Energy for Low–income Settlements

Table of Contents

Energy for Low-income Settlements

United Nations Centre for Human Settlements (Habitat)
Nairobi, 1991

HS/245/91E
ISBN-92-1-131169-1

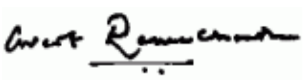
FOREWORD

The bulk of the population in developing countries is poor and survives on non-commercial energy sources such as fuelwood, agricultural residues or animal dung which are the most easily available and can be gathered at almost zero private cost. However, the exploitation of forests and natural fertilizers for energy needs leads to environmental degradation and consequent undesirable effects such as deforestation, soil erosion and desertification; in the case of excessive fuelwood removal, loss of nutrients and valuable fodder; in the case of burning of dung and agricultural residues, even damage to health. Rural poverty, aggravated by fuel shortages is driving villagers in numerous developing countries to shift to foods that require less fuel for cooking, although they are of low nutritional value, or even to miss some meals altogether and so go hungry. The shortages are also driving people in some areas to shift to food which can be eaten raw but is less nutritious, or to eat partially cooked food which could be toxic.

The situation of most urban poor is no better than that of the rural population. Since many slum-dwellers and squatters in Africa, Asia and Latin America are rural migrants with inadequate resources, they try to satisfy their energy needs in the same way as they had done in rural settlements: firewood and charcoal are the most commonly-used fuels for cooking and heating in the semi-rural squatter settlements on the outskirts of large urban settlements.

Strategies are, therefore, urgently required for implementation which address the issues of making increased energy available to the rural and urban poor and using available energy efficiently.

The United Nations Centre for Human Settlements (Habitat) has been making an unremitting effort aimed at alleviating the fuel crisis of the rural and urban poor. This publication is a continuation of that effort. Various studies, carried out over the years, have analysed the ways in which fuel scarcity for the poor is widening and deepening. They all tend to show that there are three types of possible solutions: increased biomass production, improved conversion efficiency and substitution by other fuels, i.e., switching. Possibilities exist for increasing the supply of biomass from homestead, crop and public land: planting of trees to increase the available supply of firewood for the local population is crucial to alleviating the domestic fuel crisis; the efficiency with which existing supplies of biomass are utilized can be improved through the introduction of improved cooking stoves or biogas plants; and, apart from producing additional biomass for fuel and utilizing existing sources efficiently, there may also be scope for relieving shortages by fuel switching. The three types of possible solutions are examined in detail in this publication. In addition to reducing fuel scarcity, these solutions could provide increased opportunities for setting up rural industries which would generate income and help in poverty alleviation. It is hoped that the publication will be found useful by policy makers as well as by officers and organizations involved in finding solutions to the energy problems of the poor and to the growing environmental questions posed by the existing energy-use patterns.



Dr. Arcot Ramachandran
Under-Secretary General
Executive Director

INTRODUCTION

Major changes in patterns of human settlements have always involved complementary changes in patterns of energy use. These changes have included interfuel substitution (switching), the development of new technologies to utilize new fuels, and efficient ways of using old fuels. There have, often, been changes in the methods and organization of fuel transport. Figure 1 illustrates past and future trends in energy use in developed countries. These changes occur for a number of reasons, e.g., the discovery of new energy resources which stimulates interfuel substitution and the development of technologies to realise the potential of the new resource. Alternatively, as existing resources of energy become scarce, there is an incentive to find replacements as well as to conserve those existing resources.

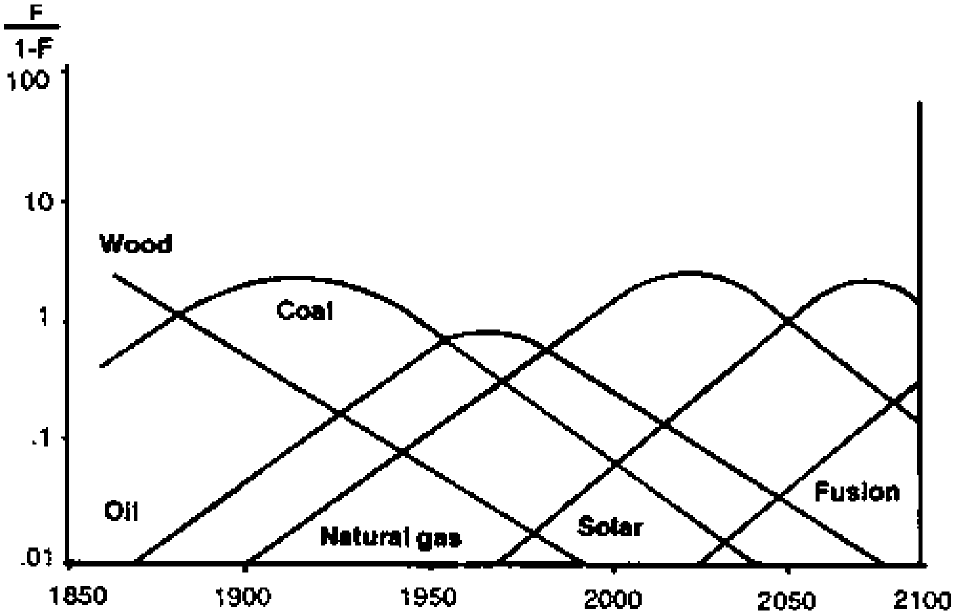


Figure 1. The evolution of primary energy inputs mainly in developed countries as predicted by C. Marchetti, "Swing cycles and the global economy", *New Scientist,* May 1985.

Note: F is the fraction of total energy used

The major switch in the first 70 years of the twentieth century was the substitution of wood and coal by petroleum products and electricity, fairly rapidly in the developed countries and slowly in the developing world. Petroleum fuels have the advantage over wood and coal of higher energy content per unit weight, and they require simple and cheap conversion technologies. They also allow both goods and energy itself to be transported long distances. In addition, the development of low−cost oil−based fertilizers, in conjunction with low−cost and convenient energy sources, has ensured dramatic increases in agricultural output.

This pattern of growth altered when the price of oil significantly increased in the 1970s. Economic growth rates declined and many countries incurred large debts to finance oil imports. These increases in energy prices and the influence of excessive dependence on oil imports were the two main causes of the revival of interest in the development of and switching to alternative sources of energy, to use local resources, both renewable and non−renewable, and in the technologies to utilize these alternatives. Programmes were also initiated to reduce the consumption of oil−based fuels by improving the efficiency of end−use devices, and by better energy management practices. These measures, combined with a global decline in economic growth rates, managed to produce significant reductions in the growth of commercial energy consumption (1). Recently, the failure of oil−exporting countries to limit production has, together with these factors, prompted a decline in international oil prices.

Yet this decline in oil prices has not appeared to benefit the majority of people in developing countries. Most of the research and development on alternative sources and technologies has focused on the replacement of petroleum products consumed primarily by the developed countries and by high−income groups in the urban areas of the developing countries. Nevertheless, a some researchers have been closely examining patterns of energy consumption amongst the majority of the population in developing countries, i.e., rural people and low−income groups in the urban areas. Their work reveals that those who rely on woodfuels and other biomass material as their main source of energy, have been experiencing both shortages in and increasing costs of energy (2). Increases in population, changes in agricultural practices and over−exploitation of existing forests have led to increasing deficits in the supply of biomass sources of energy in many countries and regions.

In rural areas, people are finding wood difficult to collect and are being forced to cut live trees or substitute wood with residues, or residues with dung (3). For low−income groups in urban areas, especially where charcoal and wood are major fuels, there have been increases in the prices of woodfuels commensurate with increases in prices of electricity and liquid fuels (see figure 2). These have often had a significant impact on disposable household incomes. Further, the shortages of both biomass, and sometimes, other fuels are often closely associated with land degradation and falling agricultural yields, further reducing incomes and employment.

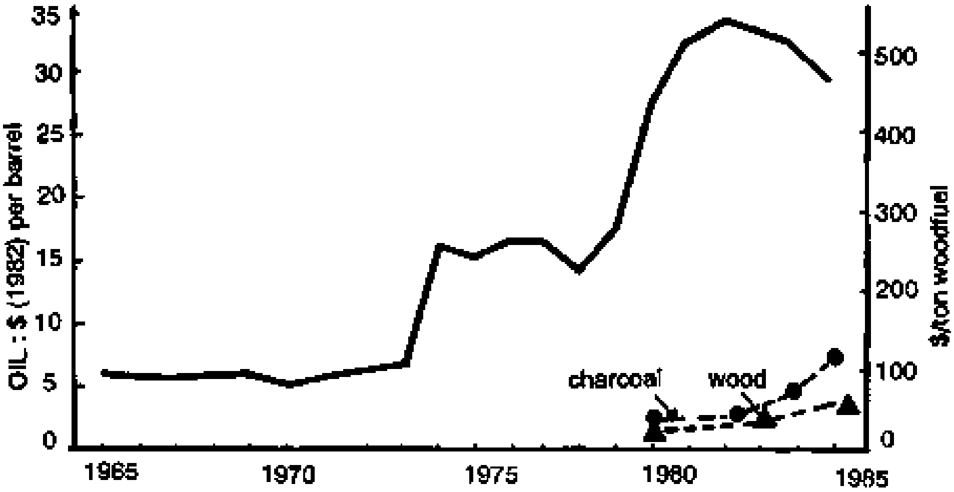


Figure 2. Changes in the OPEC price of oil and woodfuel (for Kenya)

Source: Biomass Energy Services and Technology (1984)

To assist developing countries in reducing petroleum imports, increasing the useful energy available to low−income groups and stimulating economic growth, many analysts have advocated programmes and technologies to encourage a switch from non−renewable to renewable sources of energy in the domestic, agricultural, industrial and transport sectors. Although funding has been limited, a number of technologies have been developed, and some renewable−energy programmes have been implemented. However, most funding has been for large hydro−electric schemes and, to a lesser extent, energy plantations (mainly wood and sugarcane). In most cases, the major part of the energy generated from such projects has been used by large industries, private transport or by high−income families. Relatively little funding has been allocated to programmes on alternative fuels or technologies appropriate or accessible to the rural poor such as small farmers, landless labourers or to low−income urban groups. Some programmes, for example, on improved stoves, tree production and power alcohol, have achieved their objectives, and there are instances of new technologies being introduced in relatively large numbers. However, on the whole, work on renewable energy sources and conversion technologies seems to have had little impact on patterns of energy consumption amongst rural and urban low−income groups.

A solution to the energy problems of human settlements requires revised and innovative strategies, namely, switching, emphasizing the rational use of non−commercial alternative energy resources and adoption of new technologies aimed at modernizing the use of traditional energy sources. There are wide variations in the potential supply and need for energy among different settlements: choice of technology and implementation have, therefore, to be tailored to the specific conditions of each settlement. Urgent attention should be given to ensuring an uninterrupted supply of the most appropriate energy to meet, at least, the minimum basic needs of the rural and urban poor and, wherever possible, to generate employment through setting up cottage industries.

I. TRENDS AND IMPLICATIONS OF ENERGY SWITCHING

Introduction

Energy switching can be implemented at different levels within the national economy. At a general level, switching implies a relative decrease in the use of one or more energy sources, with a corresponding relative increase in others. As these are relative changes, switching also occurs if the use of a given source or form of energy decreases, whether in a specific end−use or, generally, because of improvements in end−use efficiency. Thus, broadly, there are two main categories of switching: (a) switching between renewable and non−renewable sources of energy; and (b) switching within categories of energy sources.

- Switching between renewable and non−renewable sources of energy includes:

  (a) Replacement of a non−renewable source of energy by a renewable source of energy; for example, the use of wind to replace diesel fuel as a source of power for pumping;

  (b) Replacement of a renewable source of energy with a non−renewable source of energy; for example, the replacement of charcoal and wood by LPG and/or kerosene as a source of heat energy for domestic cooking.

- Switching within categories of energy sources can involve:

  (a) The replacement of one renewable or non−renewable energy source by another renewable or non−renewable energy source, for example, a switch from the use of wood to residues for domestic cooking in the renewable category. The switch may also be in terms of a shift in the quality of a fuel, as measured by its calorific value or convenience, for example, in the case of non−renewables, a switch from coal to a higher−grade fuel such as LPG for domestic cooking;

  (b) A switch from a sustainable use of renewable energy sources, usually biomass, to a non−sustainable use of the same resource, trees being harvested more quickly than they are being replaced; or the soil being rapidly degraded by the continuous harvesting of an energy crop without replacement of the nutrients needed for soil fertility;

  (c) A switch from one level of fuel efficiency to another, either higher or lower; for example, an improvement in cooking−stove efficiency, which reduces the amount of fuel needed for a given cooking task.

A. Present trends in energy switching and energy consumption patterns

Available evidence indicates that most or all of the switching processes mentioned above are occurring simultaneously in many countries. For example, in Bangladesh the following changes have been observed (3,4). In urban areas, middle−income and upper−income groups have been switching between non−renewable sources for domestic cooking from kerosene and electricity to LPG; industry has been switching both within non−renewables sources, from coal and oil to LPG; and from renewable to non−renewable sources, from wood to oil. In rural areas, with the recent rapid removal of tree cover, households and industry have been switching within renewable sources from wood to residues. With declining real incomes, farmers in some areas have been switching from non−renewable to renewable sources for power: from tractors, diesel pumpsets and diesel or electrically−powered process machinery to bullock−powered and human−powered irrigation and processing. In other areas, the switch has been in the other direction, especially where electricity is, or is about to become, available. Where the bullock population has declined, for example, due to lack of fodder (itself due to pressures on land), small−scale sugar processors are being forced to purchase or hire diesel power for cane crushing, instead of using bullocks, leading to reductions in the profits available to small farmers and, in many cases, to reductions in cane production. Clearly, the changing energy system, is extremely complex.

In rural areas of developing countries, the household sector consumes the greatest amount of energy, primarily in the form of fuelwood for cooking. This is true despite the absence of space−heating requirements in tropical areas and the generally simple lifestyle. This relatively high consumption reflects the small amount of energy used for other productive activities and is also due, in part, to the inefficiency of end−use technologies. In the majority of households, fuelwood is used on the open fire with a "three−stones" arrangement.

In regions where space heating is required and where there is unrestricted fuelwood collection, consumption estimates are between 2.6 and 2.9 tons of fuelwood per person per year. In areas where space heating is not a necessity, the annual per capita consumption generally drops to between 1.2 and 1.5 tons (5). Contrary to urban areas, the percentage of biofuels in the rural household energy budget tends to be independent of income level.

It is generally agreed that, as long as fuelwood remains available, it will continue to be widely used for cooking in rural areas of developing countries. Apart from the fact that fuelwood is the traditional source of energy in these areas, another reason for its popularity is that, while other fuels are unavailable or expensive, wood is generally a "free" commodity in rural areas. An open fire provides the household with light and heat and acts as a social focal point. Wood smoke both flavours and preserves food and keeps insects from infesting the organic material of the house's walls and roof. Fuelwood is also easy to use and provides a wide range of cooking temperatures.

If this traditional fuel is unavailable, other, less valued, sources are generally employed. Two recent surveys in East Africa seem to indicate a greater pressure on firewood than revealed by time allocation studies. In the United Republic of Tanzania, women are recorded as spending up to 12 hours per week seeking firewood at a distance; this is supplemented by twigs picked up by women and children traveling to and from the farm fields (6). A lower figure is recorded in a Kenya study which indicates that women spend between 30 and 60 minutes a day collecting firewood. Three fifths of these families also had charcoal burners and used two types of fuels for different purposes. The wealthy farmers purchased the charcoal but, in one quarter of the households, the householders made charcoal for their own household use and sale (7).

Three trends in energy consumption patterns have emerged over the past decade. First, there have been decreases in the rate of growth in world consumption of non−renewable energy sources. In most developing countries that are major importers of energy, this has contributed to declining growth rates and increasing percentages of export earnings that have to be allocated to payments for oil imports (see figure 3). In many countries, these act as major constraints on economic growth. Secondly, and as a corollary to the first, there have been switches between and within renewable and non−renewable energy resources of the type described earlier. These changes are complex and varied, but the overall effect has tended to be an added pressure on both renewable sources of energy, almost entirely in the form of biomass, and on non−renewable sources of energy, mainly oil−based liquid fuels.

A third trend common to virtually all developing countries is the increase in demand for oil−based liquid fuels for transport. According to a study, transport accounted for half of the total increase in oil use between 1970 and 1984 in Argentina, Brazil, Chile, Colombia, India, Indonesia, Malaysia, Mexico, Pakistan, Philippines, Republic of Korea, Thailand and Venezuela (8). Figure 4 shows the use trend in transport in nine developing countries between 1970 and 1985. Combined oil use in transport for these countries increased at an average of 5.8 per cent per year between 1970 and 1985 while GDP growth averaged 4.9 per cent per year. Most of the oil use in transport in developing countries and most of the growth in oil use, is in road transport. In 1984, the study estimated that the share of road transport was over 90 per cent in the majority of the countries mentioned above.

With wood and residues as the dominant sources of energy in most of the poor non−oil−producing countries, the pressure on biomass resources manifests itself as an increase in their non−sustainable use, as the annual rate of removal of tree and other biomass cover has become greater than the annual increment.

Within these global trends, particularly the last, there are marked differences between countries and regions within countries. For example, 82 per cent of the total energy consumption is provided by biomass in Sudan, but only 18 per cent in Colombia (an oil−producing country). A number of distinctions will aid the analysis of these differences. A first distinction is between countries that are producers and exporters of petroleum products, and those that are importers. Increases in consumption of petroleum products in the former tend to be greater than in the latter, while increases in the pressure on and use of biomass tend to be greater in the latter. A second distinction occurs between the few countries that have net annual increments of biomass resources, for example, Fiji (9), and the many that have an annual deficit, for example, Sudan. Unfortunately, sufficient data are not available to illustrate differences in changing patterns of consumption between these groups, although such differences are likely to be significant. Although not so important in global terms, a third distinction occurs between countries that are net exporters of renewable sources of energy, mainly hydro−electric power and wood or charcoal, and those that are importers. At present, some countries are exporting wood and charcoal to deficit countries. Most of this trade is illegal, and although the quantities are relatively small in relation to national consumption, they, nevertheless, have significant local economic and ecological impacts.

These trends show that patterns of energy supply and consumption, and changes within them, vary widely between countries and between regions within countries. They illustrate the need for the development of highly location–specific energy or switching strategies at both regional and national levels.

B. Implications of energy switching

The above changes illustrate a number of important issues. Perhaps the most important is that energy itself is not the main issue: it is the sources, the end–uses, the means of conversion and its distribution which both determine and are determined by switching processes. Because of this, a study of switching between energy sources and technologies cannot be confined to discussion of the energy sources or conversion technologies alone. Instead, it must include consideration of the development framework within which changes and switching take place, and should consider the employment, distributional, income generation and ecological aspects of any changes in energy supply and consumption patterns, and of energy commitments. Although energy is necessary for all productive activities, an increase in the total amount of energy in a system may not in itself lead to an increase in the well–being of the population as a whole. For example, increasing energy inputs to agriculture by switching from bullock to tractor power might, in some cases, reduce both employment and yields, although the change might have been designed to increase, at least, the latter. Similarly, changes in land–use patterns induced by energy concerns might lead to undesirable changes in patterns of energy consumption. For example, a switch to energy crops for export outside the rural community might increase competition for land to produce food and fodder, and reduce the amount of energy available locally for humans and animals. A corollary is that, if increased supplies of energy and its redistribution or improved utilization are to be achieved in ways which conform with over–riding requirements of development policies, it is essential to take a broad systems approach to the analysis of energy problems and the design of interventions. Only this type of approach can lead to the development of comprehensive strategies that would increase energy supplies to low–income groups in rural and urban areas, and improve utilization in all applications in the household sector, on the farm, in small industry or in transport.

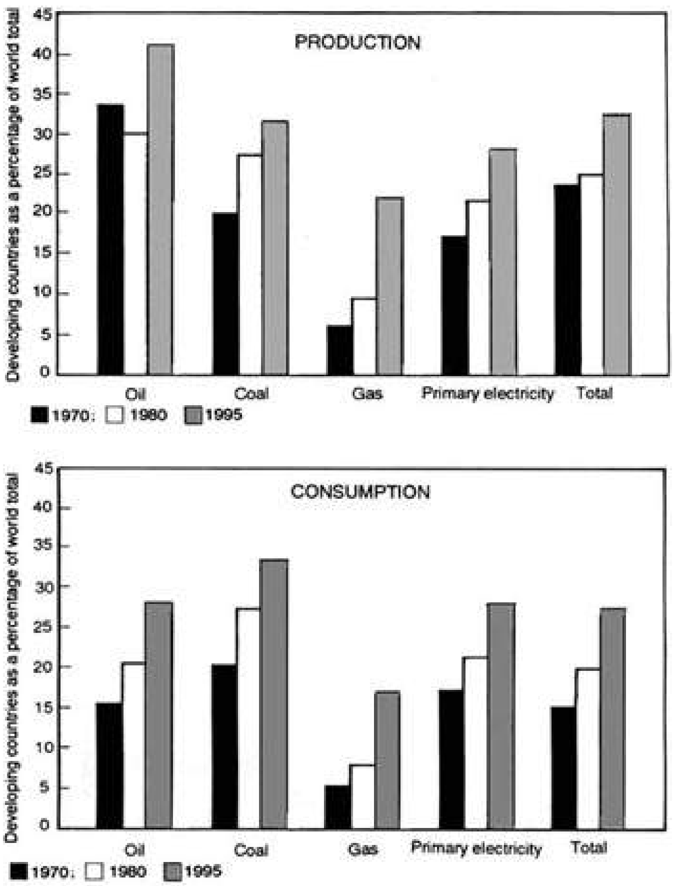


Figure 3. Shares of developing countries in world primary commercial energy production and consumption, 1970–1995.

