Case Study One

Impact of Alternative Energy Technology in Reducing Pressure on Forest Resources in Ghandruk

INTRODUCTION

A major problem in the mountain areas of Nepal, where tourism is popular or has potential, is the increasing pressure on forests as a result of the derived demand for firewood by tourists. Firewood is the only source of energy for cooking and heating in the remote areas of the mountains. With the rapid population growth that Nepal has been experiencing for nearly two decades, deforestation has also occurred on a large scale and the firewood demand in many places has exceeded the regenerative rate of biomass growth. Alternative sources of energy have not developed as people are poor and cannot afford them, even if they were to be made available. Furthermore, the main occupation is subsistence agriculture and there are no alternative employment opportunities, thus prohibiting scope for income generation. For a long time to come, fuelwood will most likely be the main source of energy in many areas in the mountains of Nepal. Therefore, the local people have no alternative other than to continue using firewood.

When an activity such as tourism is promoted in mountain areas, especially in the absence of alternative energy sources, pressure on forests for the supply of firewood continues unabated. Although, in many areas, firewood use by group tourists is not permitted and kerosene or other alternative energy has been made mandatory, yet the derived demand for firewood by tourism continues to remain high. Group tourists require a larger number of porters, who also depend on firewood to cook their meals and keep themselves warm (Banskota and Sharma 1995a). This demand for firewood by porters is a derived demand for firewood by tourism. The other group of trekkers to the mountain areas, generally called free independent trekkers (FITs), rely on local outlets (lodges or private homes) for food and accommodation. Some of these outlets are beginning to switch to alternative energy and firewood-saving technologies. Despite substitution of firewood with other forms of energy, firewood use nevertheless continues to be high with lodge owners finding other uses for firewood to attract visitors. Hot showers are provided, for example. Such facilities, although they tend to improve visitor satisfaction, also put pressure on the forests.

This pattern is, however, changing slowly in selected places where tourism has been complemented by community development and conservation education. For example, in Ghandruk in the Annapurna region, the development of a 50kW micro-hydro-electric plant and establishment of other conservation education programmes have enabled many lodges to appreciate the value of conservation. More and more lodges are beginning to use firewood-saving stoves, heating gadgets, solar panels, and electrical gadgets such as rice cookers and electric jugs, liquid petroleum gas (LPG), and so on. A great deal of substitution between energy types has been taking place among the lodges in Ghandruk, thereby resulting in saving firewood and, consequently, reducing pressure on the forests. This change is confined primarily to lodge-owners. Tourism has enabled the lodge community to improve their incomes and standards of living and to be able to afford alternative energy sources as well as new technologies. The cost of this transformation is passed on to tourists, who receive better services and are willing to pay for the better services. There is (relative) benefit to all in this process — visitor satisfaction improves, lodge-owners earn better incomes, and forests are protected.

In spite of the increasing use of alternative energy and technology in the lodges, the costs and benefits of bringing about the changes are not known. There are costs associated with purchasing new gadgets as well as for using different types of energy in comparison to using fuelwood. How does this cost compare with firewood savings? In other words, what have been the resultant savings in firewood in the lodges now using the new technology? If alternative technology and energy had not been introduced, lodges would have continued to use firewood.

Information on the magnitude of firewood used by lodges in Ghandruk prior to the introduction of the new technology and energy was not available. Information is available on the magnitude of different forms of energy consumed by lodges in Ghandruk and Ghorepani. Ghorepani relies entirely on firewood and, apart from kerosene, no other forms of energy are used. The use of different firewood-saving technologies in Ghorepani is also significantly lower than in Ghandruk. Therefore, the main assumption from the study is that, firewood use in Ghandruk prior to the introduction of electricity and alternative technologies was similar to that in Ghorepani. On this basis, the study serves to derive an idea of the substitution among energy types, after which the direct net benefits of this adaptation can be addressed. This knowledge will be useful for tourism development planning in remote mountain areas.

OBJECTIVES AND SCOPE

The main objective of the study is to analyse the impact of alternative energy technology in reducing the pressure on the forest resources in the Ghandruk tourist area. The specific objectives of the current study are:

- to analyse the impact of alternative energy technologies in reducing the use of fuelwood in the lodges of the tourist area of Ghandruk and estimate the consequent reduction in pressure on forest resources;

- to compare the present energy-use pattern in tourist lodges in terms of primary, final, and useful energy and the related costs and savings with the energy-use regime before the introduction of alternative energy technology; and

- to discuss the technology-specific and institutional process in the adaptation of alternative energy technology in terms of energy flows from source to end use and draw lessons of relevance for promoting alternative energy technology in similar tourist areas in the mountains of Nepal.

ENERGY EFFICIENCY: METHODS AND ASSUMPTIONS

Technical efficiency, as defined by the first law of thermodynamics, measures the relationship between total energy input and useful energy output (i.e., the ratio of useful energy output to total energy input). The output energy is called 'useful energy' and differs from 'supplied energy' by the amount of energy losses incurred between input into the final user's equipment and the output from that equipment. While the first law of thermodynamics provides the conventional framework for estimating the potential for conserving the energy by reducing energy losses, it does not provide a framework for analysing the most efficient methods of providing energy services (Kodani et al). The second law of thermodynamics provides a framework for analysing efficient processes (minimum energy requirement). It is defined as the ratio between the minimum energy required to perform a particular task and the actual energy that is required by the system (i.e., minimum energy input/actual energy input). Therefore, while according to the first law, the reduction in energy losses can improve efficiency; according to the second law the use of relatively more efficient processes can improve efficiency.

There are two methods of analysing energy use data, namely, Energy Balance Table and Reference Energy System (RES). The RES emphasises the rate of efficiency at which different types of fuels are converted, transported, and consumed using various end-use devices. It involves fuel mix and end-use consumption, which are both prime concerns for energy demand analyses and planning. There are several possible structures of RES. Under the fuel-cycle approach, RES can be structured to trace energy flow from source to the service. For example, primary energy provided by energy sources is converted into secondary energy through process technology. Conversion technology converts the secondary energy into final energy. Similarly, end-use technology converts final energy into useful energy which is what really counts for the consumers. In this manner, energy lost at each stage of energy conversion has to be taken into account in deriving the total primary energy requirement. It is generally easier to obtain the loss in primary and secondary energy for conventional commercial sources of energy than in final and useful energy that is actually sought by the consumers.

