a slurry which is a better fertiliser than the manure feedstock.

More than 5,700 biogas plants have been installed in more than 50 districts of Nepal (Pokharel and Yadav 1991).

Gasification

Gasification is a thermo-chemical process in which biomass is converted into a combustible gas that can be either used for direct combustion or as a fuel for internal combustion engines. At present, various types of biomass gasifiers have been adopted by manufacturers in both developed and developing countries. Some years ago, Research Centre for Applied Science and Technology (RECAST) also designed and developed a wood and charcoal gasifier. National Structure and Engineering (Pvt.) Ltd. also developed some biomass gasifiers. The gasifier designed by RECAST was the down-draught type which is designed for operation with charcoal (Shrestha 1983). However, the efficiency of the gasifier and the composition of the gas were not mentioned.

Successful use of this technology was reported in Indonesia, when a 15kW wood gasification system was successfully operated for over 4 years (Susanto 1988). This system supplies electricity to about 300 houses on a daily operating basis from 5 to 11 p.m. A small gasification system capable of developing up to a 10kW shaft power output, using producer gas generated from rice husk, was developed in Thailand by Coovaltanachai in 1988. For the hill regions in Nepal, this type of gasification system can be used for electricity generation as well as for replacing diesel engines in rice mills.

Switching to Non-biomass Fuel

In urban areas, consumption of kerosene and eletricity for domestic purposes has been increasing rapidly. Transition from the use of traditional fuel to modern commercial fuel can be of considerable significance in the domestic energy consumption pattern. In particular it widens the range of possible responses open to the consumer under the pressure of increasing fuelwood scarcity. On the one hand, it brings many benefits - it helps to contribute to the over-exploitation of biomass resources - but it adds greatly to the pressures on scarce resources of capital and foreign exchange.

The best alternatives to fuelwood are kerosene and electricity which are economically more feasible in comparison to the high price of fuelwood in the local market (Table 2). Notwithstanding, where fuel supplies are predominantly non-commercial, the potential for fuel switching is minimal.

Table 2 also shows the technological option of end use devices and economic comparison of different types of fuel with respect to the type of stove and its efficiency. The thermal efficiencies are calculated by means of the boiling water test. Taking into account the conversion efficiencies, the total rupees spent per MJ of useful heat is calculated. By comparing the useful heat generated, if the price of fuelwood is less than Rs 1.50 per kg, the ICS will be financially economical to use. There are other factors that justify continued support for the cooking-stove programme. These are: significant advances in technical know-how in stove design, positive responses from users, better knowledge of the constraints in the existing programme, and greater access to information exchange. With this in mind, the Master Plan for the Forestry Sector has recommended the continuation of the ICS programme, and, recently, USAID/Nepal chose to support it.

Table 2: Economic Comparison of Different Types of Fuel by Stove Type

Technology Options	Fuel Type	Average Stove Power kW	Efficiency %	Conversion Factor	Purchased Rs/unit	Fuel Rs/MJ	Useful Heat Rs/MJ
Insert Stove	fuelwood	4.4 ± 0.2	21.5 ± 1	16.5 MJ/kg	2.5 Rs/kg*	0.151	0.70
					1.4 Rs/kg	0.084	0.39
					0.8 Rs/kg	0.048	0.22
Tamang Stove	fuelwood	6.2 ± 0.5	24.7 ± 1	16.5 MJ/kg	-	-	0.61
							0.34
							0.19
Improved Two-ring Mud Stove	fuelwood	6.6 ± 0.3	26.7 ± 1.5	16.5 MJ/kg	-	-	0.56
							0.31
							0.18
Improved One-ring Mud Stove	fuelwood	3.4 ± 0.4	22.7 ± 2.5	16.5 MJ/kg	-	-	0.66
							0.37
							0.21
Burner Stove (small size)	kerosene	1.5 ± 0.0	56.5 ± 1.2	36.3 MJ/lt	8.5 Rs/lt	0.344	0.41
Wick Stove (small size)	kerosene	1.4 ± 0.0	49.3 ± 1.5	36.3 MJ/lt	8.5 Rs/lt	0.232	0.47
Local Electric Heater	electricity	.8 ± 0.0	62.0 ± 0.0	3.6 MJ/kWh	1.2	0.333	0.53

Source: 1. Devtec 1989.
2. Sulpya 1984.
3. RECAST 1987.

Note: A 24cm diameter *dekchi* (flat pot) was used for the test 15 minitues simmerging without lid after boiling was done throughout the test.

* Pricing structure of fuelwood from private agents to Nepal Fuelwood Corporation.