Source: (2)

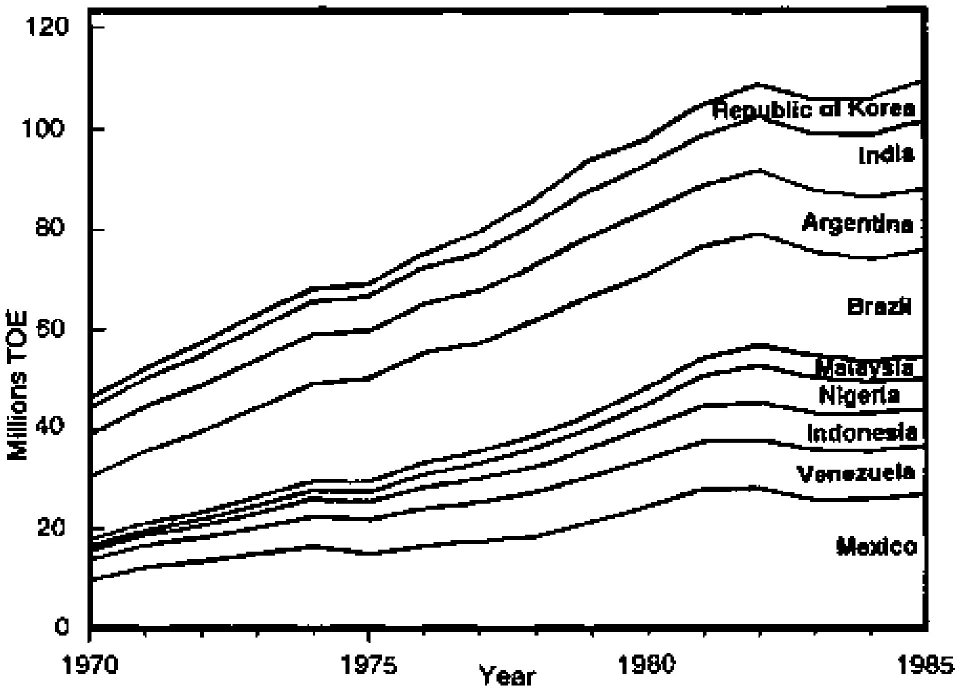


Figure 4. Use of oil in transport in nine LDCs, 1970–1985

Source: (8)

Such strategies will be complex and far reaching, and extend over considerable periods of time. To give a simple example of such a strategy, in an oil–importing country, where the rural and low/middle–income urban groups rely on ever decreasing supplies of wood, the following could be applied. Initially, kerosene prices would be reduced and kerosene stoves made available to decrease the rate at which low–income groups switch to wood, and to reduce the rate of tree removal in rural areas. At the same time, a long–term programme of tree planting would be started, along with the introduction of efficient biomass conversion devices such as domestic stoves and industrial furnaces. Briquetting agricultural residues could, in some cases, allow the production of substitute fuels. To avoid reductions in agricultural output, farmers would be provided with assistance in planting trees on marginal lands or intercropping trees with food crops. They would also need assistance with domestic, on–farm and crop processing technologies using wood or other renewable energy resources. Pumping programmes would be developed to use renewable energy sources and technologies to supply the water needed to increase yields of both food and energy crops. Where increased amounts of energy in the form of wood, charcoal or briquetted residues are to flow from rural to urban areas, increases in both on–farm and off–farm transport might be necessary, together with improvements in the utilization of whatever transport already exists. Once increases in the supply of wood, charcoal or briquetted residues is assured, and improved appliances have been developed that are acceptable to users, kerosene pricing policies could then be reversed to re–encourage the use of wood fuels in urban areas.

If successful, such a strategy would contribute to rational economic development policies, including increases in agricultural production and rural employment, and re–distribution of income towards the rural areas and the urban poor.

C. National responses

Like the changes themselves, the policy responses of governments to changes in pricing and supply patterns for oil–based and biomass fuels have varied between countries. Some have concentrated on the search for indigenous sources of non–renewable energy. Others have established programmes to promote switching from non–renewable to renewable sources in specific sectors, for example, the alcohol for transport programme in Brazil. Many countries, for example, Sri Lanka, have started to exploit large–scale hydro resources fully, using known technologies.

In some countries, the response has been significant reversals of previous policy. For example, Indonesia originally encouraged a switch from renewable biomass fuels to non–renewable kerosene and LPG in the domestic and informal commercial sectors, by subsidizing the retail price of the latter, one major objective being to maintain or increase tree cover. However, in the past few years, the Government has realized that rapid increases in domestic consumption of oil−based liquid fuels would soon eliminate export earnings. Subsidies on these fuels were removed and there appears to be a switch back to renewable biomass fuels. Soedjarwo (in a personal communication) observed that the numbers of people and vehicles selling and transporting charcoal in the central Java area seem to have increased dramatically, since the price of kerosene was doubled. In Ghana, a different type of policy switch was made, this time within the renewable sector: groundnut shells are being briquetted and substituted for charcoal as a domestic fuel in urban areas.

Despite these and other examples, only a very small number of countries, Nepal being, perhaps, the best example, have allocated significant resources to conservation of non−renewable energy resources, and to long−term increases in the supply of renewable resources by increasing the tree cover or other means such as briquetting residues previously wasted. In the Pacific region, the emphasis has been on restructuring petroleum prices, energy conservation and switching from oil to wood for power generation.

D. Factors affecting energy consumption

Existing patterns of energy consumption, and the constraints on and potential for switching in rural areas depend on complex interactions between several factors, including land ecology and fertility, population density, patterns of land use, income levels and distribution, and proximity to net energy importing and exporting regions. Definition of most important factors and of distinctions between them is, therefore, a pre−condition for thorough analysis. Recent studies suggest that the most important of the many factors affecting household and on−farm consumption is the potential of the land to produce biomass. As biomass, whether converted by animals or by humans, or through direct or indirect combustion, is the most important source of domestic, on−farm and small−industrial energy in rural areas (10, 11, 12, 13). Analysis of this potential requires the definition of three distinct categories of land zones: low−potential, medium−potential and high−potential zones (14).

(a) Low−potential zones, are usually arid, the main activities being nomadic and pastoral and subsistence farming. These zones have no forests and the main forms of biomass cover are shrubs, grasses and bushes. In many areas fuel wood is scarce, and people use dung or twigs, leaves and residues;

(b) High−potential zones are areas with an abundance of rainfall, fertile soil, and potential net exports of food, fodder, fuel and other agricultural raw materials. In some cases, much of the land is owned by large estates, in others most of the farming is done by smallholders. In the latter case, population densities tend to be high, and many families have to pay for, at least, part of their fuelwood supply or are switching to agricultural residues. In some areas, farmers have found it profitable to grow trees for building poles or fuel, instead of allocating land for food or fodder crops production;

(c) Medium−potential zones are areas which are in−between the low−potential zones and high−potential zones.

In all three zones, distinction should be made (10) between villages or districts where there are shortages of fuel and where there is relative abundance of fuel (11). Distinction should also be made between areas where households and rural industries must buy all their fuel (i.e., fuelwood is commercialized) and areas in which they collect all fuel (i.e., fuelwood is not commercialized). Available data suggest that, in many areas, most households both collect as well as purchase their domestic fuel whilst most industries purchase their fuel.

Given these distinctions, Foley (10) has suggested that analysis of energy supply and consumption patterns, particularly in the domestic sector, requires both a definition of the potential for biomass production, and consideration of whether or not the area being studied is one in which fuel supplies are constrained or unconstrained. If the former, the degree of fuelwood commercialization has first to be examined; only when this is done, can the implications for increasing or redistributing energy supplies, or other energy commitments, be made.

The potential for switching between or within renewable and non−renewable sources of energy is very different in each set of categories: the following paragraphs illustrate some of the common and important examples of switching.

Where wood supplies are constrained and commercialized, low−income groups who do not own trees tend to switch from wood to residues, but they often collect wood on communal, government or private land, as an income−generating − activity. Those with access to small quantities of wood might initially conserve existing stocks by careful operation of the fire or drying of the fuel. Subsequently, they might switch to residues, or purchase improved stoves if available. Those who own or have access to land have an incentive to sell some wood and/or to plant trees, where such access permits them to produce food in excess of their household requirements. Large−scale landowners might consider major and long−term investment in the production of wood fuel. If alternative fuels, such as kerosene, that are cheap per delivered unit of energy and which are convenient to use, are available, wealthy households might purchase new stoves to use this fuel. Indeed, such fuels are often used for convenience, even when their costs are high.

In high−potential areas with constraints on both fuel and fodder, there might be switching from draft−animal power to human power for agriculture, agricultural processing and transport on the part of low−income groups, and to mechanized power and mechanized transport on the part of high−income groups. The specific directions of such switching and their extent depend on complex interactions between relative fuel prices, their availability, the relative convenience of different end−uses and conversion devices (for example, LPG stoves which cook fast, do not make pots dirty and do not produce smoke), the price of end−use appliances, the available markets for wood, transport availability and cost, distribution of wealth, and existing land−use patterns.

In low−potential areas, the options are few. The main direction is a switch from wood to residues or low grades of wood−fuels, and to dung. Wealthy groups in these areas tend to switch to kerosene, if available.

The above comments apply, in general terms, to all user sectors, especially the domestic one. Specific comments about the farm sector are made by Bhattia (15), who suggests that for the different ecological zones, the pattern of energy use in farming systems will depend on:

(a) The type of enterprise (seasonal crops, plantations, livestock);
(b) Farm size and organization (small/large−scale, private/cooperative/collective);
(c) Extent of commercialization (subsistence, commercial, mixed);
(d) Intensity of labour use (extensive, intensive);
(e) Extent of irrigation (rainfed/irrigated).

Patterns of energy consumption also depend on the type and availability of transport. Where there are extensive road networks and agricultural productivity is high (e.g., in Punjab, India), there tends to be extensive use of motorized transport as well as animal and human power, which allows considerable movement of energy resources. Where productivity is low (as in parts of the United Republic of Tanzania) much transport is by human or animal power. In such areas, there is little movement of energy resources between villages, or from rural to urban areas.

In urban areas, patterns of energy consumption depend on a restricted range of variables such as income, the availability of a small range of different fuels, the relative costs of appliances, transport costs and distribution of sales outlets. An important aspect of switching in urban fuel consumption patterns is noted by Alam and others (16), who suggest that they are not isolated from parallel changes in price and availability of fuels in the rural areas and vice versa. This is discussed in more detail in later sections.

On the basis of these distinctions and relationships, it is possible to draw up a basic framework which could help to organize and analyse data on energy supply and consumption patterns, for the development of energy interventions in different areas. Developing the framework requires seven separate stages.

(a) Initially consider urban and rural areas separately;

(b) In urban areas determine the major patterns of domestic energy consumption and to what extent it depends on income, occupation, availability of fuel, supply, or location, etc. Determine how patterns of consumption have changed in the last 10 years and the major reasons for any switching that has occurred. In particular, examine how government fuel−pricing policies, especially for non−renewable domestic fuels, might have affected the fuel market, and what future changes in policy might imply. On the basis of this analysis, predict how patterns might change in the future;

(c) Divide the rural areas into ecological zones based on their potential to produce biomass;

(d) Divide each zone into areas of high level and low level of commercialization. Further divide each of these into areas of constrained and unconstrained fuel supplies;

(e) Within each area examine the patterns of energy consumption in four separate sectors − household, farm, small processing industry, and transport. Determine for each sector how and why patterns have changed, both within and between renewables and non−renewables;

(f) Determine how increases or decreases in the supply of a fuel or switching in one of the sectors produces changes in other sectors;

(g) Finally, examine how changes in urban patterns of energy consumption affect changes in the rural areas, especially the commercialization of wood fuel and switches from wood to agricultural residues. Consider the transport implications if switching does occur.

II. SECTORAL PATTERNS OF ENERGY USE AND THE POTENTIAL FOR SWITCHING

Introduction

One of the first requirements for the development of the framework described in the previous chapter is the acquisition of data on existing energy supply and consumption patterns and changes therein. Much of available data are very inaccurate owing to the short duration of studies or poor data collection techniques. This lack of high quality data is a serious constraint on evaluation of existing trends and programmes and on the development of further energy commitments. Finally, the complexity of energy flows, especially in the rural areas, is such that complete separation of the flows into those that apply to different sectors is possible only to a limited extent, as the flows in one sector often depend on and affect flows in others.

A. Overall energy−use patterns in rural areas

Partly because of the complexity of energy flows in rural areas, very few thorough relevant studies have been carried out so far. Most of them indicate that the major demand for energy in rural areas is from households (17): studies by Bialy in Sri Lanka (18) and Pathak in Punjab, India, (19) indicate that the energy required for cooking is two to three times greater than the energy content of the food being cooked. This is then followed by agriculture, including on−farm and off−farm activities and small−scale industry. Energy used in transport is approximately one tenth of that used for cooking. The studies indicate that, at present, trees and natural vegetation provide about twice as much biomass energy as agricultural residues. The energy used in transporting surplus food is very low, probably not much greater than the energy used to transport the wood from farms to households and to urban areas.

A study in the village of Ungra, a medium−potential production area in India (20), provides a graphic indication of energy use in the different sectors (see figure 5, tables 1 and 2). It confirms that the major energy requirement is for domestic cooking, followed by commercial/agroprocessing and agriculture. It also points out the important and complex links between production from the farm, the level of transport and domestic energy consumption. Land is used for the production of food for animals and of humans, and trees for fuel and for use as building materials. Animals use the energy derived from food to transport goods and to prepare the land for production. They also produce fuel and fertilizer (dung) and some produce food (milk and meat).

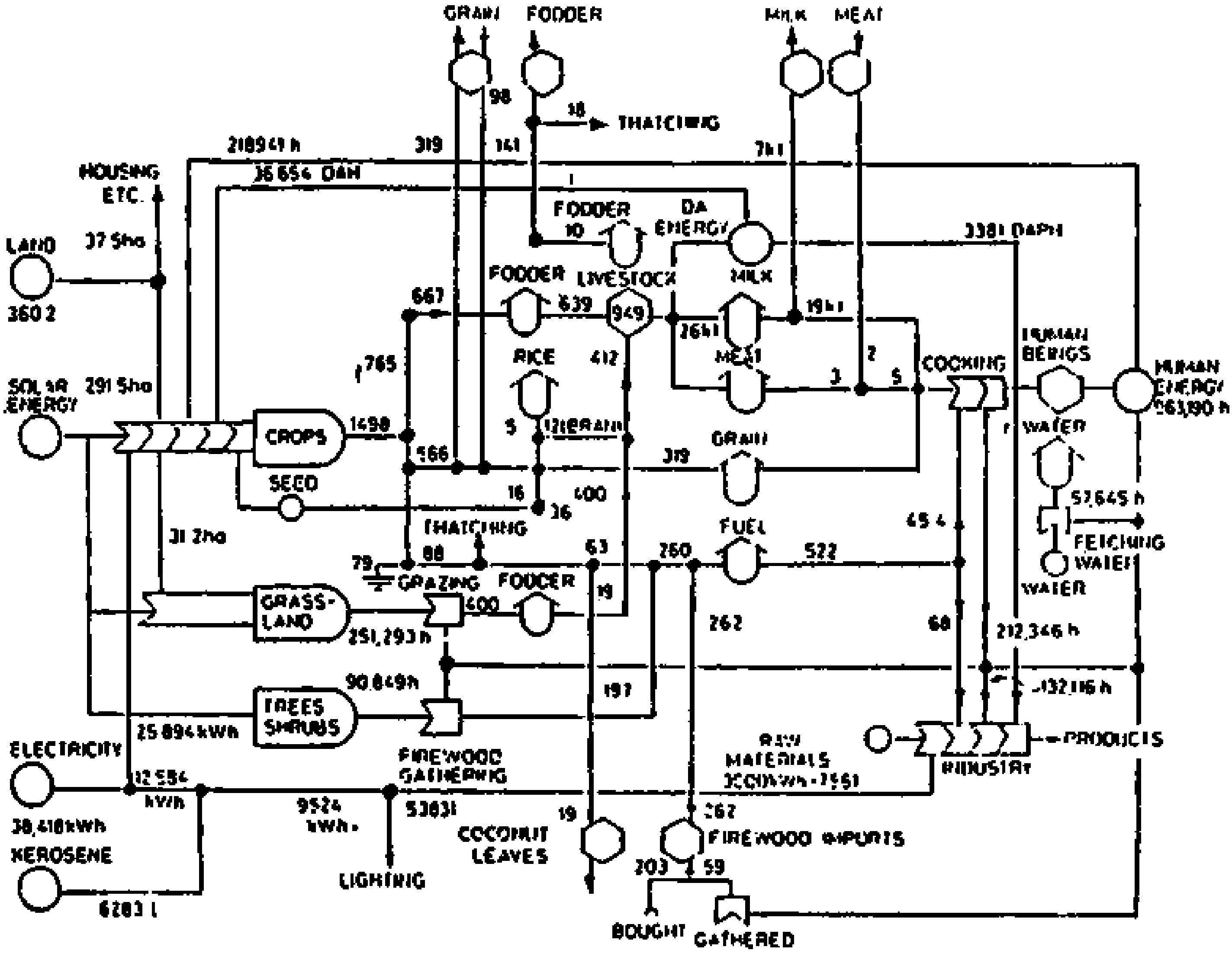


Figure 5. The Ungra agricultural ecosystem

Source: (20).

Another important point brought out in this study is the delicate balance between the production of food, fodder and fuel. The greater the animal population, the smaller is the amount of land available for crop production, or the amount of crop and food residues available for other purposes. FAO (21) suggests that 6 hectares of land which could otherwise be used to grow trees or food crops are needed to maintain one draught animal in semi–arid areas. Clearly, switching to different energy sources, either on the farm or in the household, can make a significant difference to the product mix and to the productivity of the land.

Table 1. Energy sources and activities in Ungra

Source	Units	Agriculture	Domestic	Lighting	Industry	Total
Human	h	218 941	612 133	–	132 116	963 190
Man	h	143 549	168 671	–	110 135	422 355
Woman	h	75 392	305 304	–	19 426	400 122
Child	h	–	138 158	–	2 555	140 713
Animal	h	36 654	–	–	3 381	40 035
Firewood	kg	–	411 636	–	68 085	479 721
Agro–waste	kg	–	42 808	–	–	42 808
Electricity	kWh	25 894	–	9 524	3 000	38 418
Kerosene	litres	–	144	5 383	756	6 283
Diesel	litres	32	–	–	–	32

Coal	kg	–	–	–	1 500	1 500

Source: (20)

Table 2. Ungra energy source–activity matrix (x10^6 kcal per annum)

Source	Agriculture	Domestic	Lighting	Industry	Total
Human	51.0	119.9	–	31.7	202.6
Man	35.9	42.2	–	27.5	105.6
Woman	15.1	61.1	–	3.9	80.1
Child	–	16.6	–	0.3	16.9
Animal	84.3	–	–	7.8	92.1
Firewood	–	1 564.2	–	258.7	1 822.9
Agrowaste	–	162.7	–	–	162.7
Electricity	22.3	–	8.2	2.6	33.1
Kerosene	–	1.3	48.3	6.8	56.4
Diesel	0.3	–	–	9.9	9.9
Total	157.9	1 848.1	56.5	317.5	2 380.0

Total village energy = 2.766 × 10^6 kWh year^{-1} = 7578.5 kWh day^{-1} = 8.12 kWh day^{-1} per capita

Source: (20)

A study of energy use in three high–potential districts carried out in Indonesia by Weatherly and Arnold (22) also found that the biggest consumer of energy was the domestic sector, followed by household and small–scale industries (see figure 6). No separate data are given for on–farm energy use, and only very crude estimates for transport or industry have been given.

No studies exist on overall energy consumption patterns for village systems over extended periods of time. The available evidence is that each village has a unique energy map, which implies that the form and results of switching in each village will be different. However, a general conclusion that can be drawn from the available data is that there has been a general trend amongst wealthy villages and villagers to switch from woodfuels for all domestic needs to kerosene, LPG, or charcoal and electricity for cooking, and to kerosene, LPG and electricity for lighting. There have been large increases in the use of electricity, diesel and petrol on wealthy farms in the medium – and high–potential zones, and a subsequent decrease in the use of animal and human power. Simultaneously, there has been a decrease in the availability of all forms of high–grade energy to poor farmers and landless labourers who, then, tend to switch from kerosene to wood and residues for lighting, and from wood to residues for cooking.

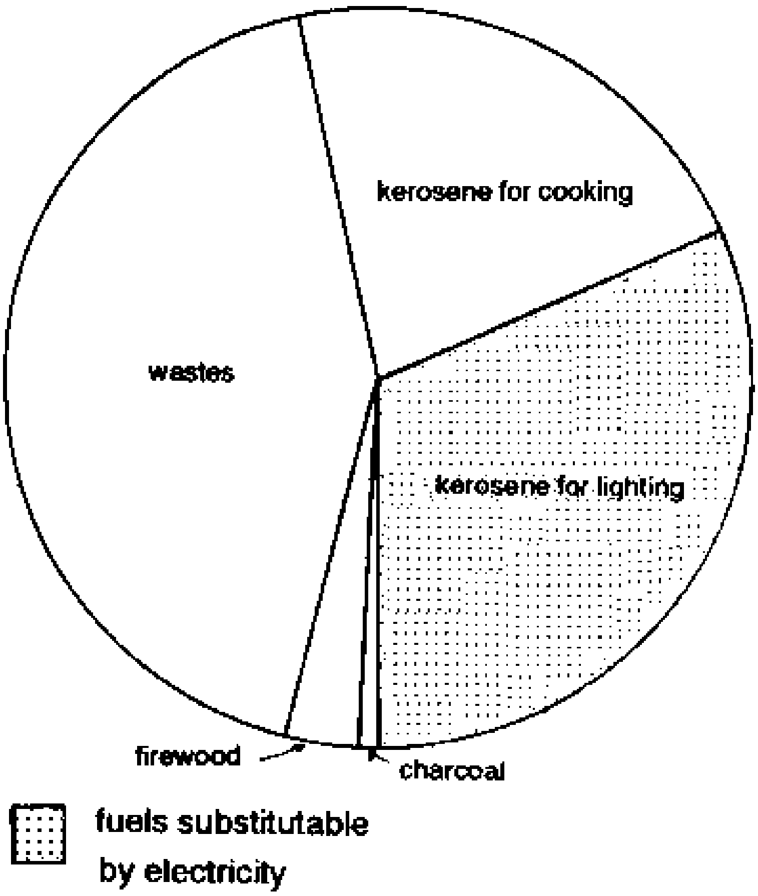
B. Rural domestic and industrial energy–use patterns

1. Present energy–use patterns

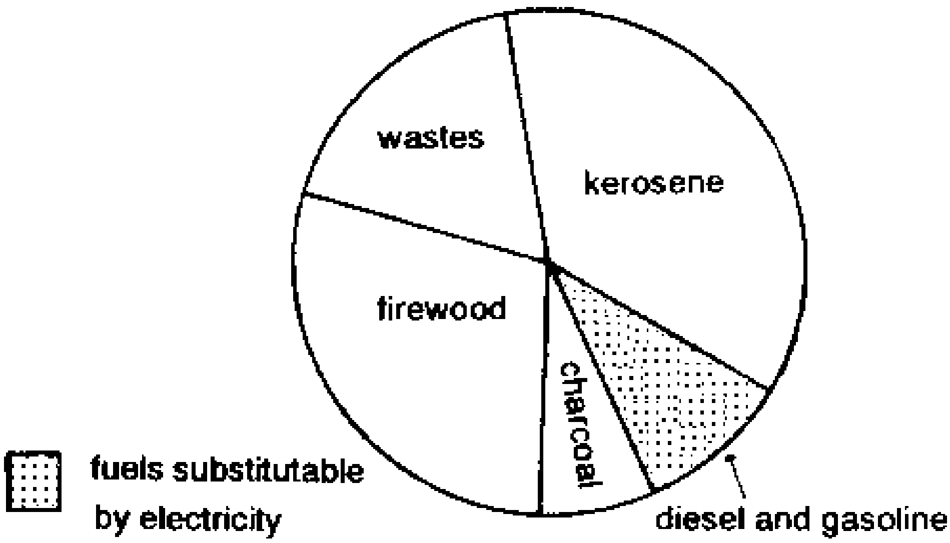
Many studies of domestic energy consumption have been undertaken in rural areas throughout Africa, Asia, the Pacific and Latin America, but these studies usually examine consumption patterns over a very short period of time and only a few examine them over a number of years. Some studies focus on a few households, while others look at a number of villages or regions (see reference 23 for an extensive bibliography on these studies). The methodologies used to collect and process data vary considerably: some studies actually measure consumption, while others report household perceptions of consumption. Despite inaccuracies inherent in these and other methods, and estimates of consumption within and between areas varying by 100 per cent, the following conclusions can be drawn.