Useful energy consumption in the present study has been deduced using the national level energy efficiency parameters reported in the Perspective Energy Plan of the National Planning Commission (NPC) for the commercial sector. The end-use efficiency matrix reported by NPC was adjusted to reflect the situation prevailing in the study area (which was based on survey information). More specifically, the procedures and underlying assumptions adopted for deriving useful energy consumption in the lodges of Ghandruk and Ghorepani are as follow.

- The physical quantity of all energy sources expressed in local/natural units are all converted into giga joules (GJ) using the standard energy conversion factors reported by the NPC.

- The primary/final energy requirements for five different end-use activities (e.g., cooking, boiling water, space heating, lighting, and motive/process heat) have been developed separately for both Ghandruk and Ghorepani lodges based on the use of different end-use technologies. The assumed end-use energy requirements for lodges in Ghandruk and Ghorepani are reported in Table 1. The primary/ final energy use by end-use activities and energy sources were then derived for lodges in Ghandruk and Ghorepani.

Table 1: **Assumed End-use Requirement of Energy by Lodges in Ghandruk and Ghorepani (proportion)**

	Cooking	Water Heating	Space Heating	Lighting	Motive	Total
Ghandruk						
Firewood	0.25	0.45	0.3	0	0	1
Kerosene	0.35	0.35	0.1	0.2	0	1
Electricity	0.36	0	0.1	0.44	0.1	1
Solar	0	1	0	0	0	1
Gas	0.8	0.2	0	0	0	1
Ghorepani						
Firewood	0.5	0.4	0.1	0	0	1
Kerosene	0.2	0.2	0	0.6	0	1
Electricity	0	0	0	0	0	0
Solar	0	0	0	0	0	0
LP Gas	0.9	0.1	0	0	0	1

Note: *The parameters for end-use requirement were obtained from NPC (1995) and were modified to reflect the situation in the study area based on discussions with energy experts at ICIMOD.*

Source: *National Planning Commission 1995*

- Given the large variations in end uses due to variations in the quality of energy devices among lodges in Ghandruk and Ghorepani, the end-use efficiency matrix has been prepared separately for these two areas. Ghandruk is adopting a variety of end-use devices such as rice cookers, space heaters, light bulbs, and so on. Similarly, improved stoves, brick stoves, LPG stoves, and back boiler stoves are some of the other end-use devices used in both areas. The efficiency of these end-use devices has been derived from several references (NPC 1995; Joshi et al. 1991; Rijal et al. 1990). Given the field information on the proportion of lodges using such devices, the variability in end-use efficiency has been captured by taking the weighted average efficiency of end-use devices. For example, the efficiency of an improved stove and that of a local stove have been adjusted according to the proportion of lodge owners who have used such devices to arrive at an average efficiency of firewood use for cooking. Similar procedures have been adopted to adjust the other end-use efficiencies. The end-use efficiency matrices used to derive useful energy in Ghandruk and Ghorepani appear in Table 2.

Table 2: **End-use Energy Efficiency Matrix for Lodges in Ghandruk and Ghorepani (in %)**

Ghandruk	**Cooking**	**Water Heating**	**Space Heating**	**Lighting**	**Motive**
Firewood	0.191	0.22	0.73	0	0
Kerosene	0.48	0.48	0.511	0.0006	0
Electricity	0.65	0.5	0.9	0.05	0.85
Solar	0	0.25	0	0	0
LP Gas	0.65	0.65	0	0	0
Ghorepani					
Firewood	0.157	0.21	0.65	0	0
Kerosene	0.45	0.45	0	0.0006	0
Electricity	0	0	0	0	0
Solar	0	0	0	0	0
LP Gas	0.65	0.65	0	0	0

Source: National Planning Commission 1995; Joshi et al. 1991; Rijal et al. 1990

- Finally, the estimated primary/final energy consumption for different end-use activities in each area are multiplied by their respective end-use matrix to arrive at the total useful energy which, when divided by the respective primary energy, gives the efficiency of the specific energy source.

The Study Area

Both Ghandruk and Ghorepani are two heavily impacted tourist areas. The Ghandruk-Ghorepani circuit is one of the most widely used trekking routes within the Annapurna Conservation Area (ACA). The mountains from Ghandruk to Ghorepani are covered with forests. However, with the growth in tourism the once dense Ghorepani forests have now been cleared and tourist lodges have been built all along the Ghorepani-Ghandruk route. There were altogether 27 lodges in Ghandruk and 19 in Ghorepani (KMTNC/ACAP 1994; Gurung and Arthur 1995). Information from a sample survey of 20 lodges from Ghandruk and 18 lodges from Ghorepani carried out in 1994 indicates that most of the lodges (78%) were of a permanent nature and were mostly owned by people from these villages. An average lodge, in both the areas, provides employment to about seven persons a year. Employment during the peak season is higher than during the slack season. However, most of the lodge employment is taken up by family members and local labour is hired to meet about 25 per cent of the labour demand during the peak season. The average number of rooms per lodge in Ghorepani (8.7) is a little higher than in Ghandruk (7.3). Likewise, the average number of beds per lodge in Ghorepani is 17.3 compared to 15.9 in Ghandruk.

Forest Resource Conditions

The forests around Ghandruk were degraded in the past due to lack of management and excessive firewood demands in the absence of alternative energy technologies.

Once the Ghandruk VDC was declared a pilot area of the Annapurna Conservation Area Project (ACAP) in 1987, a central forest management committee (FMC), consisting of 14 members representing all nine wards of the VDC, was constituted to manage the surrounding forests. For ease of operational effectiveness and control in management, forest management sub-committees were also constituted under the FMC. Two forest guards were appointed to patrol the forests and to report regularly to the committee. The main functions of the FMC and sub-FMC included:

- development of a plan of operation (timber, fuelwood, and grazing regulations) in the beginning of the year;
- regular monthly meetings to discuss issues on forest management; and
- supervise and monitor forest guards.

Forests that are within a two hours walking distance from village settlements are classified as protected and those beyond two hours are classified as non-protected forests. The protected forests cover 935 hectares or 31 per cent of the total area (28,931 ha) of Ghandruk VDC. The natural forests, on the other hand, cover 1,564.5 hectares or 47.5 per cent of the total area of the VDC. Felling of green trees of any species and animal grazing are prohibited in protected forests. In natural forests too green tree felling is not permitted. Cutting and collection of timber trees is regulated through permits issued by the FMC.

NEW ENERGY TECHNOLOGY AND SOURCES OF SUPPLY

In an attempt to reduce pressure on forest resources, ACAP introduced a number of fuel-efficient technologies for cooking and heating and alternative energy sources. This section first briefly highlights the new technologies introduced which will then be followed by a discussion on the impacts of the technology in relation to reducing the pressure on forest resources.

Kerosene

In response to the depletion in forest resources due to excessive use of firewood by lodges and campers, ACAP, with the support of the local people, banned all firewood use from Chhomrong to the Annapurna base camp (Map 1). To implement this policy, a 3,000-litre kerosene depot was established at Chhomrong in 1987 with financial support from the German Alpine Club. A kerosene depot management committee was subsequently constituted to manage regular supplies of kerosene to the depot for sale. The capacity of the kerosene depot was increased to 5,000 litres. At first it was a difficult task trying to convince lodge-owners to switch over to kerosene. However, the use of kerosene has gradually picked up and the consumption of kerosene has increased several fold since 1987. The capacity of the depot was further increased to 10,000

Map 1: Annapurna Conservation Area

litres in an attempt to meet the growing demand for kerosene. Group tourists and mountaineering teams are not allowed to use firewood; this has also increased the demand for kerosene. Currently, there are five kerosene depots in the Ghandruk sector.

At the time the kerosene depot was established, firewood consumption in most lodges was estimated to be 250kg per day. Each trekking group alone consumed about 100kg of firewood per day. With kerosene being made available, it was assumed that about 350kg of firewood could be saved in a day. It was estimated that the use of kerosene would save about 4,000kg of firewood per day in a busy trekking season as more and more lodges and group trekkers were beginning to use kerosene (KMTNC 1994).

Micro-Hydroelectricity

The installation of a 50kW micro-hydroelectricity power plant in Ghandruk was another significant step to improve access to alternative technology and bring about reduction in firewood use. The total cost of this scheme was US $ 72,000, i.e., at the rate of US $ 1,440 per kW installed (Bell 1994). Ghandruk Power Plant provides electricity to all houses for lighting purposes. In addition, all lodges and about 20 per cent of the households use some electricity for cooking. A village electrification committee was established to oversee the project. The electricity tariff has been set at a level sufficient to pay back loans within five years and to cover maintenance costs and salaries for three local people who were trained to run the system. Different tariff rates were set so that cross subsidies for commercial and industrial consumers and households could be made possible. People pay a flat tariff and lodges pay 50 per cent more than households. It is planned to invest the revenue generated after loan recovery into village development. Currently one-third of the available power is used by tourist lodges alone. Estimates indicate that, before the scheme, families used between one and five litres of kerosene a month for lighting purposes, which is a little more than double the cost required to light a 25 watt electric bulb (Bell 1994).

Cooking with Electricity

In Ghandruk, ACAP has subsidised all the capital costs of the *Bijuli Dekchi* (BD), or an electric cooker of under 20 litres capacity, by 30 per cent, apart from all transportation and repair costs for the first year. BD (Diagram 1) is a low wattage cooker consisting of a cooking pot. Water takes an estimated two hours to heat up fully, and it can be used to cook rice, meat, and other boiled food; it cannot be used for fried food. In the first two years of the programme, 85 cookers were sold in Ghandruk with the initial demand coming mostly from lodges. Large (20-litre) cookers, exclusively used by lodges, are however, not subsidised. A revolving fund has been set up to provide subsidies on BDs as an incentive to households.

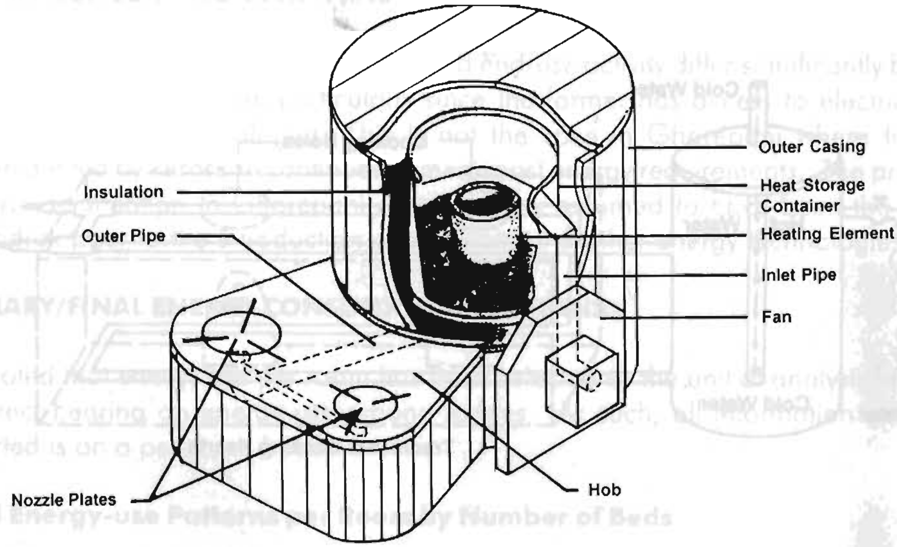

Diagram 1

Solar Water Heater (SWH)

Solar water heaters are also simultaneously being promoted as an alternative energy source, although the installation cost of this gadget is relatively high. Also, the high cost of the solar panels limits its widespread use. ACAP provides no loan but offers a discount of 10 per cent as an incentive for installing the solar panel. Keeping in mind of the high capital cost, a prototype model of a low cost solar heater was promoted and installed in Ghandruk. The newly developed model with a 1,001-litre capacity seems to be more cost effective at a cost of only Rs 5,000 than the 2001-litre capacity conventional heater which costs Rs[1] 21,000 (ACAP 1994). By 1991, four solar water heaters were installed in lodges in Ghandruk and Chomrong. By then ACAP was subsidising this technology by offering free transport and installation costs. Tourist are required to pay Rs 20 for every hot shower they take during their stay. Recently lodge-owners in Ghandruk installed six solar panels. It is learned that they can make returns on their investments in two to three years (Bell 1994).