The principal fuels used by rural populations are wood and residues. In general, biomass fuel consumption depends on distance from forests or woody areas, patterns of ownership of Wood and residues, types of food cooked, the need for heat, light, preparation of cattle feed, and types of appliances used in the household (24). Average consumption can vary from 0.5–2 kg/person/day for wood to 0.2–0.3 kg/person/day for residues.

Figure 6. Current fuel use in Klaten, Indonesia



Household use



Industry (home and small–scale) use

Source: (24)

There is evidence (25) that domestic energy use in high–potential and medium–potential areas is declining. The most likely reason for this is the decline of biomass availability in many areas, at least for certain groups with limited access to biomass resources. People are changing their cooking patterns, e.g., by preparing two meals each day instead of three, or by operating their fires or stoves carefully (14). However, in some areas such as some low–potential districts in Kenya, energy consumption actually has increased (13). The reasons are not entirely clear, but it is possible that, owing to population pressures, there were increases in agricultural activity, with increasing land clearance; thus, fuel in the form of newly cleared wood had become available, at least in the short term.

There appears to be little difference in aggregate consumption patterns of energy between high−potential, medium−potential and low−potential zones in many countries (3, 25). The main exceptions are found in the high−altitude areas in Latin America and Nepal where fuel is very scarce and consumption is consequently low. Also, in some high−potential zones, possibly, consumption is low when there is very little wood available or people have to purchase wood (i.e., when there is a constraint on supplies).

Within any one zone, the time spent in gathering fuel seems to increase as the size of the holding decreases (26). Those with little or no land are forced to purchase fuel, or collect from perhaps communal sources further away from holdings, in which case they tend to spend more time in fuel collection than those with land. The differences in energy consumption (see figure 7) between different zones and different socio−economic groups in Kenya illustrate these points.

Wood is becoming commercialized in areas where there are supply constraints from population pressures, demand from urban areas, lack of reliable supplies of petroleum fuels or electricity, or from changes in the scale, type or product mix of agricultural production. For example, data from the Gambia (10) indicates that some families had decided to allocate more time to agricultural or wage earning activities than to fuelwood collection and, instead, relied on the purchase of fuel from other villagers.

Kerosene is the main lighting fuel (approximately 10−20 gm/person/day). The total consumption of kerosene for lighting by a country the size of Kenya or Sri Lanka is likely to be less than 2500 tons a year, a very small fraction of total petroleum imports and of biomass energy use.

Charcoal is used mainly by wealthy households, by wage labourers who do not have ready access to wood (25) and in many households for special occasions (e.g., marriages).

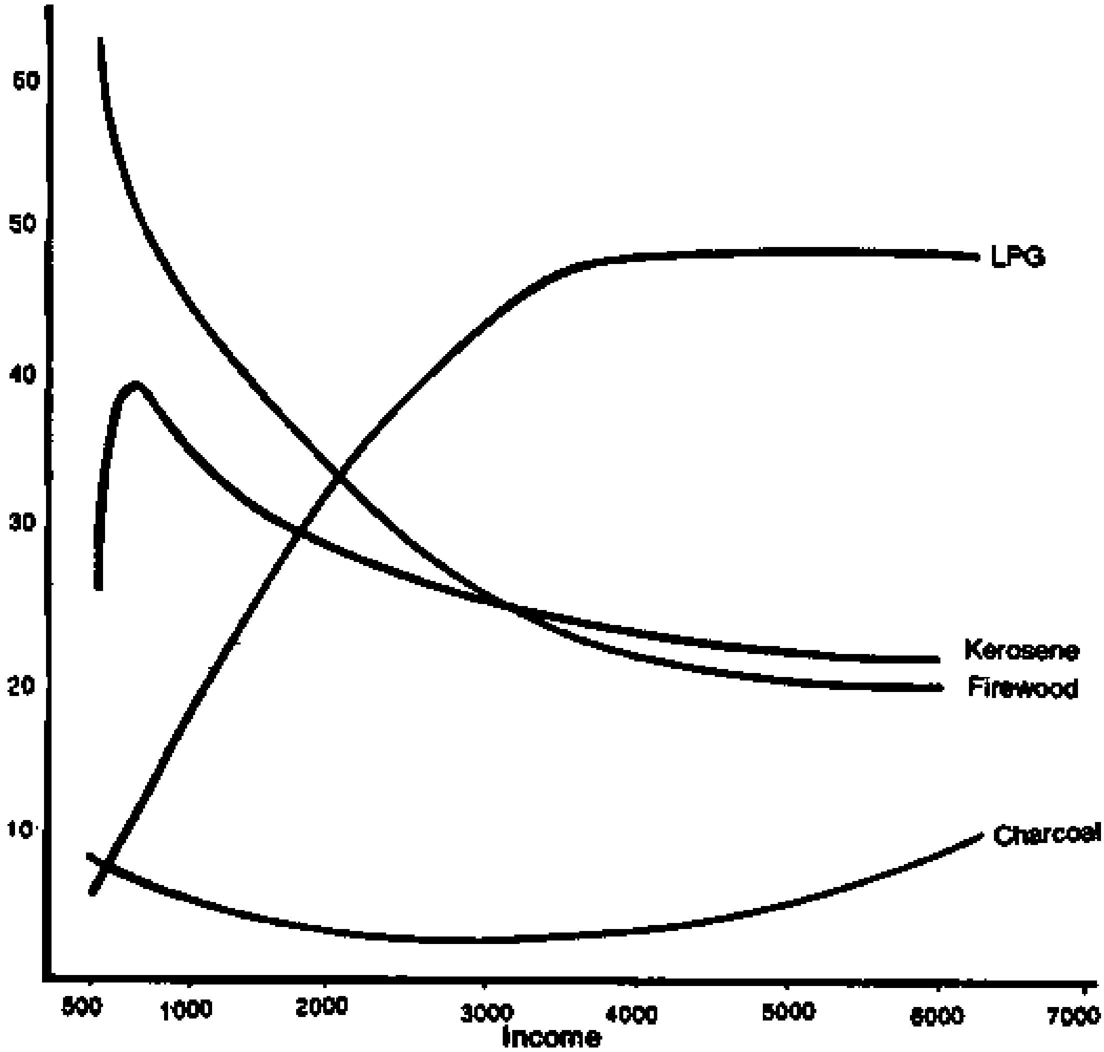


Figure 7. Plot of percentage of total energy versus income

Source: (17)

Electricity has become available to small numbers of rural villages but in most of them, only a small minority of wealthy households have connections, and even fewer use electricity for cooking. Weatherly concludes from his study on Indonesia that

> "the current pattern of fuel use for cooking will not be affected directly by rural electrification.... If poor families are forced by local firewood scarcity... to buy fuel for cooking, the expense of using electricity for lighting will make it very difficult to maintain a year−round electricity hookup" (24).

There is also evidence that the demand by industry in rural areas is increasing, causing important price increases. For example, some tea factories in Kenya which switched from diesel to wood fuel for leaf drying, and to electricity generation purchase wood from the rural areas around the factories and have reported that the price of wood has increased while its availability has decreased.

2. Consequences of the energy−use patterns

The response to the increases in prices and switches in demand varies between countries, regions and sectors. In Kenya, the main response of those who cut wood for the market is to cut into the remaining forests at a greater rate. In other parts of Kenya, the Government and industry, for example, the tobacco industry in Western Kenya, have been assisting farmers grow trees to meet the increasing demand. In Gujarat, India, wealthy farmers are planting wood on high−potential land, mainly for poles, but also for fuelwood. For these farmers, production of wood gives better returns than food crops.

The response of households and industry to changes in the availability of different fuels also varies. Most poor households probably reduce their consumption or switch to low−grade fuels such as residues. In Kenya, Hosier reports that the commercialization of wood and its scarcity are leading to a decline in aggregate consumption (25). Although the poor are using less fuel, in some areas, they are increasing their income by collecting and selling fuel.

Although data for industry are even more scarce than that for households, indications from Asia and Kenya strongly suggest that many industries, especially crop−processing industries requiring process heat, are switching to renewables in the form of wood or residues as a replacement for oil−based fuels. As this switch occurs, residues which might have been virtually free goods become commercialized, with consequent rising prices. Initially, prices tend to rise very rapidly, but once they reach a level commensurate with the costs, calorific values, convenience and availability of other fuels, they probably do not rise faster than those of other fuels. However, there are reports of price increases of 300 per cent for rice husks in India over a period of four years.

The switch to residues has important and complex consequences. The first is that residues often have other end−uses besides fuel, including fodder, building materials, raw materials for domestic and other industries etc. Any increase in demand from one end−use can lead to shortages for other end−uses. For example, in Sudan, projects to produce groundnut shell briquettes for domestic fuel would, if they had gone ahead, would have reduced the availability of groundnut shells as fodder. Further, changes in agricultural practices are already affecting the supply of residues, especially to small and marginal farmers and landless groups. Vidyathi (26) notes that high−yielding varieties of rice and wheat produce less residue than older varieties, and they are often less suitable as fodder. Both factors cause shortages of fodder, increasing the costs of animal power, and making the small and marginal farms which, to a greater extent than larger farms, rely on animal power, less viable. Also, as mechanization and consolidation of small landholdings progress, farmers shed labour, there is less share cropping, and a higher proportion of residues remains with landlords. Although data are scarce, this suggests that lower−income groups are likely to have decreasing access to low−cost or free residues for fuel or fodder. The overall result in many areas will be commercialization of residues, increases in their prices, and severe losses to low−income groups. However, in some cases, increasing use of residues may have a net benefit. For example, in many rice−growing areas, the unused husk remains at the mill and either rots or is burnt. Using husk directly or after briquetting can replace wood or petroleum fuels and help reduce pressure on wood supplies. It may also create employment in handling etc., and is likely to increase profits to the mills.

Increasing the use of residues may create other problems. Some residues, especially dung, are returned to the fields to provide nutrients and organic matter. If the amounts returned to the fields are reduced through dung being used as a cooking fuel, soil fertility decreases. This can be rectified where funds are available for the purchase of fertilizers but, even so, depletion of organic matter can lead to increases in erosion and a loss of soil−water retention. Barnard and others (27) point out that loss of organic matter can lead to greater erosion in areas with steeply sloping terraces, or where there is little tree cover and the soil is bare, and in regions prone to violent rainstorms or high winds. Finally, another consequence of using residues, especially in unsuitable stoves, is an increase in the incidence of eye and lung diseases amongst stove users.

C. Energy−use patterns in agriculture

Most farms in developing countries have less than 5 hectares of productive land: for example, Kalkra (28) estimates that some 85 per cent of land holdings in India are below 5 hectares. For this reason the following paragraphs concentrate primarily on small−scale farms. The main crop inputs which are significantly dependent on energy are fertilizers, water, land preparation, planting, weeding and harvesting, and some post−harvest activities. For livestock, the main inputs requiring energy are water and fodder, the latter itself requiring additional energy inputs. In hilly areas, energy is also required for cooking animal feeds.

The energy can be obtained from human, animal, wind, water, chemical or electrical sources but, on most small farms it is obtained from a combination of human, animal and biomass sources. Energy from animals may come in one of three forms − as draft power, as food, or as dung. Biomass fuels, other than dung, are in the form of wood or crop residues, and may come from fields, common land or forests.

The amount of energy derived from biomass which can be used on farms depends on the amount of residue that is actually produced from crops, the other uses to which it might be put, the area of and access to grazing and forest land, and access to whatever fodder, dung or residues can be obtained from common land or in and around fields. Thus, the determinants of energy consumption both on−farm and in the household are closely linked: switches in one have important implications for supply and consumption patterns in the other.

The few comprehensive studies carried out on patterns of energy consumption in farming systems refer to high−potential areas, with cropping patterns based on rice or wheat. Many of the studies rely on aggregated or estimated energy use, thus making comparisons difficult. For example, to calculate the increase in the use of on−farm mechanized energy the Food and Agriculture Organization of the United Nations (FAO) (29) considers the number of tractors sold multiplied by an average usage rate. This assumes that petroleum price increases do not affect usage rates, and that the life of a tractor and its efficiency are equivalent throughout the world. Further, units of energy are often not compatible, and can be misleading: energy can be defined in terms of the work carried out, in hp/hr/ha, or in terms of fuel/feed ratios (30). Energy calculations for bullocks are especially complicated as the bullock consumes part of the crop to which its energy input, in the form of draft power, contributes; it produces dung that can be returned as a fertilizer in on−farm energy consumption or burnt as part of household energy consumption; and it can produce milk and meat. In some cases, the work of an animal or a person is given in "tractor equivalents", a concept open to enormous variations in interpretation according to time and place. These assumptions make it extremely difficult to determine with any precision patterns of on−farm energy switching other than at a local level, where specific studies might have been conducted. Only broad trends and conclusions can thus be drawn from the few in−depth studies carried out.

The main broad trend for energy supply in the farm sector is the considerable increase, illustrated by FAO, in the use of energy in agriculture in developing countries between 1972 and 1982, although agriculture still consumes only about 4.5 per cent of the total commercial energy. Bhattia (15) has estimated that the use of non−renewable sources of energy has increased by 210 per cent in the planned economies of Asia, followed by the Near East (95 per cent), East Asia (89 per cent), Africa (54 per cent) and Latin America (51 per cent). Most of this increase can be attributed to increases in fertilizer use, in turn, often due to the availability of low−cost natural gas and, to a lesser extent, to increases in mechanical and electrical power inputs.

Increases in energy use are concentrated in high−potential lands, but one of the most significant aspects of these increases is that they do not appear to have led to proportional increases in crop yields. For example, Desai (31) estimates that, for India, increases in energy inputs of approximately 250 per cent have resulted in increases in crop yields of only 23 per cent. Binswanger (32) found that

> "the tractor survey failed to provide evidence that tractors are responsible for the substantial increases in intensity, yields timeliness and gross returns on farms in India, Pakistan and Nepal".

Several studies show that for the small farmer, even with low−cost credit, the use of tractors and electric/diesel pumps is often not economic. Dhawan (33) estimated that the minimum size of farm for economic use of diesel pumpsets was 3.5 ha and 10.2 ha, and for electric pumpsets 2.6 ha and 7.3 ha, for Eastern Uttar Pradesh and West Bengal, respectively, which eliminates many small farms. Similarly, a recent study in Indonesia (34) has shown that, with recent increases in petrol prices, the benefit/cost ratio for tractors is less than 1. However, the introduction of small tractors in some areas (35) has led to improvements in the profits of many farmers and benefits to society as a whole.

In contrast, animal power, where available, appears to be a cost−effective method of pumping water, although Hurst (36) questions this. Vassant (37) suggests that this is especially the case if the social costs of powered pumps and machinery, such as the cost of extension and of subsidies on the energy sources, are taken into account. He estimated that the total subsidy on an electric pumpset in India was $2400 during its lifetime, compared with its capital costs of about $400. Except in a very few, mainly experimental or demonstration, projects, equivalent subsidies for renewable technologies or sources of energy are not available.

In general, it is possible to conclude that where fodder is a scarce resource, increased energy inputs from humans are needed to maintain or substitute draft animals and, under these conditions, small tractors tend to become cost−effective. A farm of 3−5 hectares requires an energy source with an output of 1−2 kW (2 bullocks have an output of approximately 1.2 kilowatts) to achieve a high level of overall energy efficiency (38). A prime mover, whether a pair of bullocks or a small tractor, with this output will be able to pump water, till the land and process the crops. In this context, larger tractors are only efficient for transporting heavy loads and for clearing land. Many larger farmers invest in tractors to obtain reliable and easily−managed supplies of power for irrigation and transport. In Sri Lanka, Farrington and Aberyratne (39) found that many farmers buy tractors to enter the very profitable hire market.

A number of authors have commented generally on the high social costs of intensive energy agriculture. Lockwood (40) notes that the increase in consumption of non−renewable sources of energy, as with other resources, has often led to the further marginality of small farmers. It might be thought that increasing yields would enable small farmers to purchase and run pumpsets, for example. However, in many instances, they are unable to get the necessary credit or extension assistance. Even with such facilities the pumps might not be technically viable, because of the scattered nature of land holdings (41). Other problems arise from economies of scale and, hence, the most common non−renewable energy sources for pumping are not economic for small farmers, and there are few, if any, smaller alternatives. Similar problems are encountered, even with bullock power. For example, a pair of bullocks is adequate for a 5 hectare farm, but since a plough usually requires two bullocks, rather than one, farms smaller than 5 ha will still have to find feed for two bullocks, or take additional time and risks over ploughing with one bullock. In contrast, for owners of larger farms, increasing crop yields obtained with better access to credit and other services allow them to purchase smallholdings from marginal farmers as the latter are heavily indebted owing to their circumstances. A possible exception to this trend of marginality and high social costs is the replacement of animal−powered and human−powered threshers, shellers and mills by mechanically − powered units, mainly diesel.

D. The potential for energy−switching in agriculture

For large farmers, especially in medium−to high−potential zones, the switch to non−renewables, although unlikely to lead to major increases in yields or output, appears irreversible, at least in the short to medium term, although there will be cases where low−cost and convenient supplies of renewable energy sources and technologies coincide with only high−cost and or scarce non−renewables: for example, the use of biogas on pig farms, in the Philippines, and windpumps, in northern Kenya. However, these cases tend to be the exceptions, rather than the rule, unless and until some of the interventions are developed to readily acceptable levels. Assured supplies of electricity or petroleum products are of particular value to large farms in this range.

For marginal, small and many medium farmers, the situation is very different. The shortage of energy sources and conversion technologies, which are both convenient and available at acceptable costs, is becoming an increasingly important constraint on the viability of their holdings. The scope for switching of various types is considerable for these farmers.

Conservation farming and the improvement of existing techniques − i.e., switching within, rather than between existing renewable/non−renewable energy supply and consumption patterns − are probably effective and economic means of improving energy inputs. Efficient distribution of water, less energy−intensive land preparation techniques, and timely application of fertilizers, water or weeding, can all contribute to improvements. For example, Alan (42) found that better maize farming practices could lead to yield improvements of 145 per cent using existing direct−energy−input levels. Ravindranath and others (43) noted increases in rice and wheat yields of 50 per cent to 70 per cent with improvements in farming techniques. Other techniques such as zero tillage that reduce soil preparation and water inputs but increase the use of herbicides, could also have a major impact on on−farm energy consumption.

Other options for commitments, although not directly related to energy production and conversion, exist, e.g., ensuring the availability of grazing land, or increasing yields of fodder crops, may provide small farmers with sufficient fodder to make bullocks economic, as may improved animal health care; improving bullock equipment, such as harnesses and carts, may reduce the bullock energy needed for specific tasks and thus reduce fodder needs; similarly, the development and improvement of bullock − powered or manual pumps may reduce energy requirements for a given supply of water. Cooperative ownership of pump−sets may help small and medium farmers overcome the lack of very small, reliable diesel or electric pumpsets.

E. Energy switching as a means of alleviating rural poverty

Scope for radical switching to renewable sources of energy or technologies, either to substitute for existing non−renewable systems or to provide entirely new energy inputs, exist. There is considerable potential for the long−term development of farming systems which rely, as far as possible, on local energy sources, especially in regions with high costs of non−renewable sources of energy or scarce supplies. In the first instance, this requires the development of intensive agro−forestry techniques, with extension, credit, supplies of improved seeds, etc. Although the energy requirements are, generally, secondary, they are, nevertheless, vital. They include systems of water supply and power for agricultural processing and other low−technology industries where some of the renewable energy sources and technologies may make an important contribution towards income generation and alleviation of rural poverty.

Of particular interest are systems based on biomass, in which increased production of biomass contributes wood and residues that can be used to fuel producer−gas, steam or biogas systems, supplemented by solar and wind technologies, where appropriate, for agricultural processing and rural industries. However, it is necessary to emphasize that if this approach is to benefit the small farmers, technologies of the appropriate size need further development. Secondly, institutional changes in land tenure, local social and political structures, and in the supply of credit are as important as technical changes. Removal of subsidies on non−renewable sources of energy and on relevant conversion technologies would also enhance the possibilities of use of the renewable sources of energy as a means of promoting the rural industries and alleviating poverty.

A further way in which there can be a switch, probably within the renewable energy category, for small farmers, is in those activities which account for the considerable increase in non−renewable energy inputs which occur as farm size increases. For example, for rice production, one of the main differences in non−renewable energy inputs between traditional and mechanized farming is for drying. The large farmer can afford both the equipment and the fuel needed to dry his rice, even in wet weather, and to store it until prices are at their peak. In contrast, the small farmer who relies on sun drying can often lose a significant proportion of his crop because of rot, and cannot store it at the moisture levels to which he is limited. Development of simple, biomass−fuelled dryers could help, although as with other developments, low−cost credit would be vital.

F. Domestic energy−use patterns in urban areas

An in−depth study of domestic energy consumption in urban areas of an oil−producing developing country was carried out in Hyderabad, India, by Alam and others (16) who collected information from households and from fuel suppliers, and physically surveyed the amounts of fuelwood and charcoal entering the city by road. Comparing their results with those of a similar survey carried out in 1966, they found that household consumption increases with household size, which is associated with income level, but per capita use of cooking fuel declines with size of family. As shown in figure 8, the wealthy households use mainly kerosene and LPG and the poorest households use mainly wood and kerosene, but many households use a mixture of all three fuels. Charcoal is a minor fuel as it is brought in from long distances and is mainly used to cook special foods, and is mostly consumed by commercial food enterprises.

The study found that there has been a major switch in fuel use, from wood to kerosene and to LPG. The wealthy households which use kerosene and LPG tend to have high−efficiency cooking devices, both because of the higher−grade fuels they use, and because their greater disposable incomes allow them access to better quality equipment. The result is a decline in energy use, owing to the high conversion efficiencies and the fact that these households actually obtain more useful energy for cooking, heating and lighting from a given energy input than the low−income groups; the poor pay more than the wealthy to cook the same food (see table 3).