Back Boiler

The traditional method of providing hot showers to trekkers was to fill a 200-litre drum and surround it with firewood and burn it all day – a highly inefficient method. To reduce the large amounts of firewood required for this purpose, a new fuelwood-saving device, namely, the back boiler, was introduced by ACAP. This system consists of a pipe and a galvanised iron drum with a capacity of about 220 litres. The pipe is connected to the drum and then buried within the traditional cooking hearth. The cold water from the bottom of the tank flows through the coil and heats up with the heat generated from the hearth. This gadget (Diagram 2) has been successful in saving fuelwood and

1 There are 58.05 Nepali rupees to one US dollar.

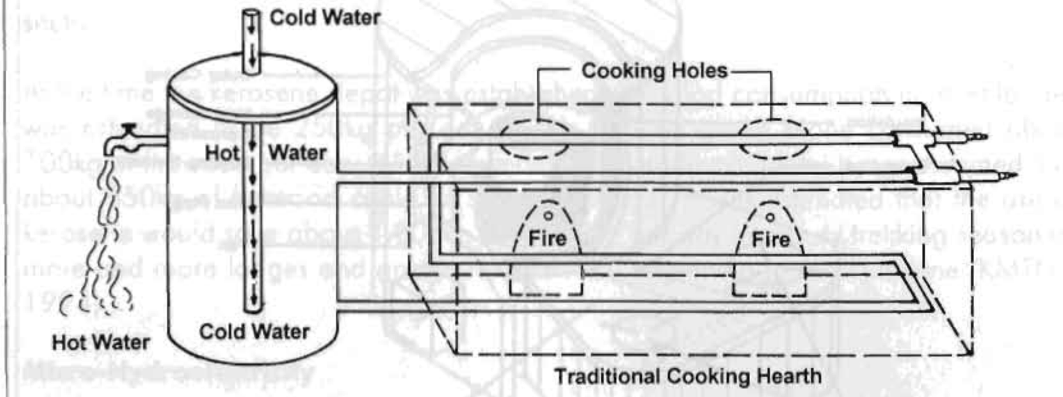

Diagram 2

consequently its demand has been growing. Back boiler technology is becoming popular among the lodges, because it is relatively inexpensive and is easy to build and operate.

The installation cost of a 100- to 200-litre drum ranges from Rs 600 to 800. The installation of a back boiler is free, and it is covered for six months for repairs and maintenance. ACAP provides a subsidy for transportation and 50 per cent of the cost of the circulatory part of the system. Reduction of the subsidy to 25 per cent has affected the demand. Moreover, it is learned that some lodge-owners have encountered technical problems with this device, leakages from the drum and blockage in the pipe being the main ones. Investigations are underway to refine this device.

Available estimates indicate that this system has been able to save on an average 675kg of wood per month, per lodge during the peak tourist season – a net reduction of 23 per cent of firewood use (Seimann and Steinbach 1993).

Improved Cooking Stoves

Improved stoves have not been widely disseminated despite their improved efficiency as well as the positive impact on health. First, the demand for space heating, and the local belief that smoke helps control pests in the wooden structure of the houses have caused some reluctance among users to fully adopt this new technology. Second, there are still some technical errors in the design of the improved stoves due to lack of interaction between end users and designers. As such, only 50 per cent of the improved stoves were reported to be used and maintained well. ACAP has slightly changed its incentive policy recently. Besides providing all construction materials, the stove owner now must pay Rs 25 to the foreman while ACAP pays the remaining Rs 55 as a subsidy (ACAP 1994).

ENERGY CONSUMPTION PATTERNS

Energy consumption patterns by sources and end-use activity differ significantly between Ghandruk and Ghorepani particularly since the former has access to electricity and other energy mix technologies. This is not the case in Ghorepani where firewood supplemented by kerosene continues to meet most energy requirements. The prevailing energy use situation in Ghorepani can be safely assumed to have been the case in Ghandruk prior to the introduction of electricity and other energy technologies.

PRIMARY/FINAL ENERGY CONSUMPTION PATTERNS

It is noted that energy use per room has been selected as the unit of analysis in view of its direct bearing on energy use among lodges. As such, all information on energy reported is on a per room basis.

Final Energy-use Patterns per Room by Number of Beds

The variation in energy use per room by number of beds is presented in Table 3. For the purpose of the analysis, lodges are classified into three groups based on the number of beds per room: low (less than 12 beds); medium (12 to 20 beds); and high (above 20 beds). The results indicate that firewood consumption per room in Ghandruk decreases and that of other energy sources, such as kerosene, LPG, and solar, increase slightly with the increase in the number of beds. The overall energy-use rates among low, medium, and large categories of lodges in Ghandruk have been found to be 19, eight,

Table 3: **Primary Energy Use Per Room Per Year by Number of Beds in Ghandruk and Ghorepani**

	Low		Medium		High	
	Mean	STD	Mean	STD	Mean	STD
Ghandruk						
Firewood (kg)	703	742	404	799	55.7	90.32
Kerosene (lit)	185	255	11	9.36	33.3	18
Electricity (kWh)	100	89	84	41	67	2
Gas (cylinder)	0.3	0.84	0.37	1.06	0.53	0.92
Solar (kWh)	0.107	0.303	0.33	0.36	0.35	0.11
Total (GJ)	19	10.25	7.74	12.96	2.77	0.37
Bed/Room	2.44	0.55	2.32	0.33	2.16	0.37
Ghorepani						
Firewood (kg)	1103	766	2171	1293	1760	1678
Kerosene (lit)	157	148	46	19	23	13
Electricity (kWh)	0	0	0	0	0	0
Gas (cylinder)	0	0	0.04	0.13	0.05	0.15
Solar (kWh)	0	0	0	0	0	0
Total (GJ)	24	15.78	38	21.70	30	28
Bed/Room	2.09	0.11	1.94	0.33	2.05	0.07

Source: Survey data

and three gigajoules (GJ) per room respectively. The corresponding figures for Ghorepani are 24,38, and 30 GJ per room. While the available information does not permit us to clarify and estimate the different effects (substitution, economies of scale, and efficiency effects) that have occurred as the number of beds per room increase, the inverse relationship observed between energy use and size of room in the case of Ghandruk warrants some plausible explanation. Given the existence of alternative sources of energy and fuel-efficient technology options, lodges in Ghandruk have diversified their energy use and this energy diversification or energy mix has enabled them to attain greater energy efficiency. The higher number of beds or rooms may be taken as a proxy for economic status. Such lodges can afford the new sources of energy and efficient technologies which are relatively expensive for smaller lodges. This implies that lodges having a larger number of beds are more likely to enjoy the advantages of energy mix, although a full substitution of fuelwood with other energy sources is not likely to take place in a short period of time. It is a gradual process.

Firewood

The average annual consumption of firewood in Ghandruk is estimated to be 475kg/room/year (or a daily average of 1.3kg/room) which is far lower (by 75%) than in Ghorepani (1,865 kg/room/year or a daily average of 5kg/room). Considering that the lodges in Ghandruk, prior to the availability of electricity and other alternative technology, would use the same level of firewood as is currently consumed by the lodges in Ghorepani, there has been a net saving of 1,390kg of firewood (75 %) per room in Ghandruk. The impact of this saving in reducing pressure on the forests is obvious as there has been less demand for and, hence, less extraction of forest resources by lodges in Ghandruk.

It should be noted, however, that variations in firewood use are much more pronounced among lodges in Ghandruk than in Ghorepani (Table 4). The quantity of firewood consumed by lodges depends, among other things, on the number of tourists served by the lodges, end-use technology, and energy mix during the peak tourist season (which normally lasts for seven months a year). Rayamajhi (1994) reported the average daily consumption figure of 28.5kg per lodge in Ghandruk after the restriction imposed by the Forest Management Committee. The estimated daily firewood consumption among Ghandruk lodge-owners in the present study is much lower, about nine kilogrammes

Table 4: **Primary Energy Use Pattern Per Room Per Year**

Energy use	Ghandruk		Ghorepani		Difference
	Mean	STD	Mean	STD	
Firewood (kg)	474.98	719.79	1865.00	1381.80	-1390.02
Kerosene (litre)	87.84	180.80	68.42	90.84	19.42
Electricity(kWh)	88.46	62.28	0.00	0.00	88.46
Solar (kWh)	0.24	0.32	0.02	0.09	0.22
Gas (cylinder)	0.37	0.90	0.02	0.09	0.35

***Source**: Survey data*

per lodge. The corresponding figure for Ghorepani is 45kg per lodge per day. Available information indicates that firewood demand per lodge is about 10 to 15 per cent of the total demand in Ghandruk (Rayamajhi 1994).

Despite a significant reduction in the use of firewood due to the introduction of alternative technology, about two-thirds of the lodges in Ghandruk still continue to use firewood. Also, firewood still continues to be the dominant energy source in Ghandruk in terms of its contribution to total energy requirements, although the share of firewood in total energy use in Ghandruk is lower (67%) than in Ghorepani (93%). Table 5 shows the contribution of different energy types to total energy consumption in Ghandruk and Ghorepani.

Firewood prices in Ghandruk (Rs 0.5/kg) have also been found to be half of the price prevailing in Ghorepani (Rs1.03/kg), perhaps reflecting its higher demand relative to supply in Ghorepani. Also, an average lodge in Ghorepani spends Rs 19,054 annually for firewood compared to Rs 5,298 in Ghandruk. Several studies carried out in the past provide estimates of the deforestation taking place in Ghorepani forests due to tourism activities. Ghorepani is an entirely new settlement that has developed due to tourism. It contains mostly lodges and almost no household settlement. Lodges in Ghorepani have no option but to consume firewood to meet their energy requirements as the contribution of other limited alternative energy sources, particularly kerosene and LPG, to the total energy is about eight per cent (Table 5). Also, Ghorepani is further away from the roadhead than Ghandruk, and this tends to increase the transport costs of any imported alternative energy and is, therefore, a disincentive to switch to alternative energy sources, unless income levels rise to make this switch possible.

Kerosene

Kerosene consumption by lodges in Ghandruk varies considerably ranging from four to 750 litres, with an annual average consumption of 88 litres per room per lodge (or a daily average of 0.24 litres per room). The corresponding figure for Ghorepani is 68 litres (0.18 of a litre a day per room) and this is about 25 per cent lower than in Ghandruk (Table 4). Almost all lodges sampled in both Ghandruk and Ghorepani use kerosene. The price of kerosene in Ghandruk (15/litre) is found to be lower than in Ghorepani (Rs 21/litre), reflecting the higher transportation costs for the latter relative to the former. Kerosene meets 27 per cent of the energy requirement in Ghandruk compared to eight per cent in Ghorepani (Table 5).

Electricity

Electricity consumption per room in Ghandruk is estimated to be 88.5 kilowatt hours (kWh) per year or an annual average of 550 kWh per lodge. About 74 per cent of the lodges reported using electricity for cooking and heating purposes as well. Among those who use electricity, the firewood consumption rate is found to be low, i.e., around 326kg per annum or a daily average of less than one kilogramme. Similarly, kerosene

Table 5: **Final Energy Use in GJ/room/Yr**

Energy use	Ghandruk		Ghorepani		Difference
	Mean	Per Cent	Mean	Per Cent	
Firewood	7.932	67.73	31.14	92.57	-23.22
Kerosene	3.189	27.23	2.48	7.38	0.70
Electricity	0.318	2.72	0.00	0.00	0.32
Solar	0.001	0.01	0.00	0.00	0.00
Gas	0.27	2.32	0.02	0.05	0.26
Total energy/room/yr	11.71	100	33.65	100	-21.94

Note: The average number of rooms per lodge in Ghandruk and Ghorepani is 8.7 and 7.3, respectively.
Source: *Survey Data and Calculations*

consumption among lodges using electricity was found to be only 22 litres a year (0.06 of a litre per room/day). Increasing use of electricity among the lodges has thus reduced dependency on forests and imported kerosene and, at the same time, saved energy bills. The substitution effects do appear to be fairly strong.

Similarly, only 74 per cent of the lodges in Ghandruk were found to have used the *Bijuli Dekchi* (BD) for cooking purposes. The annual average electricity consumption rate among BD users (105 kWh) is about 2.5 times higher than among non-users of the BD (41.6 kWh). Annual firewood consumption among BD users (190kg) was also found to be less than one-fifth the consumption rate among BD non-users (1,273kg/room/year). Similarly, kerosene consumption among BD users (46 litre/room) is about 23 per cent that of BD non-users (205 litres /year). However, kerosene use rates among space heater users were also found to be much higher than among non-users of this technology.

Solar

About 42 per cent of the sampled lodges in Ghandruk were using solar water heaters. Solar water heaters with a capacity of 200 litres are found to be rather expensive (Rs 11,000 per panel) and unreliable given the climatic conditions (sunshine) of the area, as cloudy days limit their use. As such, the consumption of solar water heaters is very low even among the users of this technology, 0.5001 GJ/room/annum. Both firewood (133kg/room) and kerosene consumption rates (23 litres/room) among solar water heater users are found to be much lower (by 83%) than among those not using this technology .