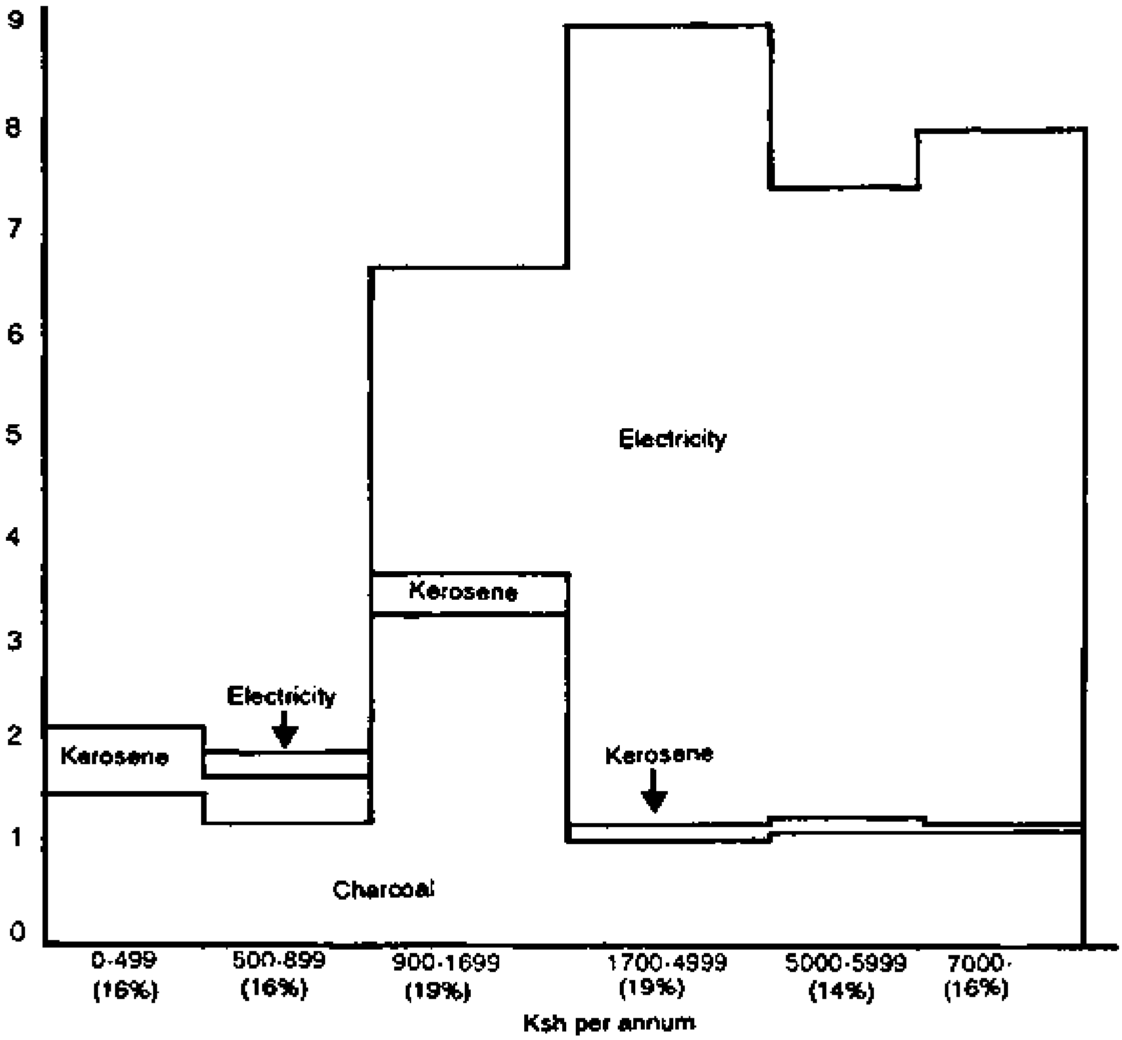


Figure 8. Kenyan urban energy consumption by income category, Nairobi, 1981

Source: (13)

Note: The percentage in parentheses refers to the percentage of the population in that income category.

Table 3. Average domestic cooking-fuel costs[a], Hyderabad, 1991

a/ Costs of firewood and charcoal are based on household survey. Prices of kerosene and LPG are controlled by the Government.

	Original units	Rs/MMBtu	After costs adjusted for combustion efficiencies Rs/MMBtu
Firewood	0.454 Rs/kg	31.81	187
Charcoal	1.082 Rs/kg	38.52	193
Kerosene	1.87 Rs/l	50.89	106
LPG	52.0 Rs/15kg	80.12	134

Source: (16)

The choice of fuel amongst the group of fuels normally used by a given household depends on price and availability. Petroleum prices are controlled, and there are periodic shortages. Thus decisions by wealthy households to switch between different petroleum fuels, or to charcoal and wood, depend more on availability than on price. For poor households, the price of stoves appears to be the main determinant of choice. Although the price per delivered kilojoule of petroleum fuel is cheaper, poor families are often not in a position to invest in expensive LPG or kerosene stoves.

The report by Alam and others concludes that if the population and incomes maintain their present rates of increase, and supplies of LPG increase in line with increasing demand at current real prices, there will be very little increase in firewood demand. However, if these assumptions are incorrect, there may be a dramatic increase in wood demand. If the demand for firewood remains at present levels, the authors conclude that from the limited data available, existing supplies would meet the needs of the urban population on a sustainable basis. However, they warn that there are signs that the amount of wood grown on private land is decreasing as additional land is cleared for agriculture. This might initially lead to a surplus, a decrease in the price of fuelwood and, possibly, a switch back to wood for some groups. But, as the supply dwindled again, the price of wood would start to increase, whether more farmers would grow wood, or consumers would reduce their consumption or switch again, is difficult to forecast. Clearly, if LPG supplies become a problem or its price increases, there will be different switches, to wood or kerosene.

The study found that the main sources of firewood are private farmers, only 8 per cent coming from government forests, with availability depending on the cost of fuel and that of transport. Cheap offcuts, collected from forests close to urban centres, present the lowest costs to the country (in terms of energy used in transport) and to the consumer. Much of the cost of wood is in its transport and in the profits of intermediaries.

A comprehensive urban study in an oil importing country that imports fuel was carried out in Kenya by Hughes−Cromwick (44). He found that low−income groups use mainly charcoal for heating and cooking and kerosene for lighting, but electricity was the main source of energy for both purposes amongst high−income groups. Both charcoal and wood were used by some groups for some cooking and heating. There is a switch from charcoal to electricity as income increases, electricity being preferred to LPG because of supply problems with the latter.

With increases in the price of charcoal, low−income groups are forced to spend more than 20 per cent of their cash income on charcoal thus leading to a switch back to wood.

One of the main effects of the increases in the use of charcoal as the dominant cooking fuel in urban areas is large−scale deforestation around these urban areas (45). One reason is that, from an energy standpoint, the use of charcoal can be very inefficient: even if improved charcoal kilns are used, conversion efficiencies under field conditions are probably not more than 60 per cent and are no more than 30−40 per cent in most traditional kilns. With a conversion efficiency of most existing charcoal stoves of 20−35 per cent, the maximum wood to useful cooking energy efficiency that can be achieved is not more than 21 per cent and in most places where improved kilns or stoves have not been introduced, it is 6−14 per cent. Open wood fires are 10 to 20 per cent efficient (depending on operator and fuel parameters) and many of the new improved wood stoves have 25−35 per cent conversion efficiencies and, hence, in wood−to−useful−energy terms, the use of wood can be more efficient than that of charcoal. Thus, in theory, a switch back to wood in urban areas would reduce the rate at which deforestation related to urban domestic cooking occurs. However, energy is more easily and cheaply transported in the form of charcoal, charcoal can be stored for a long time, and is a cleaner fuel to use than wood used in an open fire. In some cases, where land clearing has taken place, wood would rot if it were not converted to charcoal, so the use of the latter provides a net energy benefit.

The data from these and other surveys suggest that, in terms of national priorities, the main switching issues to be addressed are not the switching of relatively small numbers of upper−income groups between high−grade fuels or forms of energy such as electricity, kerosene or LPG, or indeed between these non−renewables and renewables, such as solar water heating: the main issues are the switching of much larger numbers of middle−income and low−income groups between kerosene and charcoal, wood and residues, and between these latter three.

G. Energy−use patterns in the transport sector

As the focus of this report is the rural and urban poor, analysis of energy use in the transport sector focuses on the movement of goods on−farm, and between rural and urban areas as transport is a key link in any switching between energy sources in the on−farm and the domestic sectors.

Transport, whether motorized, animal−powered or human−powered, consumes about 5 per cent of the total energy used for economic activities in most rural societies, but 20−60 per cent of the total commercial energy consumed nationally. Most transport is used to move people and goods between urban and rural areas, the major means being truck, bus and rail. Barwell and others (46) noted the following main points concerning rural transport:

(a) Few regular transport services operate away from all−weather road networks. However, many people live remote from such networks and, hence, lack easy access to transport services. For example, in Bangladesh, 80 per cent of people have no access to mechanized transport, and in India 55 per cent of villages are not connected to any type of road or track that will accept anything other than very light and narrow carts;

(b) In areas having all−weather road access, motor vehicles are beyond the financial means of the majority of people. Equally, many people cannot afford to use the transport services which do operate;

(c) Most trips are on−farm. The average trip is 1.5 km and the average transport loads are 20−50 kg.

Little non−renewable energy is used to move goods between fields, households, and local industry and markets: Ramaswamy (47) estimates that 26 per cent of the world's total motive power is supplied by draft animals. In rural areas of developing countries, they account for a very large proportion of transport energy. Most trips are on−farm and only a small percentage are off−farm (Barwell reports 10 per cent in a Nigerian study). Most agricultural produce in all ecological zones is still carried or hauled by humans, or hauled by draft animals. Implements are carried to the fields and crops, whether food, fodder, or fuel are brought back in baskets carried on head or shoulders. Hall (48) reports that the sole job of one person in many families in developing countries is to collect and carry wood full time. Carrying water is also a major consumer of labour, average loads for both tasks being 25−50 kg. Very few rural people own motorized vehicles: most rely on carts and bicycles. Table 4 provides a percentage distribution of trips by various modes in a village in Malaysia and one in Kenya. Although at harvest, produce is sometimes carried by small trucks or tractor rather than by animal−drawn cart, the major mode of transport is still the human back, the bicycle, and the cart, whether human−powered or animal−powered.

Table 4. Percentage distribution of trips by mode in two villages in Malaysia and Kenya

Location	Walking	Animal cart	Bicycle	Public transport	Other	Total
Malaysia	72.0	1.5	7.5	7.5	11.5	100.00
Kenya	71.0	6.0	10.5	7.5	5.0	100.00
Average	71.5	4.5	9.0	7.5	7.5	100.00

Source: (45)

The type of transport used depends in part on the type and distribution of roads and paths, landholding size, degree of fragmentation of landholdings, and the crop mix, all of which are themselves related to income and ecological conditions. At the same time, transport facilities can, in part, determine agricultural practices. For example, Somashekar and others (49) found that in South India high−yielding rice varieties are planted near roads as they need to be near irrigation canals or wells, which themselves tend to be near roads, both to give access, and because the wealthy who can influence the development of transport facilities also tend to be those with the greatest access to irrigation facilities. Another reason is that the use of irrigation, especially in conjunction with high−yielding varieties, gives rise to higher yields and in many cases an increase in the number of crops per year.

Typical requirements for on−farm vehicle transport are relatively small. Somashekar (49) found that the average 5−hectare holding requires a cart with a payload of 400 kg for 20 days a year, the total distance travelled being 183 kilometres. The total energy expended was 0.893 tons of diesel tractor equivalent (tdte), or 0.016 tdte per cart−owning family, as carts tend to be held or hired among groups of holdings. This is equivalent to the tractor input which would be required for replacement of bullocks by tractors. They also calculated that the replacement of bullocks by tractors would only lead to an increase of 7 per cent in total petroleum consumption in the agricultural sector. At first sight this implies that there is considerable potential for switching from renewables in the form of bullocks to non−renewables in the form of tractors, with the advantage of reduced demand for fodder and hence pressures on land. However, the costs of a tractor are beyond the reach of most small farmers, even on a hiring basis, and bullocks have a number of functions such as other draught activities, supply of dung, food, etc., not performed by tractors.

Larger farms with commercial crops tend to be the main users of tractors. Their main use on−farm is for clearing and ploughing, but they are often hired out to other farmers and small industry for other on−farm uses and for transport. As already pointed out, studies suggest that tractors are not economically viable, unless they are used for transport as well as for on−farm uses or, unless there are constraints on fodder supplies for draft animals.

For low−income and medium−income groups, ownership of motor vehicles is not an issue. Barwell has concluded that many people aspire to a bicycle as a means of transporting goods and people efficiently around rural and urban human settlements, but animal transport is still critical to the movement of goods in many areas. As mentioned earlier, there is a tendency for decline in the number of draught animals in areas with high population densities (26), due to fodder shortages and rapid increases in the costs of the high grades of timber needed to construct carts.

In most countries that have seen a decline in draught−animal transport, there have been corresponding increases in the use of motor bicycles and two−wheeled tractors. Motor bicycles with side−cars are also becoming popular, for example in South−East Asia, with capital costs only 1.5−2.0 times the cost of a cart, and many times less than that of a tractor. They do not need wide roads and have relatively low fuel consumption. However, their lifetime is 5−10 years compared with 25 years for a cart.

An important role of the transport sector is carrying woodfuels from rural and peri−urban areas to urban areas. The Hyderabad study cited earlier highlights links between urban fuel supply, the availability of transport, and the cost of energy for low−income groups. The study shows that approximately 97,000 tons of wood is transported 88 kilometres by truck, and 6000 tons by cart. If an 11−ton truck consumes 1 litre of fuel for every 6 kilometres, 94 tons of fuel are required to transport the wood to the city. Of the total cost of wood transport ($.031/ton/km), petroleum fuels thus account for approximately 25 per cent of the cost of primary transport. The retail price of fuelwood is $28/ton, of which transport accounts for approximately 10 per cent. Charcoal is transported, on average, 224 kilometres, a distance about 2.5 times the distance wood is transported.

An interesting point is the effect on the consumer of differences in the moisture content of the wood under present buying patterns. Wood is normally purchased by volume: to obtain the same useful heat, the consumer has to purchase, perhaps, twice as much wood at 40 per cent moisture content as would be necessary with 12 per cent moisture content, as wet wood has lower calorific value than dry wood, and wood stoves are less efficient with wet woods. Clearly, to the consumer, the costs of useful heat increase as the moisture content increases. However, to the transporters, there is no incentive for ensuring that the wood they transport is dry. To transport a load of wet wood costs them marginally more than transporting a load of dry wood: transporting wet wood to meet a given heat energy requirement will actually provide them with more business than transporting dry wood. However, there is evidence to suggest that the increasing costs of fuels are shifting retail purchasing practices to measurement by weight rather than by volume: all other things being equal, this gives the consumer greater control over the amount of useful energy sources actually being purchased.

The other factor highlighted in the study is the lower cost in terms of both energy and price of transporting fuel by rail: it is difficult to estimate the energy cost, but given the relative efficiencies of truck and rail it is likely to be 50 per cent lower for rail, especially when transporting charcoal.

Unfortunately, the Hyderabad study does not indicate the impact on the transport sector of the continuing switch to wood consumption and the increase in distances that wood has to be transported. Yerrel (personal communication, Transport Road Research Laboratories, United Kingdom) estimates that the number of trucks bringing goods into a city the size of Hyderabad would be of the order of 300 to 600 a day, wood accounting for 5 to 10 per cent of the total: major fuel switching would thus put extra strain on an already over−crowded road system. Other reports show that at harvest−time, in some places, the use of additional trucks to carry grain for processing or storage causes shortages of trucks and of fuel (Morgan personal communication). In the Gambia, for example, the banning of charcoal manufacture and the resulting switch to fuelwood for the capital, Banjul, led to a major shortage of trucks and consequent fuel shortages in the city.

Clearly, the issue for the urban woodfuel user is one of decreasing the cost of transport and ensuring the supply of woodfuels. This could be achieved by both improving the management to the transport sector – for example, by ensuring that trucks always have full loads – and by developing energy plantations close to urban areas.

For many governments, there is also an urgent need to reduce the import costs of oil−based fuels used for transport. There are two possible approaches. The first, as suggested by the World Bank (1), is to improve the fuel−efficiency of existing transport units and systems, and to improve their management. The second involves production of liquid fuels from energy crops such as sugarcane, wood or oil crops. This option raises important and complex issues of the relative merits of the use of land and investment in food production, fuelwood production and biomass−based liquid−fuel production. Despite the experiences of Brazil and, to a certain extent, of Zimbabwe and other small−scale pilot programmes, the issues are clouded in rhetoric and insufficient data have been published to allow assessment of the relative merits of different strategies. The initial work of Stuckey and Jumla (50) and Hall (48) shows that the relative costs and benefits for a particular country depend on a wide range of factors, including end−use technology, market size and feedstock availability, land−use conflicts, fermentation technology, finance and infrastructure.

To summarize, the main issue in transport is not of switching between renewables and non−renewables, except insofar as the greater use of motor−bicycles can and should be encouraged, but the provision of more extensive and more efficient transport systems within the renewables sector, i.e., for animal−powered and human−powered transport. The key issue in animal transport is to increase the supply of fodder, given increasing pressures on land and the present change to high yielding varieties of rice and wheat, and to increase, if possible, the efficiency of animal−transport equipment.

III. STRATEGIES FOR OPTIMIZING BIOMASS AVAILABILITY

Introduction

Today, there is growing realization that the assumption that villagers gathering their own firewood are the major cause of deforestation is only a small part of the cause of severe land degradation: as shown earlier, extensive cutting of trees near urban centres and along roads, as a result of growing demand for wood in urban areas, is an equally important cause of such degradation. Strategies for improving energy availability should, therefore, address this issue: there should be an appreciation of the roles of forests and trees in the lives of the people, both women and men.

For household usage, families should be encouraged to plant a mix of fast growing and multi−use trees on their homesteads. The landless should be given seedings provided free of charge and given ownership of trees on rights of way in return for their guarding and watering the seedlings. This applies to urban areas as well: few towns in developing countries are without rural sections, even downtown, where trees could not grow. Urban tree planting on home plots, along the road, and around cities, could help supply firewood to the urban poor.

A. Agroforestry

Agroforestry involves intercropping trees with food crops, either intermixed with the crop or at the sides of fields. Many trees used for intercropping fix nitrogen and provide mulch, both of which can increase the fertility of the soil. Intercropped trees also help prevent erosion and increase the water retention of the soil. Crop yields need not be reduced provided trees are properly matched to soil and crop types, and to other environmental conditions (51). In many farming systems, particularly where there are pressures on land, farmers have traditionally practiced agroforestry. These cases can benefit from research on improvements to existing practices and to meet changing demands and conditions.

A small number of experimental programmes have been initiated in recent years, and initial results seem promising. Major requirements for such programmes include well−resourced local silviculture research programmes, well−trained and − motivated extension agencies, and strong local community groups willing and able to cooperate with the agencies promoting the programmes.

B. Community forestry

As the name implies, community forestry is planned tree planting on community owned land. In some cases government−owned forest−lands have been handed over to the community which then becomes responsible for their management. Species are chosen by the community which allocates land between food, fodder, fuel and timber. In most successful programmes, national forestry legislation has had to be changed to allow communities to own or take over forest land. The forestry service still has a role to play, albeit a role different from its traditional functions: it may help establish nurseries, undertake silviculture research relevant to community programmes, help the community establish local organizations to plan and implement programmes, and provide follow-up to improve local management. Successful community-forestry programmes have been established in China, India, Nepal and the Republic of Korea.

In the Nepal programme, 1.2 million seedlings were planted by individuals, 8000 hectares of forest out of a total of 15,300 ha were planted by communities, and 400 nurseries established by the Forestry Department. The cost of this programme was of the order of $15 million, and the survival rate is reported to be as high as 80 per cent for owner-planted trees. The development cost is approximately $80/ha/year and the recurrent cost of managing the forests is approximately $15/ha/year. The average survival rate was approximately 63 per cent for forests and 55 per cent for private seedlings.

C. Farm forestry and fuelwood plantations

A number of countries (e.g., Haiti, India and the Philippines) encourage farmers to plant fast-growing trees for poles and fuelwood for domestic use or electricity generation. Seedlings are usually provided at cost or subsidized. Fast growing species are planted on fairly fertile soil, and are usually fertilized and irrigated. With correct selection of species and assured domestic or industrial markets, very high rates of planting can be achieved; for example, in Haiti 1,750,000 seedlings were planted in the first year of a four-year programme costing $8 million. In Gujarat, India, approximately 200 million seedlings were planted on some 200,000 hectares of land. However, some of these programmes benefit the wealthy at the expense of the poorer farmer (14). Wealthy farmers are more able to accept delayed returns on investment of two to three years, and to afford fertilizer and water inputs. Two farm-forestry projects in the Philippines and in Gujarat, India, which were to produce wood for sale as building materials, for which financial analysis has been carried out, showed rates of return to the farmer of more than 12 per cent (52).

D. Requirements for biomass production

The main technical requirement for successful tree planting programmes is that tree species are chosen that are suited to local soil and climatic conditions, to local agricultural practices, and meet local needs, including shelter, fodder and food as well as firewood or poles. Silviculture research to help develop and/or choose these species must be a vital part of any programme. As farmers will be reluctant to participate in production programmes, unless they see rates of survival and growth that are, at least, as high as those of indigenous species, planting and maintenance methods should be chosen which, as far as possible, make such survival rates feasible. It is also important to determine whether or not the chosen species compete with food crops for sun, water or nutrients: where they do compete, provision of fertilizer and irrigation to compensate at acceptable prices might need to be a component of the programme. Obviously, this will add to costs, and will tend to make programmes less viable.

Meeting all these technical requirements can be very difficult. According to Palmberg (53):

> "Although it is often said that the establishment of fuelwood plantations does not present serious technical problems, planting programmes of non-industrial species are, in practice, still generally conducted at a species rather than provenance level, basically due to lack of basic biological information. With the exception of some eucalyptus, few arid and semi-arid tropical tree-species have been sufficiently well-explored botanically and genealogically to provide a solid basis for their efficient utilization and conservation."

At the institutional level, innovation is important for successful tree planting programmes. So far, most programmes have had to establish tree nurseries run by governments, NGOs and local groups that are expensive and time consuming, often requiring imported polythene bags. Various alternatives have been developed which include transplanting seedlings without the use of polythene bags (the roots and stems are heavily pruned and then distributed without soil), and direct planting from cuttings or from seeds (54). An important input into an energy-tree planting project is the provision of transport at planting time to move the large numbers of seedlings from nurseries to fields.

Similar technical and institutional inputs are needed for energy crops such as sisal, papyrus, and sugarcane. However, energy crops need greater inputs in the form of fertilizer and labour than trees providing the same energy outputs.

E. Briquetting

Most agricultural residues are costly to transport and relatively difficult to burn in their natural state. When briquetted, the density of residues such as sawdust, rice husks, groundnut shells and wood chips is more than doubled, drastically reducing transport and handling costs, and easing combustion. In the Gambia, the cost of groundnut shell briquettes is $32/ton, whereas that of wood is $41/ton. Briquetting machinery uses screw or ram presses to produce continuous logs through a die, or a series of steel rollers to squeeze the material through a number of dies to produce pellets. Bulky biomass materials are dried and reduced in size by chipping before they are briquetted. Briquetting machinery is manufactured mainly in the developed countries, with outputs ranging from 120 kg/hr to 5 tons/hr, and costs of $10,000−50,000 depending on the output and the raw material, but a manufacturer, in Thailand, has designed and developed a briquetting machinery which costs approximately $5000.

Small powered briquetting machines, and animal − and human−powered machines are also available with capacities as low as 10 kg per hour, but few of them appear to operate successfully and few economic data have been published on the cost of briquetting using these machines.

Over the past few years, a some projects in developing countries have attempted to make briquettes out of residues using two different approaches. The first approach has involved making briquettes out of existing residues under existing crop production systems, either at factories that process the crops or at the village level. The second approach has involved harvesting a high yielding crop grown for the purpose on marginal land (e.g., papyrus), and making briquettes at a plant near to the area where the crop is grown. There have also been proposals to carbonize the material to reduce the energy needed to produce acceptable briquettes, or, using a starch binder, to make briquettes from the material using hand or very simple mechanically−driven presses, but no successful programme using these proposals has yet been recorded.