Gas

LPG is another form of energy used by the lodges, although its use is confined to about 16 per cent of the lodges surveyed in Ghandruk compared to only one lodge in Ghorepani. The average annual consumption of LPG is 0.272 GJ/room (or 3.15 kWh per lodge) in Ghandruk. The corresponding figure for Ghorepani is much lower (0.02 GJ/room). Even among those, the LPG consumption rate per room is less than 1.36 GJ in Ghandruk.

SHARE OF DIFFERENT TYPES OF ENERGY

Table 5 shows the average quantity of different energy use per room (all expressed in gigajoules) in Ghandruk and Ghorepani along with the percentage share distribution. The total quantity of overall primary/ final energy consumption amounted to 11.7 gigajoules per room in Ghandruk compared to 33.65 GJ per room in Ghorepani. This indicates that lodges in Ghandruk require about 67 per cent less energy than lodges in Ghorepani. Out of the total primary energy consumption in Ghandruk, firewood alone accounted for about 68 per cent, kerosene for 27 per cent, electricity for three per cent, and the remaining two per cent was met by solar and gas. In Ghorepani, where lodges have no access to electricity, over 92 per cent of the total energy requirements were found to be met through firewood alone, with the remaining percentage being met through kerosene and LPG. This clearly indicates the significant reduction in both the share of firewood and overall final energy requirement in Ghandruk relative to Ghorepani as a result of the availability of electricity as well as energy-efficient technologies.

FINAL ENERGY CONSUMPTION BY END-USE ACTIVITY

Table 6 shows the quantity of energy consumption by end-use activity in Ghandruk and Ghorepani. The results indicate that about 30 per cent of the total primary energy use in Ghandruk is for cooking, 40 per cent for water boiling, 23 per cent for space heating, and less than seven per cent for lighting and running electrical appliances. In Ghorepani, about 48 per cent of the total energy is used for cooking, 38 per cent for boiling water, nine per cent for space heating, and the remaining four per cent for lighting. The details are provided in Table 6.

Table 6: **Primary /Final Energy Use by End-use Activities (GJ/room/yr)**

	Cooking Heating	Water Heating	Space	Lighting	Motive	Total	Per Cent
Ghandruk							
Firewood	1.983	3.569	2.380	0.000	0.000	7.932	67.73
Kerosene	1.116	1.116	0.319	0.638	0.000	3.189	27.23
Electricity	0.115	0.000	0.032	0.140	0.032	0.318	2.72
Solar	0.000	0.001	0.000	0.000	0.000	0.001	0.01
Gas	0.218	0.054	0.000	0.000	0.000	0.272	2.32
Total	3.431	4.741	2.730	0.778	0.032	11.712	100.00
Per Cent	29.30	40.48	23.31	6.64	0.27	100	
Ghorepani							
Firewood	15.57	12.46	3.11	0.00	0.00	31.15	92.57
Kerosene	0.50	0.50	0.00	1.49	0.00	2.48	7.38
Electricity	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	0.01	0.00	0.00	0.00	0.00	0.02	0.05
Total	16.08	12.96	3.11	1.49	0.00	33.65	100
Per Cent	47.80	38.51	9.26	4.43	0.00	100	

***Source**: Survey Data and Calculations*

USEFUL ENERGY USE PATTERNS

Following the procedures, as stated earlier, useful energy consumption in Ghandruk and Ghorepani has been estimated, and the results are reported in Table 7. Total consumption of useful energy in Ghandruk is estimated to be about 4.45 GJ per room per year, which is roughly 38 per cent of the primary energy requirement per room. The corresponding figure for Ghorepani is 7.54 GJ per room, which is just 22.4 per cent of its total primary energy use rate. Thus, the adoption of alternative energy technologies and energy mixes has not only reduced the overall energy requirement in Ghandruk but also improved the efficiency of energy.

As is evident from Table 7, about two-thirds of the useful energy consumption requirements in Ghandruk are met by firewood (65%), with the remaining percentage being accounted for by kerosene (28%), electricity (3%), and gas and solar (4%). In Ghorepani, firewood meets 94 per cent of the useful energy requirements with the rest being met mostly by kerosene (Table 7).

The efficiency of different energy forms in both tourist areas can be better judged from the result presented in Table 7. Energy efficiency in Ghandruk is found to be amongst the highest for gas (65%), followed by electricity (43%), kerosene (38.7%), firewood (37%), and solar (25%). It is worth noting that the efficiency of electricity used for lighting purposes has not been treated separately in terms of lumen per watt, rather

Table 7: **Useful Energy Consumption Pattern in Ghandruk Tourist Lodges (GJ/room/yr)**

	Cook-ing	Water Heating	Space Heating	Light-ing	Motive	Total	Share %	Effic-iency %
Ghandruk								
Firewood	0.379	0.785	1.737	0.000	0.000	2.901	65.19	36.58
Kerosene	0.536	0.536	0.163	0.000	0.000	1.235	27.75	38.72
Electricity	0.075	0.000	0.029	0.007	0.027	0.137	3.08	43.10
Solar	0.000	0.001	0.000	0.000	0.000	0.000	0.00	25.00
Gas	0.141	0.035	0.000	0.000	0.000	0.177	3.97	65.00
Total Useful Energy	1.130	1.357	1.929	0.007	0.027	4.450	100	38.00
Shares (%)	25.40	30.48	43.34	0.17	0.61	100		
Efficiency (%)	32.94	28.61	70.64	0.95	85.00	38.00		
Ghorepani								
Firewood	2.445	2.616	2.025	0.000	0.000	7.086	93.93	22.75
Kerosene	0.224	0.224	0.000	0.001	0.000	0.448	5.94	18.04
Electricity	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00
Solar	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00
Gas	0.009	0.001	0.000	0.000	0.000	0.010	0.13	65.00
Total Useful Energy	2.678	2.841	2.025	0.001	0.000	7.544	100	22.42
Shares (%)	35.49	37.66	26.84	0.01	0.00	100		
Efficiency(%)	16.65	21.93	65.00	0.06	0.00	22.42		

Source: *Survey Data and Calculations* lighting purposes has not been treated separately in terms of lumen per watt, rather simple efficiency of bulbs has been used for the purpose of the study as reported in Joshi et al. (1991). For this reason, together with the fact that about 44 per cent of the electricity consumption in Ghandruk is for lighting, the overall efficiency of electricity can be believed to be higher than has been estimated in the present study.