New processes are being developed which require lower compaction pressures than conventional technologies. If successful, these may reduce the main constraints on making briquettes in developing countries, i.e., the high demand for conventional energy (diesel or electrical power), the high rates of wear in the dies, and the high maintenance requirements. These processes might also, perhaps, allow increased use of local techniques and materials. The first process involves heating the raw material before it is compressed. This softens the fibres and brings out the lignin in the raw material which both binds and reduces the friction in the machine. The pressures required are reduced from around the 200 Mpa (Megapascal) required by conventional powered briquetting machines to about 20−40 Mpa, while the mechanical energy required is reduced by a factor of up to 5. The second method is to extrude the material in its green state and then allow it to dry. However, briquettes produced in the green process, normally, do not have a long shelf life. Both methods will produce briquettes with lower density than those produced with conventional high pressures.

If briquetting is to be a significant component of switching, a great deal of technical work is still needed, along with extended field trials. It is possible that hand machines might be viable if the output can be increased to around 50 kg/hr and the material can hold together without binders. An additional secondary, but nevertheless important, requirement, is the development of special briquette stoves to minimize the production of smoke.

IV. NEW AND IMPROVED WOOD−STOVE TECHNOLOGIES

Introduction

The introduction of improved stoves should be seen in a wider socio−economic context than that of energy saving *per se,* i.e., that of poverty. Improved stoves are for poor people who cannot afford modern stoves and who use the cheapest available fuel for cooking: wood, dung and residues. Approximately 40 million wood stoves have been introduced in China, over 5.6 million in India, and over 400,000 in the rest of the world in 1987 (55). Most of these stoves are made by artisans and cost between $2 and $10; payback periods for householders who purchase their fuel are usually from one to five months. Dissemination and rates of use are greatest in urban areas where fuel is purchased, and in rural areas where there is a strong community development effort.

Where new stoves have to be introduced, it should be remembered that there is no single new technology which can be adopted worldwide. The first step is to involve the women users to improve the traditional stoves. For example, and as described later, rural women in Burkina Faso were shown how to build a clay shell for the traditional three−stone stove, thus improving the efficiency of the stove by 40−50 per cent (55). This version of the old stove has been widely adopted, because: (a) it is cheap (the "cost" of the women's time only); and (b) it is a "women's stove" which can be easily repaired by women themselves and which takes minimal adjustment in cooking techniques.

In order to disseminate such information to the rural poor, extension programmes utilizing women as extension workers have to be set up. The workers would help construct the stoves, advise on its use and maintenance and on changes required in cooking methods.

An important issue for the rural poor is the food−fuel equation. Very often, the emphasis has been solely on fuel. However, often, the time constraint of food processing is of greater concern to villagers than energy needs: if the time consumed in food preparation were reduced, less energy would be used. In addition, women would have time to earn money which could go some way towards alleviation of their poverty.

In order to enhance the rational use of biomass, conversion of biomass into biogas using low−cost digesters has to be actively promoted, in rural areas, as part of an energy−mix. For households in urban areas, the use of low−power energy−efficient appliances and the judicious substitution of cost−effective new renewable technologies such as solar water heaters and other space heating and cooking devices, the use of kerosene and other fossil fuels would be another strategy warranting active promotion. Nevertheless, charcoal is bound to continue to play a very important role as a fuel for the urban poor and even for the middle class. Hence, improved charcoal−production methods need to be promoted.

Designing new cookstoves for the urban poor is likely to have a great impact. In East Africa, the usual charcoal metal stove is made from a five−gallon gasoline tin and sold without any insulation. Such stoves were improved using a ceramic liner, adopted from the Thai bucket stove. Although the addition of the liner almost doubles the cost, the savings of charcoal ranges from 25 to 50 per cent, so that the extra costs of the stove are soon recovered. Furthermore, the improved stove can use alternative fuels such as wood chips, coconut shells and maize cobs. (See the annex for the case study of the improved Kenya claystove.)

Once the parameters of successful interventions of new and improved technologies have been clearly defined, the following technologies appear to be the most appropriate for improving energy availability and efficiency for low−income populations: improved wood stoves, charcoal stoves and charcoal kilns, and biogas. Other renewable technologies which could be promising in the medium to long term are solar, wind, small−scale hydropower and, possibly, hydrogen. These, and other renewable technologies have been described in detail in an earlier UNCHS (Habitat) publication (56).

A. Improved stoves

Most rural people in developing countries use open fires, mud stoves or, in some cases, very simple charcoal stoves. In theory, better designs could reduce fuel consumption by 70 percent. International efforts to develop improved stoves have been underway for the past 15 years, and designs have been developed in all the regions of the developing world claiming to reduce fuel consumption by 20 to 50 per cent. These reductions can only be achieved if stoves are built and installed to the design specifications, and if they are maintained regularly and operated properly. Most of the more efficient designs are built from ceramics and metal and do not have chimneys, although improved mud chimney stoves have had a considerable acceptability in some countries (57).

Concerted efforts on improved stoves were started in 1983 with the convening of the first International Stove Dissemination Workshop, held in Wolfheze, The Netherlands, in 1983. The workshop brought together eminent development experts and stove specialists of the world. The objective of the workshop was to reassess stove activities and recommend appropriate strategies for enhanced wide−scale dissemination of improved stoves in developing countries. A key outcome of the workshop was the establishment of the Foundation for Woodstove Dissemination (FWD) which has focal points in Central and Eastern Africa, Southern Africa, West Africa, South America, East Asia, China, and India. These focal points, which are managed by key local stove agencies, have been responsible for the development and dissemination of the improved stoves described hereunder.

The traditional cooking method is cooking on open fires or three−stone fires. By surrounding the three−stone fire with a mud, concrete, ceramic, or metal wall−body, a combustion chamber is created and the open fire is transformed into an improved stove. Efforts at design and optimization of the combustion chamber has led to various types of stoves being tried, e.g., the shielded lightweight stoves, the shielded heavyweight stoves and the closed heavyweight stoves.

B. Shielded lightweight stoves

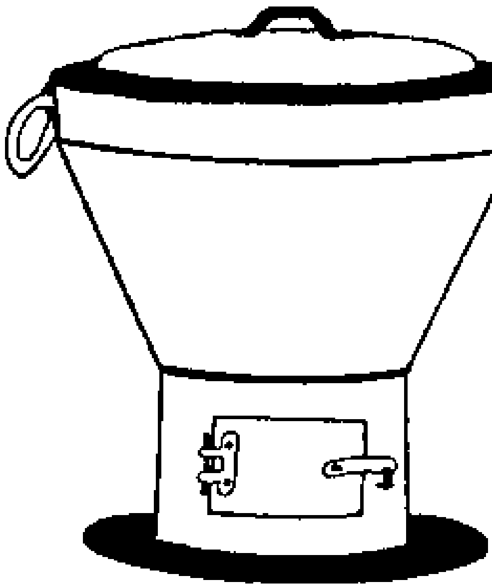
Various types of shielded lightweight stoves have been tried in many developing countries, notably, in the Sahel region of Africa. This concept covers all portable ceramic and metal stoves, e.g., the *Mai Sauki* in Niger, and the *Ouaga métallique* in Burkina−Faso and the *Sakkanal* in Senegal, which are shown in figure 9.

The *Ouaga métallique* was developed in 1983 and can use only wood. The woodfuel saving is estimated to be 40 per cent. It is a lightweight metal stove with one pot hole and has no chimney. It is produced in welding workshops or by local craftsmen.

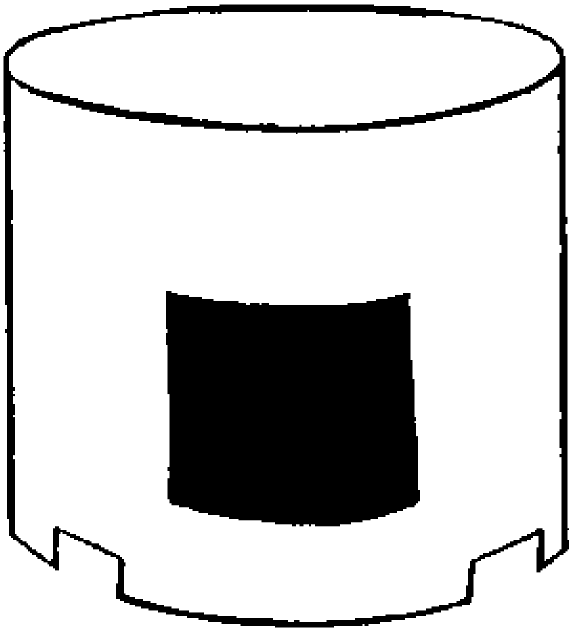
The *Mai Sauki* also developed in 1983, is made of welded scrap metal, is portable, and the stove size is made to match cooking pots. The stove uses only two pieces of wood and the stove saves 30−50 per cent of firewood as compared with the traditional stove, the *Malgache.* However, it is less stable than fixed stoves and more expensive than the *Malgache* stove.

The production and distribution structure of the *Malgache* stove was used for the *Mai Sauki* because earlier attempts to introduce other types of stoves had failed due to the competition from the *Malgache* stoves.

Figure 9. The Sakkanal and Ouaga métallique stoves



Sakkanal



Ouaga métallique

C. Shielded heavyweight stoves

Shielded heavyweight stoves are made of clay, mud, bricks concrete or other heavy materials; they are not removable and lack chimneys or other draught control facilities. For instance, the improved−three−stone−stove *(trois pierres améliorées)* (3PA), in Burkina−Faso (see figure 10), which was also introduced in 1983, is a large stove with one hole and without a chimney. It was inspired by the traditional stove, the modifications consisting of closing the space between the stones, raising the casing of the stove and reducing the volume of the combustion chamber. It is constructed by the users themselves using local materials. Woodfuel saving is estimated to be 39 per cent.

D. Closed heavyweight stoves

1. Lorena stoves

This category of stoves is almost similar with the shielded heavyweight category, but it is distinguished by the fact that stoves of this category are technically advanced, i.e., they are equipped with technical means of adjusting the air flow through the fire, e.g., chimneys, dampers, fire doors. A typical example is the Lorena stove shown in figure 11. This stove was developed in 1976 at the Estacíon Experimental Choqui (ICADA) in Guatemala as an attempt to replace the open fire. Formed from monolithic blocks of sand and clay, which are locally available, it is designed to conserve firewood − ICADA had estimated savings of 50 per cent − and decrease smoke build−up in the kitchen.

The stove was disseminated to the users by private and governmental organizations. The programme had a moderate success. As perceived by most users, the main advantages of the stove over the open fire were: reduced smoke emissions, clean and comfortable working conditions as cooking could be done standing up, reduced effort needed in cooking, and some saving of firewood. The fuel saving was not as expected due to the fact that many users sought to overcome the disadvantages (indicated below) of the stove by "adapting" it to their particular needs, thereby reducing its efficiency. These "adaptations" included removing the firebox door to provide some space heating, making almost exclusive use of the firebox to cook individual foods quickly, rather than using all the pot holes for slow simultaneous cooking of different foods as per original design, removal of the flue dampers due to an inadequate understanding of their functions in controlling and directing heat flows inside the stove, and the use of the firebox as an oven.

Figure 10. The improved three–stone stove *(trois pierres améliorées)* (3PA)

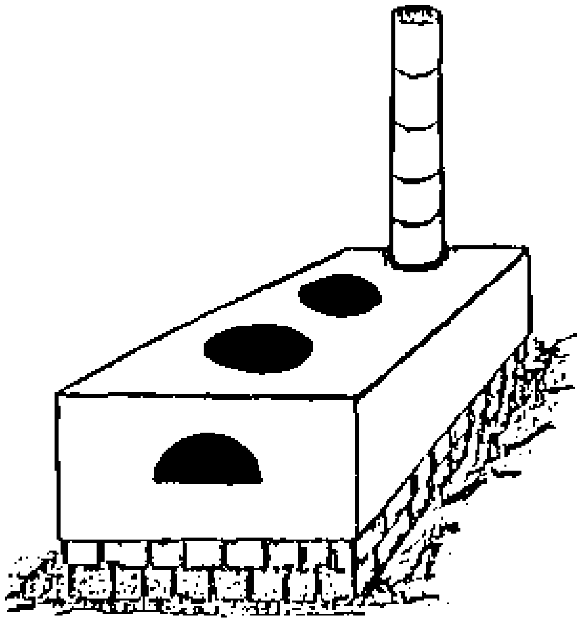


Figure 11. The Lorena stove

The main disadvantages perceived by the users were: the stove did not provide space heating, the cooking surface was inflexible and the pot holes provided in the body of the stove limited the number and size of pots which could be used, the pots often did not fit the holes which, in turn, led to an escape of smoke into the kitchen and loss of heat, and the need for careful maintenance.

2. The Nada chulha

Another example of a closed heavyweight stove, the Nada *chulha* (see figure 12) was developed in October 1980 by Madhu Sarin and refined in collaboration with the poor women of Nada Village (hence the name Nada *chulha, chulha* being the Hindi word for stove). Demand for the *chulha* increased rapidly and local women were trained as stovebuilders who, in turn, transferred the technology to other women.

The builders in the Nada programme were paid Rs. 10 for each stove and an honorarium of Rs. 50 to Rs. 100 per month for follow–up on the stoves they built. On average, each builder constructed 100 stoves before the demand was met in her village or district and earned about Rs. 2800. The builders received assistance and guidance from supervisors in case of technical, social or financial problems. They often found other employment when the demand for stoves had been met, while still being available to repair or replace the existing stoves.

The reactions of users after using the improved stoves over a period of time are very revealing, e.g., smoke removal and associated benefits are rated highest. But there is more than a two−fold reduction in the consideration of fuel saving as one of the most liked attributes. Although at first sight this appears surprising, when the socio−economic structure is considered, the reduction is valid: almost 79 per cent of users do not buy their fuelwood and they use other free fuels such as weeds and crop residues. Nevertheless, comparison between the per capita fuel consumption of the traditional stove and that of the Nada *chulha* shows a significantly lower level for the latter.

Personal comfort, which was rated as one reason by just less than 13 per cent of users, more than doubles to over 29 per cent when the users perceive that cooking pots remain cleaner than when used on traditional stoves, thus saving effort in dishwashing, and that walls need less frequent mudwashing due to the absence of smoke.

Surveys revealed that 74 per cent of users do not experience any problem in using and maintaining the *chulha,* 79 per cent were satisfied or very satisfied with the stoves and 85 per cent were willing to pay for reconstruction labour costs of the stove after one year.

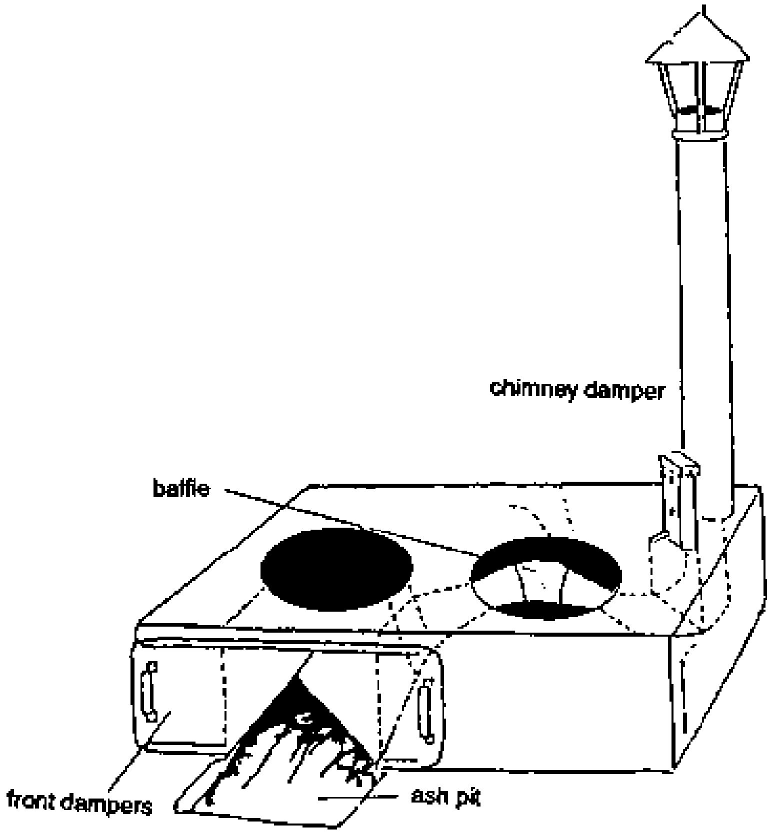


Figure 12. The Nada *chulha*

The success in India of improved stove programmes can be gauged by the fact that the Department of Non−conventional Energy Sources (DNES) lauched a National Programme for Demonstration of Improved Chulhas (NPDIC) in late 1983 (later upgraded to National Programme on Improved Chulhas). ONES reported that 5,657,000 improved stoves had been installed by 1989 (58) as against 112 million traditional stoves still in use.

The Nada *chulha* programme has revealed several key issues. The main aim of the programme was to respond to women's felt needs: this included not only the users but also the women disseminators. Consequently, various parameters of stove performance were taken into account as indicators of the programme's success, e.g., fuel saving, time saving, personal comfort, and improved indoor environment due to smoke removal. The dissemination methodology gave greater emphasis to increasing the efficiency of the person using the technology than the efficiency based on some predetermined parameters of the technology itself. The improved−stove programme initially functioned as the dominant programme for women. The stove programme, subsequently, became instrumental in defining other large women's programmes, e.g, the nature of the work of the artisans involved in the manufacture of the stove, i.e., interacting continuously with a large network of women clients made them ideal persons for identifying other pressing needs and priorities of women and, hence, became change agents or developed leadership qualities.

V. IMPROVED CHARCOAL TECHNOLOGIES

Introduction

Charcoal is a widely−used fuel in developing countries. In many cities, it is the principal cooking fuel and an important fuel for small industries and commercial enterprises. In a number of countries, charcoal is used on a large scale in the cement, steel, and other industries. In some developing countries, it is an important export commodity and there is a substantial trade in charcoal. FAO estimated the total quantity of imports by all countries at 427,000 tons in 1983. The principal importing and exporting countries are shown in table 5.

Table 5. Importing and charcoal−exporting countries in 1984

Importing countries	Quantity (tons)	Exporting countries	Quantity (tons)
Saudi Arabia	12 000	South Africa	10 000
Netherlands	14 000	Portugal	12 000
Sweden	16 000	Philippines	18 000
United Kingdom	21 000	Malaysia	19 000
Bahrain	27 000	Singapore	28 000
Japan	34 000	Sri Lanka	30 000
France	57 000	Indonesia	36 000
Malaysia	61 000	Thailand	70 000
Federal Republic of Germany	64 000	Spain	90 000

Source: Yearbook of Forest Products (Rome, Food and Agriculture Organization, 1985)

A. Domestic use of charcoal

Charcoal is an excellent domestic fuel. It requires no preparation, it burns with little smoke or flame and provides a clean and steady source of heat. It has a much higher energy content than wood and can be burned in a compact and easily portable stove; it also takes up less storage space. It can be used in small quantities, and it is easy to quench and re−use any left−overs after cooking a meal.

The main use of charcoal as a domestic fuel is in urban areas where its advantages are most obvious: its ease of use, lack of bulk, and other characteristics making it particularly suitable. Yet, in spite of its obvious attractions for urban users, there are many cities throughout the developing world where charcoal has not been adopted as a cooking fuel and firewood is used instead. A possible reason could be the climate: it is easy to make charcoal in areas where the climate is dry. Moreover, the tree species typical of the arid and semi−arid savannas are particularly well suited for making charcoal. This may be one of the reasons why charcoal−making is more common in these areas than in the tropical moist forests.

Charcoal is widely used as a cooking fuel in most African cities, e.g., in Zambia, a survey carried out in 1977/78 showed that it was used by 87 per cent of urban households (59). It is widely used as a domestic cooking fuel in much of North Africa and some of the countries of the Middle East such as the Islamic Republic of Iran. In Sudan, it is commonly used even in small villages; it is the principal urban cooking fuel in Guinea and Senegal. In Ghana, virtually everyone in the larger towns uses charcoal; it is estimated that about 70 per cent of the country's charcoal consumption is in the two largest towns of Accra and Kumasi (60).

Across Asia, there are also large variations in the patterns of charcoal consumption. In Thailand, it is very widely used in both urban and rural areas, and is growing in popularity. Unlike most other countries, where the use of charcoal as a domestic cooking fuel outside the cities is rare, it accounts for around 50 per cent of the total household energy consumed by rural households in Thailand (61). Charcoal is also widely used as a domestic fuel in the urban areas in Bhutan, Indonesia, Malaysia, Nepal and the Philippines.

Within countries, there are also considerable differences between the consumption patterns of different income groups. In the Tanzanian capital of Dodoma, charcoal is the principal fuel of the middle–income group; about 50 per cent of the population rely solely on charcoal for their cooking. Charcoal is supplemented with firewood among the lower–income groups and with kerosene, bottled gas, or electricity, at the higher–income levels; another survey in the town of Morogoro revealed a very similar pattern, although in Dar es Salaam, the use of charcoal is more or less confined to the poor (62).

B. Charcoal–making technologies

1. Traditional kilns

When biomass is heated in the near absence of air gases (rich in acid and alcohol), oil and charcoal are produced. The relative proportion of these products depends on the reaction chamber temperature and pressure, the type, size and moisture content of the feedstock, the amount and distribution of the air and the method of operation. Energy for the process can be provided by burning part of the biomass in the chamber or by burning the gases given off in the reaction.

Much charcoal for domestic consumption in developing countries is produced in pit kilns (holes dug in the ground), or in mound kilns (piles of wood stacked on the ground and covered with soil), by farmers and landless labourers. Yields (weight of charcoal/weight of wood) from pits vary from less than 10 per cent to over 25 per cent.

The most critical factor in the efficient conversion of wood to charcoal is the careful operation of the kiln. Wood must be dried and carefully stacked to allow an even flow of air through the kiln and sufficient time for reactions to take place. If kilns are not operated correctly, yields can easily decrease by 50 per cent below optimum levels.

2. Brick and concrete kilns

Kilns made of bricks can be more efficient than earth mounds, can be operated all year round and have longer lifetimes than metal or mud kilns, and are less susceptible to poor operator practices. However, the high–grade charcoal that they produce may not be acceptable to domestic users, since it is difficult to ignite. Switching to large, efficient kilns, has many economic and social implications, as most charcoal is still produced by farmers and landless peasants who, under normal circumstances, might not be able to benefit from the switch and, indeed, might suffer from it.

Brick kilns are ideal for replacing traditional kilns when consistent high–quality charcoal is required in large quantities. The throughput of a battery of seven "beehive" kilns, for example, is around 15,000 cubic metres per year. However, the construction of such kilns requires a relatively high level of brick–building skills, as well as a supply of bricks. This restricts the scope of such kilns in many countries, but in areas where they can be cheaply built and maintained, they have proved to be a very effective method of charcoal–making. The "beehive" kilns cost approximately $200–300 with yields of up to 35 per cent of input wood.

One of the major advantages of the brick kiln over earth kilns of similar size earth kilns is that their carbonization cycle is much quicker. Typically, a 50 cubic metre brick kiln has a carbonization cycle of 8–10 days, whereas that of the comparable earth kiln is, at least, twice as long. Moreover, the labour involved in operating the brick kiln is very much less than that required to construct and manage the earth kiln. Furthermore, the operation of the brick kiln is generally much simpler than the earth kiln: workers can be trained in its use relatively easily and shortages of skilled labour are not likely to be a constraint on production.

Brick kilns, however, are usually permanent structures: they are, thus, only suitable in locations where there is a supply of wood within easy transport distance and sufficiently large to last the working life of five or more years of the kilns.

3. Portable steel kilns

Portable steel kilns are in the form of a cylinder with a conical top. A kiln breaks down into three components which are designed to be easily rolled along the forest floor to new burn areas or to be transported by truck. Portable steel kilns have a small output: the annual production from a typical demountable kiln with a volume of 7 cubic metres is in the range of 100–150 tons. They are not, therefore, particularly suitable for areas where there is a need for high−volume production. Their ideal application is where the source of wood is dispersed and charcoal−making is carried out on a relatively small scale.

The advantages of the portable steel kiln are that it requires less labour than the small earth kiln and has a generally greater yield of more consistent and higher quality charcoal. It is also much quicker: the total carbonization cycle with a 7 cubic metre demountable steel kiln is 3−4 days; with a similar size earth mound, the cycle is likely to be 10−14 days.

The demountable steel kiln, like the brick kiln, has the substantial advantage over the earth kiln in that training in its use is very easy. The steel kiln can, therefore, be introduced and used even in areas where there is no tradition of charcoal−making.

The major disadvantage of the portable steel kiln is its cost: even with local manufacture, this is about $1000 and, in many places, considerably more. Given a working life of 2−3 years, it can be very difficult to justify economically in areas where labour costs and charcoal prices are low.

C. Required measures to promote new technologies

Many of the improved kiln technologies have existed for decades but, to date, few of the programmes to improve charcoal−making in developing countries have had any significant or permanent effect. Even when new techniques have been adopted, they have tended to fall into disuse after the initial enthusiasm has waned. The failures can, mostly, be traced to a lack of understanding of the needs of local charcoal makers and of the resources available to them, ignoring their priorities and often trying to impose preconceived outside views of what should be most beneficial to them.

The context in which the charcoal−making is carried out is, often, not clearly recognized: charcoal−manufacturing techniques which are suitable for a forest−management scheme are not necessarily appropriate for, say, traditional charcoal makers. The supply of charcoal should be part of a self−sustaining system of fuel supply which, in turn, would be a way of improving the economics of woodfuel replacement.

All programmes to improve charcoal making should, therefore, include an assessment of the market in which the charcoal will be sold including the quality of charcoal required by consumers, and the amount they would be willing to buy at particular selling prices.

The majority of domestic consumers are not unduly concerned by variations in the quality of charcoal between one batch and another as long as the price is right. They are concerned with charcoal which lights easily, burns cleanly, and is competitively priced: traditional methods of charcoal making are perfectly capable of satisfying this market. Industrial consumers, on the other hand, generally need a consistent quality of charcoal with a high fixed carbon content. The ability to produce this type of coal could open up a new and lucrative market to charcoal makers able to meet the necessary standards. This could provide the economic justification for introducing new types of kilns or charcoal−making techniques to some areas.

When making long−term plans for tree plantations, the likely alterations in fuel−use patterns, as incomes increase and diets change, must be assessed and taken into account. Another key factor, which is often ignored, is that the amount of charcoal purchased is related to its price: if the price increases, consumers buy less.

Finally, the context within which an improved charcoal−making programme is implemented is, at least, as important as the technology to be used: there are major differences between a programme aimed at reaching traditional charcoal makers and one which is trying to promote charcoal making as part of a controlled land clearance or forest management project. These should, imperatively, be taken into account in such programmes.

Improved charcoal stoves

Traditional charcoal stoves are made of metal and come in a wide variety of types. They are usually made by craftsmen working with locally−available materials, generally scrap metal.

(a) The Thai bucket

Early in the century, the traditional stove was improved in China through the use of ceramic cladding. This design was further improved in Thailand using an ingenious double wall and the improved design has come to be known as the "Thai bucket." It has a metal outer skin made from a bucket, often complete with the handle for carrying it. There is a prefabricated inner ceramic lining and the space between the lining and the side of the bucket is filled with an insulating material, e.g., ash from rice husks. The excellent insulation provided by the double skin sandwich reduces heat losses considerably, making the stove particularly energy efficient.

(b) The Kenya ceramic jiko (KCJ)

Following the United Nations Conference on New and Renewable Sources of Energy, held in Nairobi in August 1981, the Ministry of Energy of the Government of Kenya embarked upon improved−stove activities. One such activity was the establishment of the Kenya Renewable Energy Development Programme (KREDP) with the objective of designing, testing, developing and disseminating fuel − efficient stoves and charcoal−making techniques and promoting tree−planting efforts, especially agro−forestry.

General objectives of the improved stove programmes were to help alleviate the growing shortage of energy as well as create employment for low−income groups through the production and sale of stoves. In addition to the Ministry of Energy, several local and international organizations, e.g., Kenya Energy Non−Governmental Organization Association (KENGO), Kenyatta University Appropriate Technology Centre (KU−ATC), United States Agency for International Development (USAID), German Technical Cooperation Programme (GTZ), Intermediate Technology Development Group (ITDG) and the United Nations Children's Fund (UNICEF), were involved in the programme which developed the Kenya ceramic *jiko* (KCJ).

The KCJ was based upon the energy−efficient Thai bucket stove, whilst incorporating a number of important features of the traditional metal stoves of Kenya. It is of a low−level technology suitable for both small−scale and large−scale industries. Unlike the bucket of the Thai stove, the KCJ uses metal claddings made from scrap drums sold by local industries, and the Ministry of Works which imports raw materials and tar in these drum containers. The claddings are generally made by the same artisans who make the traditional stoves. The production of the ceramic liner is, on the other hand, undertaken by independent entrepreneous. The liner constitutes both the firebox and the insulating part of the stove (see figure 13). It is made from pottery clay and is attached to the metal cladding by a mixture of vermiculite and/or sand together with cement. Production costs of a typical 30 cm KCJ is shown in table 6. Factory price after assembly vary from KSh45 to 85 and the retail price ranges from KSh80 to 150 (55).

Surveys revealed that the KCJ consumes less charcoal than the traditional metal stove (TMS) and estimated that use of the KCJ saves 34 per cent and 24 per cent of charcoal in Nairobi and Kisumu, respectively, for the low−income groups, 42 per cent in Kisumu for the medium−income group and 25 per cent in Nairobi for the high−income group. The specific charcoal consumption per person per day for users of both KCJ and TMS, and of TMS only, is given in table 7. The table shows that the former group makes an average saving of almost 21 per cent. In addition, laboratory tests indicate that the CO_x and toxic−fume levels around the stove and in the kitchen are reduced by 80 per cent by the KCJ compared with the TMS.

The KCJ programme has had several other social benefits, bringing in its wake a new type of entrepreneur among the local tinsmiths and potters, increased income to artisans and middlemen, better health to the users, in addition to financial savings (Ksh32 million in 1985 according to one estimate) and, although no official estimates are available, the KCJ programme has most likely produced a reduction of cut trees (55). (See the annex for a detailed case study on this programme.)

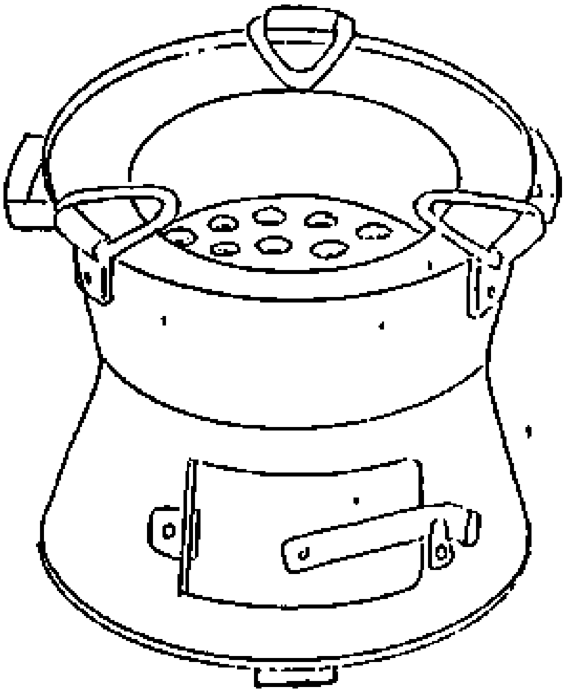


Figure 13. The Kenya ceramic *jiko*

Table 6. Production costs of claystoves in Nairobi (Kenya shillings) (1983)

Producer	Production cost/cladding	Cost/30−cm liner	Factory price after assembly
Jerri International	45	25	80
Clayworks	20	n.a.	45
Miaki	20	25	60
ATAC−Industry	17	25	70
Shauri Moyo	n.a.	17	75
Ruiru	20	15	85
Githurai	20	28	75
Thika Metal Box	20	17	85

n.a. Not available

Source: (63)

Table 7. Charcoal consumption in Nairobi in 1983 (by income group)

	Using traditional stove only	Using ceramic *jiko* only	Using both
Low−income	0.43	0.30	0.35
Medium−income	0.38	0.39	0.34
High−income	0.28	0.21	0.22

Source: (63)

D. Stove development and dissemination

The Kenya clay stove has been one of the most successful examples of stove−technology application and its experience provides useful insights for future stove and other renewable−energy technology applications.

The experience gained with the Kenya clay stove leads to the following conclusions:

(a) Clear project objectives, that is, a requirement to produce a self−sustaining stove programme and to achieve a significant level of commercial production within 18−24 months, provided a strong incentive to the Kenya stove programme to minimize experimentation and to find sustainable and economic designs, as well as effective collaboration;

(b) Early screening must be carefully done to select prototypes with specific cost, technical and social characteristics;

(c) "Need" assessment or evaluation of the target market is essential (although it was largely done informally in the KREDP by local staff and collaborators knowledgeable about local foods, cooking and social habits);

(d) Government can be effective in policy guidance, development of standards and testing, but is ill−equipped for working with small−scale entrepreneurs. Government staff effectiveness is problematic due to the unconvential nature of the skills required for renewable technology, the lack of incentives and inability to deal directly with the public, and scarcity of funds for programme execution, e.g., for materials and tools;

(e) The traditional stove production sector is extremely useful as a source for training of artisans and for production, because:

> (i) It provides a pre−existing "mass production" network adaptable to new designs;
>
> (ii) It provides simple and effective marketing;
>
> (iii) It supplies low−cost labour and low−overhead production;
>
> (iv) It makes readily available a major portion of production materials and tools;
>
> (v) It provides an innovative and competitive set of entrepreneurs.

(f) Large−scale formal production failed, apparently due to:

> (i) High administrative costs;
>
> (ii) Current high−profit activities successfully competed for facilities, staff and management resources;
>
> (iii) Location relatively distant from the small markets and from materials required for shell fabrication;
>
> (iv) Loss of trained staff to producers offering higher pay and interested in the stove business;
>
> (v) Difficulty in organizing and managing an effective system for producing complete units, rather than fired−clay liners only.

(g) Small−scale formal sector involvement results in a good mix of entrepreneurial skills, capital and motivation. This level of production matched overhead cost and output levels with the dispersed market, took advantage of the existing skilled potters and knowledge of kiln operation;

(h) Technical assistance is essential to identify the most promising prototypes, design and manage field tests, locate and train producers and solve technical hitches;

(i) NGO input is very useful in organizing and executing field tests and helping to locate entrepreneurs, as well as in augmenting government staff in extension and development of production units. NGO inputs are very cost−effective and their success appears to be leading to a redirection of funds to NGOs;

(j) Shortage of government funds and government administrative systems makes it difficult to operate a development and outreach programme. Procurement of supplies and equipment, availability of transport and cumbersome management, all often impede projects.

VI. BIOGAS

Introduction

Biogas is one of the most mature renewable energy technologies available in terms of the numbers of units installed and years of use. It is estimated that there are 1.1 million biogas plants installed in India, 7 million in China, 29,000 in the Republic of Korea, 2300 in Brazil, and a number in other countries of Africa, Asia and Latin America.

In a biogas plant, animal manure, night soil and other biomass wastes, diluted with the addition of water, are allowed to biologically degrade in a large container, in the near absence of air (anaerobic digestion): methane and carbon dioxide gases, and slurry rich in minerals, are the products of the complex chemical reactions that take place inside the vessel. The methane can be used directly for heat or light, or to fuel internal−combustion engines. The slurry is an effective fertilizer and soil conditioner, and can be directly applied to the soil or channeled through algae and fish ponds (a practice developed and used in China and the Republic of Korea) (63).

Use of biogas has the following advantages:

(a) Saving in fuelwood, with concomitant slowing down of deforestation rate;

(b) Reduced atmospheric pollution;

(c) The fertilizer obtained from biogas production helps in soil conditioning and in reducing the need to use chemical fertilizers;

(d) Overall increase in energy−use efficiency;

(e) Improved sanitation when biogas plants are connected to toilets, leading to reduced disease−incidence rates;

(f) Reduced drudgery associated with cooking;

(g) Employment generation in rural areas.

Gas production from various sources of substrates is shown in table 8.

Table 8. Gas production from various sources of substrate

Source (animal)	Availability/day	Gas per kg (m^3)	Gas per animal per day (m^3)
Cattle	10 kg	0.037	0.37
Nightsoil	400 g	0.07	0.028
Pig (45 kg)	2.25 kg	0.08	0.18
Poultry (2 kg)	0.18 kg	0.06	0.01

Source: Gobar/gas Retrospect and Prospects (Bombay, Directorate of Gobar Gas Scheme, Khadi and Village Industries Commission, 1979)

A. Utilization of the products of gas plants

The gas can be used as fuel for heating or lighting or for motive power. The gas consists of approximately 55 per cent methane and 15 per cent carbon dioxide. Since the composition of this gas is different from that of coal gas or of butane gas, the appliances (burners or lamps) have to be of special design, otherwise the efficiency is very low (35 per cent instead of 60 per cent) if coal–gas burners or butane burners are used with biogas.

Biogas can also be used for running oil engines to drive water pumps or generators, provided the quantity of gas available is sufficient. On an average, 425 litres of gas are required per horse power per hour: if a 5 HP engine is to be used for say 8 hours, at least 18 cubic meters of gas would be required per day which would require 30 to 35 animals.

Internal–combustion engines (diesel/petrol/kerosene–powered) when converted to gas engines, require a special attachment. In such engines, the proportion of diesel to gas is 20: 80.

The outlet slurry, as it comes out, is rich both in nitrogen and humus and is fully digested and in a finely divided condition. It can most profitably be applied to the farm directly by mixing with irrigation water so as to derive maximum benefit from the manure, since the nitrogen content of fresh slurry is over 2 per cent and is in an ideal condition to mix with the soil.

If the slurry cannot be used with irrigation water, it can be used for rapid fermentation of compost as the large content of bacteria and the nutrient material in the gas plant slurry accelerate the process of composting. For this purpose, a series of compost pits are dug near the gas plant. The outlet slurry is led into a channel which connects a number of pits. Vegetable refuse, grass, leaves, corncobs and other waste material are dumped in the pit in a layer on top of which the outlet slurry is allowed to spread and the process repeated until the pit is full. Thereafter, the outlet slurry is led into another pit and the process is repeated. The number of pits will depend upon the local conditions. Alternatively, the slurry may be led into a series of pits one at a time. When the first pit is full with the slurry of several days, the next one is filled. By the time the second or third pits are full, the first one is dry enough for digging out the manure, so that it again becomes available for filling. Although in this process some part of the nitrogen is lost during drying, disposal of the manure becomes easier.

The biogas manure can also form a good organic base for enriched manure, i.e., by enriching the manure with chemical fertilizer, e.g., ammonium sulphate, superphosphate etc., a very fine organic–based manure mixture can be produced.

B. Biogas plant operation

The whole system of a biogas plant is generally based on a continuous operation, i.e., the input is fed in a semi–fluid form (slurry) at one end and the fermented spent slurry is extracted at the other end periodically (normally once a day) without disturbing the whole system. Also, as cooking and other demands are not on a continuous basis, it is necessary to provide gas storage space. The total volume of gas storage space is usually equal to the volume of gas generated in 24 hours. The anaerobic digestion is affected by several factors such as the temperature of the substrate, the loading rate, the hydraulic retention time, the pH value of the substrate, the carbon/nitrogen ratio of the substrate and solid concentration.

1. Temperature of the substrate

There are two ranges of temperature over which the methane bacteria can grow: the "mesophylic" range (5°C – 45°C) and the "thermophylic" range (55°C –70°C). Most small, family–size digesters operate in the former range, with digestion and gasification proceeding at the highest rate at around 35°C. When the temperature falls to below 15°C, the process of digestion is drastically reduced and the plant produces very little gas.

2. Loading rate (LR)

The anaerobic digestion is very sensitive to the loading rate (LR) which should be kept as near as possible to the optimum rate of the LR, since if the LR is too high, the pH value tends to fall, thereby reducing the gas output. The loading rate is calculated as kilograms of volatile solids (kgVS) (organic matter) fed into the digester per day per cubic metre of digested volume – a biogas plant of 5.0 m^2 with an input of 50 kg of dung per day will have an LR of about 1.4 kgVS/day/m^3.

3. Hydraulic retention time (HRT)

The cumulative gas production from a fixed amount of feed at a given temperature, increases with time: when the slurry is completely digested, no more gas is produced. The HRT, defined as the average time spent by the slurry inside the digester before it comes out, is chosen so as to achieve a 70−80 per cent digestion. The HRT varies between 20 and 120 days depending upon the operating temperature of the digester. In tropical regions, the HRT is 40−50 days whereas in colder climates in China, the digesters are designed for an HRT of about 100 days.

4. pH value

The pH value of an aqueous solution is a measure of the concentration of hydrogen ions: neutral solutions have a pH value of 7.0, alkaline solutions greater than 7.0 and acidic solutions less than 7.0. The ideal pH for a digester is 7.0 or just above 7.0. If the pH drops appreciably below 7.0, the gas production can stop completely. When excessive loading is resorted to, the acid−forming bacteria are far more active than the methane−forming bacteria, resulting in lowering of the pH and, thus, of gas output.

5. Carbon/nitrogen ratio

All feed materials − animal dung, human waste, kitchen waste etc.− contain carbon, nitrogen and oxygen. Biogas production varies according to the carbon/nitrogen ratio, the range 20:1 to 30:1 being the optimum. The carbon/nitrogen ratio of animal dung and water hyacinth is about 25:1 making them ideal direct substrates. Poultry manure and human waste have a ratio of 5:1 to 8:1 whereas that of straw, rice husk etc. is about 70:1. Hence, when these materials are used as substrates, their proportions have to be adjusted so as to bring the carbon/nitrogen ratio to as near as possible to 25:1. Properly adjusted human waste and poultry manure produce more gas than cattle dung.

6. Solid concentration

Ordinarily, seven to nine parts of solid in 100 parts of the slurry is considered ideal, below and above which, the fermentation is retarded; four parts of cattle dung mixed with five parts of water bring the concentration to about 8 per cent.

C. Digester designs

There are four main designs of digesters: the "batch" type, the fixed dome "Chinese" type, the floating cover "Indian" type, and the bag design "Taiwanese China" type. The most widespread are the "Chinese" and "Indian" types whilst the "Taiwanese China" is increasingly popular in some countries, due to its low cost.

The "batch" type digester is the simplest option, with the operation involving charging an airtight reactor with the substract, a seed inoculum and, sometimes, a chemical to maintain a satisfactory pH. The reactor is then sealed and the fermentation allowed to proceed for 30 to 180 days, after which the gas is extracted.

1. Fixed dome "Chinese" digester

The basic design of the fixed dome digester originated in China. The reactor consists of a gas−tight chamber constructed of bricks, stone or concrete. The plants can be constructed in a variety of shapes − rectangular, cylindrical, spherical or ellipsoidal. However, the top of the reactor needs to be hemispherical to accommodate the built−up pressure of the gas which is stored under the dome. Furthermore, the dome has to be gas−tight, thus requiring several layers of mortar inside the dome. Nevertheless, gas leakage through the dome is often a problem. Figures 14 and 15 show the schematic diagrams of a flat−bottomed digester and a curved−bottom digester, respectively.

The typical feed for these digesters is usually a mixture of swine or cattle dung, water hyacinth, nightsoil, and agricultural residues, depending upon their availability and carbon/nitrogen ratios. Gas production rates are of the order of 0.1 to 0.2 volumes of gas per volume of digester per day, with retention times of 60 days at 25°C.

The technology required, materials, methods of construction and cost are well known and the digester can be built by artisans having moderate skills. In India, typical costs of different sizes of flat−bottom and curved−bottom digesters vary from Rs. 3000 to Rs. 50,000.

2. Floating cover "Indian" digester (KVIC)

The KVIC gas plant consists, essentially, of two parts: a digester and a gas holder (see figure 16). The digester is usually constructed of brick, dug and built below the ground level. The depth varies between 3.5 metres and 6 metres and the diameter is between 1.3 metre and 6 metres, depending upon the quantity of feed available. The digester usually has a central partition wall stopping short of the top of the digester to separate the incoming slurry from the outgoing slurry and is fed semi−continuously through an inlet pipe, the input displacing an equal amount of slurry through an outlet pipe.