The efficiency of overall firewood consumption (i.e., total useful firewood consumption as a percentage of firewood use in primary energy terms) in Ghandruk (36%) has been found to be higher than in Ghorepani (23%) because of the relatively higher proportion of improved stoves used in the former area than the latter area. The case for kerosene efficiency is similar, while no difference is found in the efficiency of gas. The bulk of the kerosene in Ghorepani is used for lighting, with only 40 per cent used for cooking and heating, whereas the opposite prevails in Ghandruk. The efficiency of the end-use device for cooking and heating is higher than in the case of lighting. The lower efficiency of kerosene lamps assumed for lighting purposes also partly explains the lower efficiency of overall kerosene use in Ghorepani than in Ghandruk.

Out of the total useful energy requirements in Ghandruk, about 25 per cent were for cooking, 30 per cent for boiling water, 43 per cent for space heating, and one per cent for lighting and motive power (including electric appliances) (Table 7). The corresponding figures for end-use activities in Ghorepani are: cooking (35%), boiling water (38%), space heating (27%), and lighting (less than one per cent) (Table 7).

The efficiency of overall energy by end-use activity in Ghandruk and Ghorepani is also summarised in Table 7. Despite cooking accounting for a lower share of energy in end use, cooking efficiency is higher in Ghandruk (33%) than in Ghorepani, where efficiency in cooking is only 17 per cent. Variations in end-use efficiencies between Ghandruk and Ghorepani are highlighted in Table 8. What has been observed is that due to energy mix and use of different end-use devices, Ghandruk has been able to derive more energy services from lower primary energy inputs.

Table 8: **Energy Sectors Efficiency by End-use Activity**

(%)

End-use	Ghandruk	Ghorepani
Cooking	33	17
Water Boiling	29	22
Space heating	71	65
Lighting	1	less than 1
Motive	85	-
Overall	38	22

Source: Survey Data and Calculations

REDUCED EMISSION

The extent to which the introduction of alternative energy technology in Ghandruk has been able to reduce carbon dioxide (CO_2) emission can be judged from the estimates reported in Table 9. In Ghandruk, where electricity and other fuel-efficient end-use devices are available, less firewood is being consumed and energy diversification has

Table 9: **CO_2 Emission from Main Energy Sources**

CO_2 Emission Coefficients		CO_2 Emission (Tons/room/year)		
Energy carrier	10^6ton/Pj	Energy source	Ghandruk	Ghorepani
Firewood	0.0832	Firewood	0.660	2.592
Kerosene	0.0723	Kerosene	0.231	0.180
LPG	0.0659	LPG	0.018	0.001
		Total	0.908	2.772

Source: National Planning Commission 1995 and Survey Data

noted that firewood emission is the major source of environmental pollution in the rural areas. Given the vital contribution of firewood to meeting rural energy requirements, a complete switch from firewood to other alternative energy sources is not at all likely in Ghandruk. Nevertheless, dissemination of improved energy devices and alternative energy sources that are suitable for local conditions can significantly contribute to reduced carbon dioxide, apart from improving the energy efficiency.

TOTAL ENERGY CONSUMPTION ESTIMATE

Given the information on the number of lodges and average number of rooms per lodge, the total quantities of both primary/final and useful energy consumption per year in Ghandruk and Ghorepani tourist areas have been computed. Total annual primary energy consumption amounts to 2,308.4 GJ in Ghandruk compared to 5,868 GJ in Ghorepani (Table 10). The annual firewood consumption in Ghandruk amounts to 1,563 GJ, which is about 29 per cent of the total firewood requirement in Ghorepani. This indicates a net saving of 3,896 GJ of energy from firewood per year (or 71%

Table 10: **Total Primary /Final Energy Use by End-use Activities (in GJ)**

	Cooking	Water Heating	Space Heating	Lighting	Motive	Total	Share
Ghandruk							
Firewood	390.86	703.54	469.03	0.00	0.00	1563.4	67.73
Kerosene	219.97	219.97	62.85	125.69	0.00	628.5	27.23
Electricity	22.60	0.00	6.28	27.62	6.28	62.8	2.72
Solar	0.00	0.16	0.00	0.00	0.00	0.2	0.01
Gas	42.87	10.72	0.00	0.00	0.00	53.6	2.32
Total (GJ)	676.3	934.4	538.2	153.3	6.3	2308.4	100
Shares (%)	29.30	40.48	23.31	6.64	0.27	100	
Ghorepani							
Firewood	2716.11	2172.88	543.22	0.00	0.00	5432.2	92.57
Kerosene	86.63	86.63	0.00	259.89	0.00	433.1	7.38
Electricity	0.00	0.00	0.00	0.00	0.00	0.0	0.00
Solar	0.00	0.00	0.00	0.00	0.00	0.0	0.00
Gas	2.43	0.27	0.00	0.00	0.00	2.7	0.05
Total(GJ)	2805.2	2259.8	543.2	259.9	0.0	5868.1	100
Shares (%)	47.80	38.51	9.26	4.43	0.00	100	

***Source:** Survey Data and Calculations* savings) in Ghandruk. The details on primary energy consumption patterns by source and end use in both tourist areas at an aggregated level are reported in Table 10. Similarly, the total useful energy consumption patterns by source and end use are shown in Table 11. The overall emission from lodges in Ghandruk is estimated to be 179 tons/year compared to 484 tons/year in Ghorepani (Table 12).

CONCLUSION

The introduction of alternative energy and fuel-efficient technologies in Ghandruk has brought about significant changes to the level of energy use as well as to the overall energy efficiency among lodges. There has been an energy transformation in the overall

Table 11: **Total Useful Energy Consumption Pattern in Ghandruk and Ghorepani Tourist Lodges (GJ)**

	Cooking	Water Heating	Space Heating	Lighting	Motive	Total	Share %	Efficiency %
Ghandruk								
Firewood	74.65	154.78	342.39	0.00	0.00	571.82	65.19	36.58
Kerosene	105.58	105.58	32.11	0.08	0.00	243.36	27.75	38.72
Electricity	14.69	0.00	5.65	1.38	5.34	27.05	3.08	43.10
Solar	0.00	0.04	0.00	0.00	0.00	0.04	0.00	25.00
Gas	27.87	6.97	0.00	0.00	0.00	34.83	3.97	65.00
Total (GJ)	222.79	267.37	380.16	1.46	5.34	877.11	100	38.00
Shares (%)	25.40	30.48	43.34	0.17	0.61	100		
Efficiency (%)	32.94	28.61	70.64	0.95	85.0	38.00		
Ghorepani								
Firewood	426.43	456.31	353.09	0.00	0.00	1235.83	93.93	22.75
Kerosene	38.98	38.98	0.00	0.16	0.00	78.12	5.94	18.04
Electricity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	1.58	0.18	0.00	0.00	0.00	1.76	0.13	65.00
Total (GJ)	466.99	495.46	353.09	0.16	0.00	1315.71	100	22.42
Shares (%)	35.49	37.66	26.84	0.01	0.00	100		
Efficiency (%)	16.65	21.93	65.00	0.06	0.00	22.42		

Source: Survey Data and Calculations

Table 12: **Total CO_2 Emissions from Main Sources in Tons/Year**

Energy Source	Ghandruk	Ghorepani
Firewood	130.1	452.0
Kerosene	45.4	31.3
LPG	3.5	0.2
Total	179.0	483.5

Source: Survey Data and Calculations

energy sector of the lodge community in Ghandruk. This transformation has only begun, and valuable lessons have been learned in bringing about this change. Several factors can be identified to be playing an important role.

There is little doubt that tourism has played an important role in this respect. Tourism has enabled the lodge community to increase their incomes which has, therefore, made it possible for them to afford the technology to bring about change in energy use. However, identifying increased income as the reason for this change is too simple. There are many other areas in mountain regions that have benefited from tourism and have not been able to bring about the type of change in energy use witnessed in Ghandruk, implying that affordability alone may not be the sole answer to reducing firewood consumption in areas that have benefited from tourism. The overall final energy use rate among low, medium, and large categories[2] of lodges in Ghandruk has been found to be 19, eight, and three GJ per room respectively. While such an inverse relationship between energy use and the number of rooms in the case of Ghandruk leads one to immediately draw a conclusion about efficiency gain, the results need to be interpreted cautiously. Lodges having a large number of rooms may be taken as a proxy for a higher economic status. Such lodges can afford the new sources of energy and efficient technologies which are relatively expensive for the lower categories of lodge. This implies that lodges having a larger number of rooms are more likely to enjoy the advantages of energy mix, although a full substitution of fuelwood with other new energy sources is an unlikely possibility.

In this, ACAP's role needs to be fully credited. ACAP as a non-profit INGO has been supporting a number of community development and conservation activities by involving both local people and lodge-owners in order to strike a sustainable balance in local needs, tourism management, and nature conservation. The Lodge Management Committee (LMC) and Conservation and Development Committee (CDC) are the key grass root institutions established to sustain the whole process of socioeconomic transformation, including various conservation-related programmes. Among these the forest conservation awareness programme can be assumed to have played an important role. This awareness programme is not confined to lodges alone but also is targetted at the household sector. However, technology adoption by households has not occurred to the extent that has been witnessed among the lodges. Although awareness among households with regards to conservation of forests and firewood use has also increased, the economic situation of households has not improved sufficiently to enable them to afford the technologies. This has been a weak point in the ACAP programme in which emphasis on income generation has received relatively less emphasis than on conservation and tourism development. Tourism development programmes are mostly confined to the lodges and only a small percentage of the household community benefit from tourism; and other income generation programmes have not developed (see Banskota and Sharma 1995b for more details).

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[2] Note that lodge categories are defined in terms of the number of beds.

A third important factor that has helped bring about the energy transformation has been the development of appropriate technologies. Lodge-owners have been able to use the technologies readily without involving much additional cost. Besides efficiency gains, lodge owners using the technologies have also realised health benefits as the new technologies emit less smoke. However, with regard to solar water heaters, the climatic factors appear to constrain its wider application. Experiences gained so far from many developing countries, including Nepal, show that energy efficiency is necessary but not a sufficient condition for new technology to succeed. Generally the lack of intensive interaction between technology designers and end users has been one of the reasons for discontinuing the different end-use technologies disseminated. For example, the multiple end uses served by the traditional stove for a variety of cooking purposes, in general, and space heating in particular are not found to be handled by the existing improved cooking stove design. Such problems can be cited as among the reasons why 50 per cent of the improved stoves disseminated are no longer in use (ACAP 1994).

Clearly, several factors, such as awareness of new technology and conservation, grass roots' institutions, affordability, availability, and design, appear to be important in climbing up the energy ladder. The process of moving up the energy ladder cannot, however, be expected to take place at the same pace among the commercial (lodges) and rural household sectors. The process is rather slow in the latter case for the simple reason that the rural economy is low subsistence and is slow to transform. This is why, even after the introduction of electricity in Ghandruk, the switch over from firewood to electricity for cooking and heating purposes has not taken place. The firewood consumption rate is still 3,040kg per household per year, and electricity is mostly used for lighting purposes only. Since the household sector is the major consumer of firewood (firewood demand by lodges in Ghandruk is reported to be only 15 per cent of the total demand in Ghandruk VDC), reducing pressure on forest resources calls for simultaneous efforts to improve the economic conditions of the household sector through income-generating programmes. Even within the lodges in Ghandruk, income-generating programmes are crucial. As incomes increase, lodges-owners move from simple and inexpensive fuels to more sophisticated, convenient, and costly fuels and end-use devices, depending on the availability and reliability of such technologies. In this process of moving up the energy ladder, certain risks associated with environmental pollution/emission are likely possibilities.

A number of issues and challenges need to be carefully addressed to sustain this process of energy transformation. Promotion of energy efficiency (both technical and allocative) should receive priority in future conservation programmes. A distorted pricing regulation is always detrimental to the promotion of efficient energy use as it causes faulty, inefficient fuel uses and gives wrong investment signals to consumers. Additionally, affordability also plays an equally important role in the adoption of new technology, besides attractive prices. In conjunction with programmes to increase energy efficiency, the supply of traditional fuels should be sustained through improved management of forests and plantation programmes which require strong grass roots' institutions. In other words, conservation interventions should strike a realistic balance between sustainable supply and demand management. This requires not only integrated environment-cum-economic policies and programmes but also an effective institutional framework from the national to grass roots' levels.