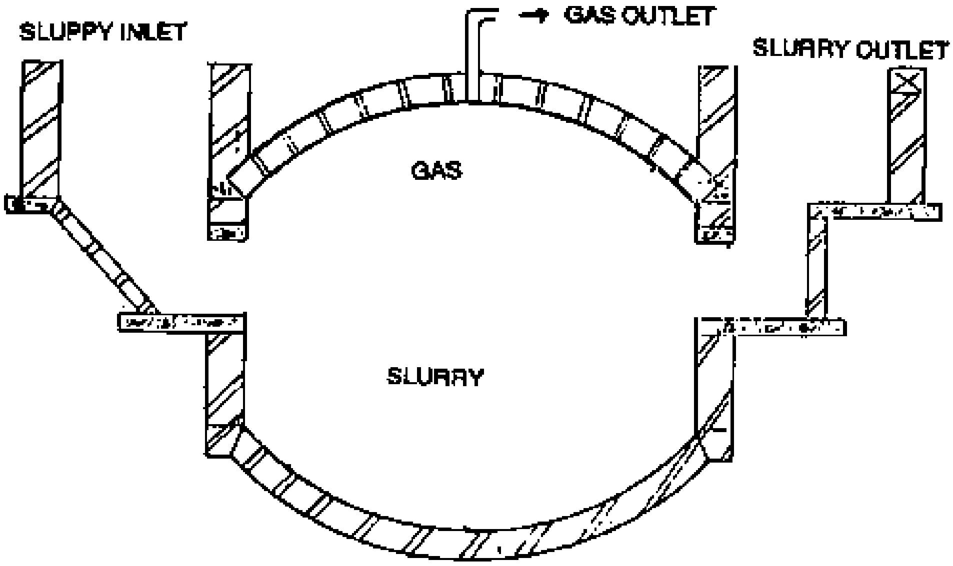


Figure 14. Cross−section of a fixed−dome digester with a curved bottom

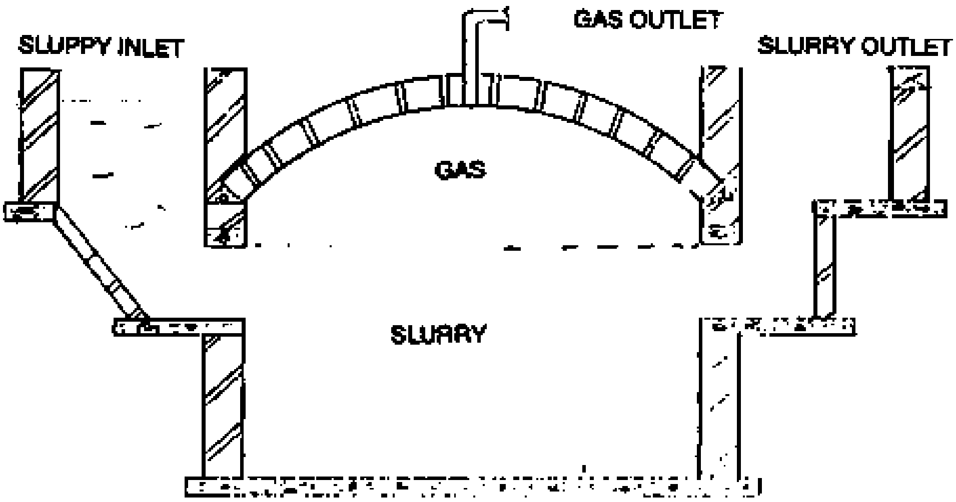


Figure 15. Cross−section of a fixed−dome digester with a flat bottom

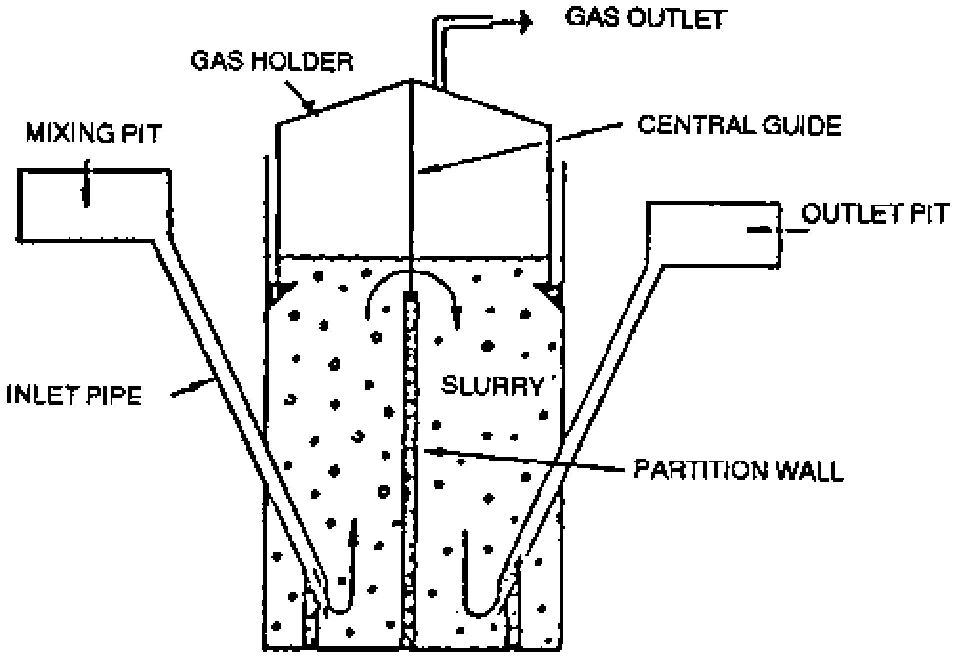


Figure 16. Floating cover digester

The gas holder is a drum−like structure usually constructed of mild steel, although, due to corrosion problems, other materials such as ferrocement, high−density polyethylene and fibreglass, have also been used. Its volume is approximately 50 per cent of the total daily gas production. The gas produced in the digester is trapped under the gas holder which rises and falls on a central guide. The gas pressure is equivalent to the weight of the drum and the weight of the gas holder being designed to give a pressure of about 90 kg/sq m of the area of the holder. This pressure is sufficient to force the gas into the household appliances.

Most digesters of this type are operated at ambient temperatures and thus, retention times depend upon the climate. In warm climates, such as Southern India, where ambient temperatures vary from 20°C to 40°C, the typical retention time is 30 days. In colder climates, the retention time can be up to 50 days.

The typical feedstock is cattle dung, although substrates such as agricultural residues, nightsoil and aquatic plants have been used successfully. The cattle dung is usually mixed with water in the proportion of 4:5 so as to obtain the required solid concentration.

Typical costs of KVIC gas plants in India vary from approximately Rs. 10,000 for the smallest (2 cu m) plant to about Rs. 50,000 for the largest (25 cu m) plant.

3. Bag (Taiwanese, China) digester

The bag digester is essentially a long cylinder made of PVC, or strengthened nylon fabric (see figure 17). The digester is extremely light and can be easily installed in a shallow trench dug slightly deeper than the radius of the digester. On account of its being prefabricated of simple construction and low cost − around $25 to $30 per cubic metre in China − bag digesters appear to be very competitive.

Typical retention times in these digesters for swine waste (the most common substrate used in existing bag digesters) are 20 days in warm climates (30C° to 35°C) and 60 days in cold climates (15C° to 20°C): but the digester can be heated by the sun thus reducing the retention time and increasing the gas yield (50 to 300 per cent higher according to some sources).

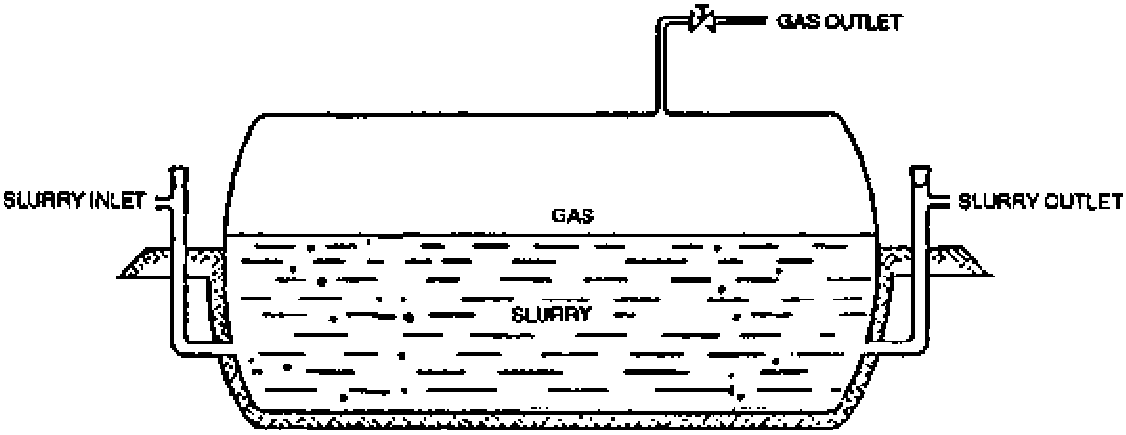


Figure 17. Bag digester

D. Community biogas plants

A pre−requisite for an individual (family) biogas plant is that there should be sufficient substrate to feed the plant: even the smallest size gas plant (2 cu m) requires about 40 kg of fresh dung per day which represents the daily droppings of four medium−size cows, buffaloes or bullocks. Thus, the majority of poor peasants, owning, at the most, one or two animals, cannot benefit from biogas plants, thus missing out from the biogas programmes normally promoted in several developing countries. Not having any alternative, they have to use the traditional fuels − wood and dung. It is in this context that the concept of community biogas plants appears attractive and is receiving attention in many parts of the world.

In India, the Department of Science and Technology initiated a programme of setting up experimental community biogas plants in the country under the All India Co−ordinated Biogas Project. The Khadi and Village Industries Commission (KVIC) (which was responsible for the design and promotion of the "Indian" floating−dome biogas digesters mentioned earlier) was entrusted with the responsibility of conducting the feasibility study, design, and execution of 12 community biogas plants in the country. KVIC was also responsible for looking after and maintaining the 12 plants for a period of three years, whilst local agencies were being identified to take over and manage the projects. Subsequently, all renewable energy programmes came under the Department of Non−conventional Energy Source (DNES) and the Department reported that 433 community/institutional biogas plants had been installed in 1989 (58).

1. Description of a community biogas project

The following is a description of one community biogas project − the Masudpur Project, the data for which are given in table 9.

The largest of all the 12 projects is situated at Masudpur village, 20 kilometres from New Delhi. This village has a population of about 1500, with 200 houses, and its life style has some urban influence due to its proximity to New Delhi. Very few people in the village maintain cattle but there is a dairy complex nearby which ensures an adequate supply of cattle dung for the biogas project which was initially set up to supply fuel gas to 72 houses.

The Masudpur Community Biogas Project consists of one biogas plant of 85 m^3/day capacity for digestion of cattle dung, one biogas plant of 85 m^3/day capacity attached to latrines for generation of biogas from nightsoil coupled with cattle dung and three biogas plants of 8 m^3/day capacity each for digestion of agricultural wastes. Seventy−two houses were given gas connections and the gas is supplied for about three hours in the morning and three hours in the evening, mainly for domestic cooking.

Table 9. Data of the Masudpur project

Capital cost for 1st Phase	− Rs. 600,000
Date of completion of the 1st phase of the project	− February 1982.
Number of bio−gas plants set up	− 5

Size of bio–gas plants:	–
Cowdung plant (1 unit)	– 85 m^3/day
Nightsoil plant (1 unit)	– 85 m^3/day
Waste plant (3 units)	– 8 m^3/day
Daily gas production	– 194 m^3
Number of latrines connected to the gas plant	– 20
Total length of pipe line for distribution of gas	– 1 600 metres
Number of houses with gas connections	– 72
Number of persons who benefited	– 360
Hours of gas supply	– 3 hours in the morning 3 hours in the evening
Capacity of dual–fuel engine installed	– 10 HP coupled with 7.5 kVA alternator

Source: "Community biogas project" (Bombay, The Director of Gobar Gas Scheme, Khadi and Village Industries Commission, n.d.).

Twenty toilets were built on the project site which are directly connected to the nightsoil biogas plant which helps in improving the village sanitation in addition to providing fuel gas.

One dual–fuel engine of 10 HP coupled with a 7.5 kVA alternator is installed on the project site. The generated electricity supplies pumps which lift water from a borewell and supply enough water to meet the requirements of the project as well as the domestic needs of the houses covered under the project.

The first phase of the project with a total length of 1600 metres of gas–distribution pipes has cost approximately Rs. 600,000 excluding the cost of land. The Delhi Development Authority is providing 1.5 hectares of land on lease for setting up the project.

During the first three years of the project, its maintenance was looked after by Khadi and Village Industries Commission. The villagers showed keen interest in the project right from the beginning with a project committee being constituted which was closely associated with the subsequent maintenance activities of the project.

2. Social benefits of the community biogas project

The community biogas complex of Masudpur gradually changed the lifestyle of the villagers: cooking time was reduced and cooking made easier; the kitchens became cleaner and vessels brighter, due to the use of smokeless fuel which, in addition, reduced incidence of eye and lung diseases.

Rural sanitation improved due to the use of latrines and the project helped conserve the organic manure.

With the availability of indigenous fuel, the demand for fossil fuels such as kerosene and coal was reduced, thus minimizing the stress on transporting kerosene and coal.

The complex, which was started solely as a biogas complex, has now taken the shape of a centre for demonstration of renewable sources of energy with the installation of a windmill for pumping water and of solar photovoltaic cells to generate electricity to operate television sets.

3. Alleviation of rural poverty

The housewives used the spare time made available by the project for some productive work and a *charkha* (handloom) unit was introduced under the project to help in supplementing the income of the families.

VII. SWITCHING: POLICY ISSUES AND REQUIREMENTS

A. Policy issues

Three main policy areas are relevant to energy and fuel switching. First, an issue which is usually a very high priority for most national governments, is the shortage of foreign exchange: most developing countries, and especially the poorer ones, suffer massive debt and foreign exchange constraints thus any contribution to reductions in these constraints is of potential benefit to the economic development of those countries. However, in most countries, the proportion of imported oil−based fuels consumed by the rural domestic and industrial sectors, and by the urban domestic sector, is relatively small. Therefore, the benefits of switches in these sectors from non−renewable to renewable sources of energy are, in most cases, unlikely to be significant.

The second policy area is environmental: one of major causes of the increasing rates of land degradation and desertification prevalent in many developing countries is the removal of biomass cover for agricultural clearance, fuel, building materials and industrial demands. Where national circumstances do not allow a switch to non−renewable fuels or other measures to counter this trend, a switch to both the supply of, and a demand for, renewable sources of energy, especially biomass, can provide the incentives for rational utilization of existing biomass sources, and for production of new biomass resources. These may be on−farm and off−farm which, in turn, can help, at first, to counter and, then, to reverse the non−sustainable use of biomass resources, and slowly reverse land degradation.

The third, and possibly the most difficult area of policy, is land reform: the present systems in many countries, especially in medium− and high−potential zones in densely populated Asian countries, with large amounts of sharecropping and rental of small farms and holdings, and a pronounced lack of security, make investment in any kind of agricultural activity difficult. Where returns are delayed even more than with conventional crops, as is the case with many biomass energy producing crops, especially trees, the situation is worse. Ownership of whatever land they have access to would therefore be of assistance to small and medium farmers in any move towards biomass production which, in turn, would generate additional income.

B. Policy requirements

The fact that biomass accounts for such a dominant proportion of the energy used by the rural and urban low−income groups, suggests that biomass commitments have the greatest contribution to make at the national level, and are at stages of development that make them already feasible in several cases, especially biomass production. Other types of commitments are also feasible, and others may become feasible in the future, but their contribution will, for the near future, be relatively minor in most cases (although any large−scale increase in petroleum prices might dramatically alter this prognosis).

Switching will clearly require some policy support at the national level. National fuel pricing policy is one of the main tools available to governments for creating a favourable environment for switching. Particularly where GNP is rising and agricultural development is energy−intensive, continuous rises in the real price of oil−based fuels are a necessary condition for substantial switching to renewable energy sources, although this must be done in parallel with policies which encourage the supply of alternative sources of energy and the means of using them. Where there is a switch to renewable sources in urban areas, interventions in the transport sector may be necessary to ensure that adequate supplies of new fuels can flow from rural or peri−urban areas to the urban areas. Restructuring of national forestry operations may also be needed to ensure that fuelwood supply becomes an important component of forest management and of future forest development. Changes will also be needed in agricultural policy: often a shift of emphasis from irrigated export crops to rain−fed food crops is needed at the national level, and a shift from extension work to large farms and estates to extension work to small and marginal farmers at the local level. There will have to be greater integration of energy policy with agricultural and forestry policies.

While governments continue to subsidize rural electrification and irrigation, the viability of renewable sources of energy remains doubtful: thus, in some cases, it might be necessary to use subsidies to encourage either the development or the use of new techniques. However, the use of subsidies must be considered very carefully: they tend to benefit mainly the relatively wealthy (as was the case in tree−planting programmes in parts of India) and careful consideration must be given to how they are implemented.

Another area of subsidy is the possible establishment of a briquetting industry for agricultural residues. However, setting up such an industry should be done only after evaluation of the effects of any removal of residues previously used on the fields, which might lead to reductions in soil fertility or stability, or to increased pest/weed control measures; and of the effects of removal of residues on groups who use them as fuel or fodder. Where a briquetting industry is appropriate, it might initially require underwriting the development costs of integration with agro−processing industries or with agricultural schemes specifically designed to produce residues.

A further area of possible subsidy is tree planting. At present, wood and charcoal usually enter urban and rural markets at prices much lower than their replacement costs using existing wood production and collection techniques. Small farmers or landless labourers often collect and sell wood from land clearance or illegal felling, so that the costs of production are extremely low. However, as the demand from urban households or rural industries increases, sources near the markets will, and in many areas of Africa already have, become exhausted, and alternative sources further from markets have to be tapped. This increases the cost of transport and the retail price of fuel. This, in turn, may provide the incentives needed for farmers and industry to grow trees, at costs lower than those possible for formal forest services. But subsidies and extension and/or credit might be needed to back up the emerging incentives, at least in the short term.

Support other than subsidies is also possible. Goldenberg and others (64) have pointed out that governments can play a role in stimulating the market for woodfuel appliances by re−allocating funds from large energy−development projects into projects that have a conservation component. For example, in urban areas, the introduction of low−cost housing could be undertaken simultaneously with the introduction of improved stoves or solar hot−water systems, or with peri−urban forestry programmes. Such projects could create demands which would encourage manufacturers to establish local production and to reduce the costs of appliances.

One of the main constraints on large−scale switching is the need for applied research and development in the production and conversion techniques of renewable energy. Co−ordinated and end−use−oriented research and development programmes are needed to ensure the use of technologies and crops/trees that actually meet users' needs and are cost−effective. These research programmes must combine technical and social science inputs *as* the social science components define local needs, and detail patterns of energy consumption and changes that are already occurring, patterns of land use, and transport networks. They also determine the influence of changes in cropping patterns on energy use and availability, and provide monitoring and evaluation inputs. Wherever possible, end−users and/or manufacturers should be involved in the development work from the initial design concept through to the final testing in the field and commercialization.

Research programmes have to cover a wide range of problems, many of which are not directly associated with energy production or conversion. For example, the introduction of new techniques to reduce tillage and weeding would need new strains of crops that can provide high yields with low water and fertilizer inputs. Water supplies are crucial to the production of food and energy crops, but there is a dearth of data to help determine the optimum water−delivery technologies for many crops in different ecological systems. This also requires further research which needs to be coordinated, in particular, the establishment of multidisciplinary teams with long−term funding.

There is, presently, a need to carry out well funded and managed pilot programmes for a range of renewable technologies. These programmes must be properly monitored so that thorough evaluation can be carried out at their completion. Improved methods of monitoring and evaluation still need to be developed to dissipate much of the confusion surrounding the role of renewables. However, before pilot programmes are established, it is essential that detailed data on energy consumption, land productivity and production be collected. Many renewable programmes are still based more on rhetoric than a detailed understanding of real needs and constraints.

C. Programme requirements

Some of the main requirements of biomass programmes, which would most likely allow policies of switching to renewable sources to make a significant contribution to economic development and alleviation of poverty for rural and urban low−income groups, are the following:

(a) It is important that farmers own the trees they plant or the land they are planted on, as many trees are not harvested for five to eight years. For example, in Nepal, success became possible only when there was a change in the legislation that returned control of some of the forest land to villagers. Landless farmers would need parcels of marginal land, in addition to the credit and extension assistance needed by all groups.

(b) Community organizations should be established for the management of tree planting programmes. However, as Skutch points out, these groups are only effective if they have effective leadership (24).

(c) Tree planting organizations should be fairly small and represent specific groups within the village. For example, in Kenya, women's groups and, in the United Republic of Tanzania, church or school groups, have proved the most successful.

(d) Where agriculture and wood collection are mainly carried out by women, they should be the main focus of extension activities. Extension work should start from perception of agricultural and fuel problems and from knowledge of tree growing, and only then, should improvements with new species and methods of intercropping and cultivation, which are compatible with existing knowledge and skills, be introduced.

(e) In many areas, extension work is more effectively carried out by non−government organizations (NGOs) than by government organizations, especially to marginal groups. Government extension is, thus, often more effectively used in supporting NGOs to assist villagers than in dealing directly with villagers.

Experience of recent programmes indicates that the introduction of new renewable technologies is often successful if it takes place within a community development framework. It also often helps if it is one component within a large programme with broad objectives − rural development, health, improving agricultural productivity, creating employment − rather than with a narrow objective linked to the provision of energy alone. Wide programmes usually have large resources and can also provide a wide range of end uses for energy sources and technologies developed within the biomass production component.

The need for a community development framework is especially important for the introduction of community biogas as shown by the Masudpur project described earlier. R. Roy (65) suggests that a community must be able to determine how the costs and benefits of community plant are to be allocated, before it is successfully utilized. With biogas, this requires decisions on who should provide the dung and collect it, on how and to whom the gas should be given, and how the costs of operation and maintenance should be met. Full participation of the community may produce changes in social relations between the various groups involved in dung collection, plant operation and gas use, along with the effects of the possible introduction of cash value to a fuel traditionally considered a free good. For charcoal, Ugandan experience suggests that if traditional producers become part of government or private forestry programmes, they can be induced by economic incentives and legal means to help manage forests and to use thinnings and sawmill residues. This has the advantage of providing extension and effective monitoring cheaply, and of introducing new or improved technologies in conditions where producers are assured of sustainable supplies of wood and ready markets. However, this approach does have the possible disadvantage that producers could be no longer free to produce charcoal where and when they wish which, in turn, could affect production.

Correct operation and maintenance of new and improved technologies is often important for successful projects, and extension work and training for local operators and repair staff are vital inputs to this. For some technologies, training and after−sales service are best provided by the manufacturers or by both manufacturers and government, the latter providing training for mechanics and upgrading of skills of local agricultural and industrial officers in the inspection, use and maintenance of new technologies. In the case of stoves, training would probably be best carried out by NGOs or artisans who produce and sell the stoves.

REFERENCES

1. World Bank, *The Energy Transition in Developing Countries* (Washington, D.C., World Bank, 1983).

2. Eckholm, E., "The other energy crisis", *World Watch Paper 1* (Washington, D.C., World Watch, 1975).

3. Islam, N., *Evaluating the Impact of Using Residues for Fuel as a Substitute to Insufficient Fuel Supplies* (Rome, Food and Agriculture Organization of the United Nations, 1983).

4. Hislop, D., *A Study of the Gur Industry in Bangladesh* (London, Intermediate Technology Development Group, 1985).

5. Leach, G., and Gowen, M., *Household Energy Handbook,* World Bank Technical Paper No. 67 (Washington, D.C., 1977).

6. Flueret, A.K., and Flueret, P.C., "Fuelwood use in a peasant community: A Tanzanian case study", *Journal of Developing Areas,* No. 12, 1978.

7. Haugerud, A., *Household Energy Use in Embu − Socio−economic Aspects of Wood Use, Cooking and Lighting Fuels and Water Collection* (Stockholm, Beijer Institute, 1981).

8. Meyers, S., *Transportation in the LDCs: A Major Area of Growth in World Oil Demand* (Berkeley, CA, Lawrence Berkeley Laboratory, 1988).

9. World Bank, *Nigeria Energy Issues and Options* (Washington, D.C., World Bank, 1983).

10. Foley, G., *Exploring the Impact of Conventional Fuel Substitution on Woodfuel Demand* (London, Earthscan, 1985).

11. Bhattia, P., "Traditional energy sources: a methodological note", A paper prepared for the Asian Pacific Development Centre, Kuala Lumpur, 1983.

12. Moss, R., and Morgan, W., *Fuelwood and Rural Energy* (Dublin, Tycooly International Press, 1983).

13. Van Buren, A., *Patterns of Woodfuel Scarcity and Commercialization* (London, IIED, 1983).

14. Foley G., and Barnard J., "Farm and community forestry" (London, Earthscan, 1984).

15. Bhattia, P., "Renewable energy sources: assessment and technology evaluation", a paper prepared for the Asian Pacific Development Centre, Kuala Lumpur, 1984.

16. Alam, M., Dunkerley, J., Gopi, K.N., and Ramsay, W., *Fuelwood Survey of Hyderabad* (Hyderabad, Osmani University, 1983).

17. de Montalembert, M., and Clement, J., "Fuelwood supplies in developing countries" (Rome, Food and Agriculture of the United Nations, n.d.).

18. Baialy, J., "Energy flows in subsistence agriculture", Ph.D. thesis, University of Edinburgh, 1982.

19. Pathak, B.S., *Energetics of a Developing Agriculture, a Case Study of the Punjab* (Ludhiana, Punjab University, 1982).

20. Reddy, A., "An Indian village agricultural ecosystem – the case of Ungra village", *Biomass,* 1 (1981).

21. Food and Agriculture Organization of the United Nations, *The Employment of Draft Animals in Agriculture* (Rome, 1972).

22. Weatherly, P., and Arnold, J., "Environmental assessment of rural electrification project in Indonesia" (Jakarta, USAID, 1980).

23. Food and Agriculture Organization of the United Nations, *Wood Fuel Survey* (Rome, 1983).

24. Skutch, M., *Why People Don't Plant Trees* (Washington, D.C., Resources for the Future, 1983).

25. Hosier, R., *Surveys of Domestic Energy Consumption* (Stockholm, Beijer Institute, 1981).

26. Vidyathi, A., "Energy and the poor in an Indian village", *World Development,* vol. 12 (1984), No. 8.

27. Barnard, G., and Kistoferson, L, *Agricultural Residues as a Fuel in the Third World* (London, Earthscan, 1985).

28. Kalkra, B.R., "Size and distribution of operational holdings", *Kurukshetra,* September 1981.

29. Food and Agriculture of the United Nations, *The State of Food and Agriculture* (Rome, 1977).

30. Desai, A., "Rural energy surveys in India" (NCAER, 1982) (mimeo.).

31. Desai, A., *India's Energy Economy: Facts and their Interpretation* (Bombay, Centre of Monitoring the Indian Economy, 1980).

32. Binswanger H., *The Economics of Tractors in South India, an Analytical Review* (New York, Agricultural Development Council, 1978).

33. Dhawan, B.D., "Economics of ground water utilisation traditional versus modern", *Economic and Political Weekly,* 21 July 1975.

34. Hafsah, J., and Berstein, R., "Economic, technical and social aspects of tractor operation and use in South Sulawesi, Indonesia", in IRRI, *Consequences of Small–farm Mechanisation* (IRRI, Manila, International Rice Research Institute, 1983).

35. Sukharomana, S., "Domestic resource cost of agriculture mechanisation in Thailand", in *Consequences of Small–farm Mechanisation* (Manila, International Rice Research Institute, 1983).

36. Hurst, C., *Energy for Small Engines: a Review of Potential Energy Sources* (Ottawa, IDRC, 1984).

37. Vassant, M., *Technologies for Lifting Irrigation Water* (New Delhi, International Labour Organisation, 1981).

38. Lockwood, B., "Farm mechanisation in Pakistan, policy and practice", in *Consequences of Small–farm Mechanisation* (Manila, International Rice Research Institute, 1983).

39. Farrington, J., and Aberyratne, F., "Farm power in Sri Lanka" (Department of Agricultural Economics, University of Reading, 1982).

40. Lockwood, B., *Farm Mechanization in Pakistan – Policy and Practice* (Manila, International Rice Research Institute, 1983).

41. Abbie, J., and others, *Economic Returns Investment in Irrigation in India* Staff working paper (Washington, D.C., World Bank, 1982).

42. Alan, A.Y., "Maize diamonds", *Kenya Farmer,* January 1968.

43. Ravindranath, N., and others, *Draught Power Availability and Requirement for Double Cropping in Dry Land Agriculture* (Bangalore, ASTRA, MS, 1984).

44. Hughes–Cromwick, E., *Nairobi Households and their Energy Use, an Economic Analysis of their Consumption Patterns* (Worcester, CENTED, Clark University, 1982).

45. Digernes, T.H., "Wood for fuel – the energy crisis implying desertification: the case of Bara" (Bergen, University of Bergen, 1977) (mimeo.).

46. Barwell, I., and Howe, J., *Rural Transport in Developing Countries* (London, Intermediate Technology Publications, 1985).

47. Ramaswamy, *The Management of Animal Energy and the Modernisation of the Bullock Cart* (Bangalore, IIS, 1979).

48. Hall D., "Biomass for Energy: Fuels now and in the future". *Journal of the Royal Society of the Arts,* 1982.

49. Somashekkar, H.I., and others, "Studies on the Ungra village ecosystem" (Bangalore, ASTRA, MS, 1982).

50. Stuckey, D., and Jumla, C., *Power Alcohol in Kenya and Zimbabwe: a Case Study in the Transfer of a Renewable Technology* (New York, United Nations Conference on Trade and Development, 1984).

51. Hall, D., and De Groot, P., "Biomass for food and fuel − a parallel process" (London, Kings College, 1985).

52. Gupta, T., "Some financial and national resource management aspects of commercial cultivation of irrigated eucalyptus in Gujarat", *Indian Journal of Forestry* (1978), (2).

53. Palmberg, C., "A vital fuelwood genepool is in danger" *UNISILVA,* vol. 33 (1981), No. 133.

54. Foley, G., *Farm and Community Forestry* (London, Earthscan, 1984).

55. Joseph, S., Krishna Prasad, K., Van der Zaan, H.B., (eds.), *Bringing Stoves to the People − An Assessment of Impact* (Nairobi, Foundation for Woodstove Dissemination, 1990).

56. United Nations Centre for Human Settlements (Habitat), *Use of New and Renewable Sources of Energy with Emphasis on Shelter Requirements* (Nairobi, 1989) (HS/183/89E).

57. Caceres, C., "Stoves and kilns mapping progress over the last decade", *Bioenergy 84* (London, Elsevier, 1984).

58. Centre for Science Technology and Environmental Policy Studies, "Status of non−conventional energy sources in India", *Third World Science and Environment Perspectives,* vol. 1 (1989−1990), No. 2.

59. Chidumayo, E.N., "Wood fuel issues", background paper for National Conservation Strategy, Lusaka, 1984.

60. Powell, J.W., "Wood waste as an energy source in Ghana", *Renewable Energy Resources and Rural Applications in the Developing World* (Boulder, CO, Westview Press, 1978).

61. Asian Institute of Technology, "Evaluation and selection of ligno−cellulose wastes which can be converted into substitute fuels" (Bangkok, Asian Institute of Technology, 1983).

62. Shija, P., "Charcoal in Tanzania" (1984) (mimeo.).

63. Stuckey, D., "Hot air or hot stuff?", *Bioenergy 84* (London, Elsevier, 1984).

64. Goldemberg, J., Williams, R., Reddy, A., "Basic needs and much more with one kilowatt", *Ambio,* November 1985.

65. Roy, R., "Family and community biogas plants in rural India and China" (Milton Keynes, Open University, 1980).

ANNEX

Case study of the improved Kenya claystove

A. Background

The supply−demand imbalance with respect to fuelwood and charcoal in Kenya has had several direct negative impacts on households, including:

(a) Increased distance over which fuelwood must be gathered and carried, hence, increasing labour effort and time.

(b) Pressure to substitute commercially sold charcoal.

(c) Escalating prices for charcoal.

The Kenya Renewable Energy Development Project (KREDP), sponsored by the United States Agency for International Development (USAID), was launched in September 1981 under the auspices of the Kenya Ministry of Energy. It was designed to help mitigate the fuelwood shortage by augmenting fuel supplies and by encouraging conservation in energy use.

The KREDP had three main objectives:

(a) To improve and promote cooking stove and charcoal kiln efficiency;
(b) To carry out research, demonstration and dissemination on agroforestry;
(c) To carry out energy planning and conservation, technical assistance and training.

The conservation efforts of KREDP, particularly the effort to design and disseminate fuel-conserving charcoal *jikos* (stoves), were designed to mitigate the negative impacts of the fuelwood supply-demand imbalance. The project is a good example of the relative role and characteristics of donor-financed technical assistance to governments, and the activities of non-government organizations and of the private sector.

B. Traditional stoves in Kenya

Tests in Kenya had shown that heat transfer efficiency (useful heat captured) from the two most common cooking technologies (the open three-stone fire and the traditional metal *jiko*) were very low: 5-10 per cent and 15-20 per cent, respectively. The hypothesis behind the KREDP stove programme was that charcoal and woodstoves could be substantially improved, thereby reducing fuel use and costs. The cookingstove/kiln programme had the following stated objectives:

(a) To provide technical assistance on energy-efficient cooking stoves through:

(i) Identification, testing and demonstration of improved charcoal and woodstoves;

(ii) Promotion of production and dissemination of improved stoves;

(iii) Building of institutional capability within the Ministry of Energy and Regional Development (MOE&RD) to enable the Ministry to implement stove programmes;

(b) Provide technical assistance in charcoal production through:

(i) Identification of improved means of charcoal production and of constraints to dissemination of such production methods;

(ii) Assistance in dissemination of improvements and development and implementation of demonstration projects.

The project eventually focused on the charcoal *jiko* due to the likelihood of its rapid dissemination in the urban market as it was estimated that some 1.5 million traditional charcoal stoves were in use, with replacement of about 400,000 annually.

C. Initial technology screening

The initial task of the stove programme was to screen available stoves and choose and disseminate the best ones. However, this task proved much more complex than anticipated and led to the development of criteria for the selection of stoves and to the establishment of a formal test procedure with appropriate facilities and trained staff.

Testing and prototype development were hindered by lack of instruments, facilities, and laboratory and workshop space. It was necessary to use the technical assistance adviser's own home, and later to borrow space and facilities at Kenyatta University Appropriate Technology Centre to conduct tests.

The basic screening criteria chosen were aimed at achieving a substantial output of improved stoves by project end. The criteria for choosing the right design of stove were:

(a) Affordability for intended low-income market (i.e., price range of Ksh 40-90),

(b) Social suitability and adaptability to local foods and cooking methods;

(c) Possibility of being produced in sufficient numbers so as to have a substantial impact on charcoal or wood consumption in a few years' time;

(d) Availability of materials and skills locally;

(e) Passing water boiling and cooking tests;

(f) Durability and ease of production;

(g) Reliability, ease of lighting and quick cooking;

(h) Acceptable levels of carbon monoxide emission (1).

The Thai bucket clay stove was one major option, as the stove was more efficient than the traditional stove as well as being capable of using local materials (clay and scrap metal) and available skills. Therefore, a team which also included two employees of a private company interested in commercial production, travelled to Thailand in March 1982 to evaluate the stove. The team gained a great deal of qualitative and quantitative information on the stove, including production methods, fuel use and kiln design, materials, tools and machinery, stove designs, marketing and transport, associated industries, economics and training systems and required skills.

The mission proved to be very important. It found that the Thai bucket clay stove production system was highly developed and that the stove closely resembled the traditional Kenyan *jiko* in size and method of use.

Subsequently, the project team reviewed the following stoves: traditional *jiko,* the Thai bucket clay stove, the "Umeme" (UNICEF), the "Pogby", the "Micuta metal" (double−walled chimney), the "Karai", the "Pipeliner" (Marwick), the "Kimaki", and the "Kimaki sawdust−waste". Only three of the stoves, namely, the Thai bucket clay stove, the "Pipeliner" and the "Umeme", were formally tested, as the others failed on the basis of one or more of the above criteria.

The test results showed that all the three stoves were significantly more efficient than the traditional *jiko.* However, the "Umeme" had technical design defects in its pot−rests, was significantly more costly, and was somewhat difficult to produce. The "Pipeliner" stove (simply constructed from a small clay pipe produced by a clay−pipe factory), was too small and the straight vertical shape did not allow maximum efficiency. Although this stove was also a variant of the Thai stove, it could only be manufactured by large capital−intensive production methods. As the aim of the Ministry of Energy was that any improved stove should be produced by small−scale methods involving current stove *fundis* (artisans) as much as possible, the "Pipeliner" stove was dropped from further consideration.

On the basis of the test results and staff assessment of the stoves on the above criteria, the Thai bucket clay stove was found to be the only stove suitable for further assessment and possible production at that time.

D. Field tests

The next phase of the process required testing the stove under actual field conditions so as to ascertain its durability, speed (lighting and cooking) and consumer appeal. The Ministry of Energy (MOE) approved a proposal for the Kenya Energy Non−Governmental Organization (KENGO) to execute the field survey and testing, which were undertaken from October 1982 to April 1983.

The field tests encountered many difficulties such as:

− Lack of KENGO technical staff;

− Erratic availability of funds from MOE and USAID;

− Too many participating organizations;

− Difficulty in controlling stoves produced;

– Difficulty in maintaining quality control over stoves produced due to clay liners breaking loose from shells;

– Stoves being very heavy and difficult to light.

Another major problem was the difficulty in producing a sufficient number of stoves. In Nairobi, only about 500 stoves were produced. It was, therefore, arranged for the stoves to be manufactured by a commercial producer who appeared to be most likely to provide follow–up commercial production. This producer, Jerri International, was a small–scale formal ceramics manufacturer employing a trained potter and having a moderate–sized electric kiln, and good access to clay. The owner had tried earlier to manufacture improved clay stoves but had failed due to lack of technical knowledge. Technical advice was provided to Jerri International by the project staff and included full details of the Thai production process. Assistance was given in making various moulds, proper mixing of clay, use of special materials such as rice husk ash, and in curing and firing.

In order to obtain a representative geographical distribution for the field tests, the Coast, the Central and the Western provinces were included. However, because of production and dissemination logistics, only the Coast and Central provinces were formally included in the tests.

After the field tests, Jerri International quickly seized the initiative and expanded its production capability and gradually created a large–scale distribution and marketing network.

During efforts to find other producers, problems arose in finding skilled potters, developing adequate kilns, ensuring adequate fuel for kilns, and clay–stove training. Partly for these reasons, and based on reports from Papua New Guinea of the stove's performance, International Technology Development Group (ITDG) collaborators suggested that a cement–vermiculite lined–stove be evaluated. Several models of the stove were constructed and the resulting design using a mixture of cement and vermiculite essentially replaced the clay of the Thai stove.

The CV (cement–vermiculite) stove was shown to be similar to the Thai stove in efficiency and seemed likely to eliminate some of the clay–related problems of the Thai bucket clay stove. It was decided, therefore, to introduce the CV stove immediately into the ongoing field tests and about 10 stoves were built and distributed, primarily in Mombasa.

E. Stove production

In January 1983, it became apparent that the MOE wanted additional effort to be devoted to stove production and, therefore, although the field tests had only produced preliminary results, albeit very favourable, attention was turned to production. It was necessary for the contractor (EDI) to take action and provide funds since the Energy Development Fund (EDF) at this time was being held up by administrative problems. EDI hired three *fundis* having either extensive experience in stove building or with experience on the survey which was underway. This team proceeded to train artisans in a number of areas (Kibera, Shauri Moyo and Kirigoya) and attempted to stimulate commercial production.

The training activity was limited to cement–vermiculite stoves and was based in Nairobi. It became apparent that there were constraints and little commercial production by the trained group was started. From conversations with the *jiko* makers, it was found that the main constraint was lack of easy access to vermiculite, and some fear as to whether the *jiko* makers would be able to sell the new stoves. The project team, therefore, undertook to help one CV–stove–maker by providing an initial supply of materials, securing an initial commercial order (200 stoves), and putting on a public cooking efficiency demonstration of the new stove in Shauri Moyo (the main stove–producing and sales area).

At about the same time, several innovative *jiko fundis* adapted the new stove by buying clay liners and inserting them into their shells. These stoves were sold at about Ksh 80 retail, and liners were purchased from Clayworks.

Further attention was directed to starting other production units. However, these were, largely, clay stove production units which were difficult and costly to initiate, but were expected to produce better–quality, longer–lasting stoves. The first three projects were: (a) a production unit at Thika staffed by artisans and organized by several women's groups; (b) in Kakamega, at Ilesi Pottery; and (c) in Kibera, as part of a Harambee–funded project to produce 50,000 stoves for that area. The principal constraints in the first two cases were lack of funds to start the projects.

The principal source of funds for the above production activities under the KREDP project design was to have been the so−called Energy Development Fund. As a funding approach to stimulate development, the EDF had initially appeared very promising. However, over several years, the Fund proved difficult to administer and development of numerous small−scale projects proved to be a much more difficult and costly exercise than envisaged in the project design.

In order to assist in determining how best to stimulate stove production, a survey of cooking stove artisans in Nairobi at Shauri Moyo was conducted. The survey was designed to ascertain the characteristics of the informal stove production system and to determine whether this system could be used to produce and disseminate stoves. Results from the survey indicated that the industry was putting out an estimated 400,000 cooking stoves per year. These came in three main sizes and ranged in price from Ksh 20 to Ksh 75, depending on quality of materials used. In the open−air workshop at Shauri Moyo that was sampled, 25 shed owners variously employed a total of up to 300 workers per day (12 each on average). The raw materials used were: oil drums, round bars, flat bars and rivets. Other scrap metal was purchased from scrap−metal dealers.

The problems facing the traditional cooking stove industry included unreliable supply of materials, lack of secure workshop space, harassment from local authorities whose land the artisans had occupied without legal tenure and production stoppages due to rains. Nevertheless, this sector holds much promise, due to the following factors:

(a) The traditional cooking stove artisans have already established a network capable of mass production of stoves;

(b) The industry employs simple but workable production processes, management techniques, marketing and distribution networks, and a labour−intensive approach;

(c) The industry's methods for personnel recruitment and training are straightforward and inexpensive;

(d) Skills for retrieval and recycling of scrap metal are well developed to supply low−cost raw materials;

(e) The industry's production efficiency has kept down the price of cooking stoves to a level affordable by the poor while maintaining acceptable profitability to the industry.

The KREDP, therefore, tried to stimulate the introduction of improved stoves utilizing the informal *jiko*−production sector as much as possible. However, due to their small size, difficulty in organizing the producers, and problems with the legal tenure of sites, it became necessary to establish new production units elsewhere and to relocate artisans to the new sites (for example, in Kibera and Riruta).

F. Current production summary

The major producers of improved clay stoves have been Jerri International, Clayworks (no longer producing the stoves) and informal artisans at Shauri Moyo, largely fabricating with clay pieces supplied by Clayworks. Other outlets with significant volumes of improved stoves to date include Riruta in Nairobi (started as a business venture by a KREDP stove adviser), Kibera in Nairobi (an NGO−promoted activity of the Alternative Technology Advisory Committee assisted by KREDP and, to some extent, by KENGO), Ilesi Pottery in Kakamega (developed through KREDP funding and outside technical assistance), and Kisumu, Siaya and Githurai, all promoted by KREDP jointly with NGOs. Total estimated production for the quarter October−December 1984 was 16,750 of which 14,580 were in Nairobi. Annual production at this level would be 67,000 units.

Clayworks produced an estimated 10,000 clay liners before going out of business. Their production system operated partly by barter with the artisans paying for clay pieces through the supply of metal shells. Unfortunately, lack of capital to purchase clay pieces and restricted storage severely hampered large−scale development of improved clay stoves in the informal sector in Nairobi.

Production in Nairobi has advantages of an abundant supply of scrap metal, a large traditional *jiko* sector and readily available clay whilst production in rural centres, for example, Western Kenya, was hindered by the high cost of scrap metal. Hence, an all−ceramic version of the stove (charcoal or wood burning) was chosen for Western Kenya.

G. Dissemination strategies

The official dissemination strategy of the project involved informal on−site training by the Government's technical staff and the EDI adviser (eventually incorporated in a so−called mobile training unit); formal training workshops for trainers; and training at agroforestry centres. The actual strategy employed was, however, pragmatic due to lack of Government counterpart staff, insufficient numbers of technical advisory staff, lack of funds for dissemination, and lack of Government support funds.

Nine production units were started in various parts of the country, with units sold at prices ranging from Ksh 86−100 for the clay *jikos,* to Ksh 35−50 for the cement−vermiculite stoves, and about Ksh 15−30 for all−ceramic stoves.

The dissemination programme also relied heavily on the lead taken in the early field testing by KENGO. KENGO is essentially an energy NGO playing a coordinating and, increasingly, an implementing role for afforestation and improved stoves programme in Kenya.

The formal programme begun by the Government with assistance from USAID suffered from problems such as insufficient staff, irregular and deficient funding and administrative problems. The KENGO programme, on the other hand, actively expanded a network of cooperating NGOs and stimulated commercial production by self−help groups and, to a lesser extent, by commercial producers, and has been very successful in securing donor grant funds.

Nonetheless, the technical assistance provided by USAID, coupled with promotion by the Government and KENGO'S relevant activities, had been essential in launching the improved stoves, and successful in stimulating and interesting the bulk of current commercial entrepreneurs. The formal aspects of the Government's programme, including its provision of technical staff, training at the six regional agroforestry centres and financial support to producers, were all largely dormant due to insufficient staff and funding. Lack of funds also hurt the programme by preventing provision of supplies for training *jiko* artisans, kiln construction for firing stoves and other necessary activities.

H. Pre−requisites for renewable−energy−technology implementation programmes

Based on the Kenya clay stove experience, a number of conclusions can be drawn about the requirements for a successful renewable energy technology implementation programme. These are:

1. Definition of relevant cultural and social patterns (e.g., foods and cooking methods) and basic needs of the target population Matching technology and dissemination to these needs, are essential.

2. Substantial resources are required for needs assessment, prototype development laboratory and field testing, extension and market development, and development of a production network.

3. Governments have an important role to play in fostering renewable−energy technology development through supporting and publicizing activities, removal of legal barriers (for example, providing land tenure) etc.

4. Strong motivation for development and dissemination of the technologies is vital, which should be supplemented with technical advice, e.g., through Government or donors. Here, NGOs play an essential role in mobilizing the informal commercial sector and other groups and in production, promotion/publicity efforts.

5. NGOs do not, generally, have the necessary management, financial and technical skills, and strong efforts need to be devoted to augmenting NGOs' skills in these areas. A parallel commercial effort with small−scale formal−sector entrepreneurs is desirable to develop commercial channels (5).

6. Effective dissemination depends on:

− Sound technology and design based on clear understanding of needs (which includes affordable cost);

– Technology which has already been proved in actual field conditions, i.e., in the home;

– Government policy guidance and general support is needed, which should be complemented by specific financial, technical assistance inputs;

– Consumer motivation by various aspects of the new technology, including appearance appeal, perception of upgrading of living standards, economic benefits, durability, ease of use and cost.

References

1. Joseph, S., and others "A Kenyan standard for charcoal stove performance" (Nairobi, EDI, 1982).

2. Kinyanjui, M., "An informal survey of the cookstove industry: a case study of Shauri Moyo, Nairobi" (Nairobi, EDI, 1983).

3. Kinyanjui, M., "Kenya charcoal stoves programme" (Nairobi, EDI, 1984).

4. Opole, M., "Review of production and sales of improved stoves in Kenya" (Nairobi, EDI, 1984).

5. Joseph, S., "An assessment of the impact of improved stoves programme" Report to the Food and Agriculture Organization of the United Nations, Rome.

Cover drawings by courtesy of KENGO Regional Wood Energy Programme for Africa

UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS (Habitat)
P O Box 30030, Nairobi, KENYA. Telephone: 230800, 520600
Cable: UNHABITAT; FAX (254) 2 226473, 226479; Telex: 22996 UNHAB KE