65311
PN-ABE-692

The Experience with
Improved Charcoal and Wood Stoves
for Households and Institutions
in Kenya

by

Eric L. Hyman

December 19, 1985

Research for this paper was sponsored by Appropriate Technology International (ATI). In particular, the author would like to thank the following people for help in making the arrangements to do this study: John Rigby, Thomas Fricke, and Hugh Allen of ATI; Sandy Hale and Amare Getahun of Energy/Development International; Achoka Aworry, Maxwell Kinyanjui, and Gerald Chege of KENGO; and Francis Njoroge of the Ministry of Energy and Regional Development. The viewpoints expressed here are those of the author and not necessarily those of ATI.

## Table of Contents

Table of Contents (cont'd)

## List of Tables

## List of Figures

## Introduction

Efforts at promoting more fuel-efficient charcoal stoves to replace traditional charcoal stoves in Kenya offer some lessons for the dissemination of appropriate technologies in energy and other sectors. A market-based approach has made the Kenyan charcoal stoves project much more successful than most of the improved woodstoves projects throughout the world. The lessons from this experience are of broader significance than the technology itself (the use of charcoal as a cooking fuel) or a particular design (the specific types of charcoal stoves promoted). A large number of different designs have been tried in Kenya and although the technology is relatively simple, it is still evolving.

The Kenyan experience shows the potential desirability of relying on local artisans to manufacture consumer durables using existing private sector channels to market these goods. It also highlights the importance of going beyond a laissez-faire approach and supporting training, demonstration, and publicity to facilitate the workings of the private sector. Nongovernmental organizations (NGOs) as well as the government played an important role in this regard. In the Kenyan case, technology choice was relatively unsubsidized and left to the preferences of consumers. Since many different characteristics of a technology affect its acceptance by consumers, the stove designs were not be optimized for the single characteristic of fuel efficiency alone.

The relative success of the design, development, and early production and dissemination efforts for charcoal stoves in Kenya does not mean that further efforts are unnecessary. In fact, since the program is about to reach the take-off stage, the time is ripe for infusion of additional resources to accelerate the rates of production, adoption, and servicing particularly in urban areas outside of Nairobi. Even in Nairobi, a system to ensure better quality control would be desirable to maintain consumer satisfaction. Furthermore, consumer education and marketing activities should be expanded so that more people can become aware of the value of the technology.

## Trends in Woodfuels Consumption in Kenya

Woodfuels (wood and charcoal) are used by 95% of rural households and greater than 70% of urban households in Kenya. Biomass (woodfuels and crop residuals) constituted 74% of the country's total energy consumption in 1980. Charcoal provided 21.1 million Giga Joules (GJ) of end-use energy in 1980; this amount is equivalent to 637,000 tonnes (t) of charcoal. It took 5,306,000 t of wood to produce this much charcoal in traditional earth kilns. In comparison, 12,900,000 t of wood (153.1 million GJ) were burned directly as fuel in 1980. Although charcoal provided only 10% of the end-use biomass energy, it accounted for 37% of biomass fuel combustion because of the energy loss in converting wood to charcoal (O'Keefe, Raskin, and Bernow 1984).

This charcoal was used in the following ways: 49% by urban households for cooking; 25% by rural households for cooking; 10% by rural, industries in the informal sector (mainly blacksmiths and butchers); 9% by households for other purposes such as space heating or ironing; 5% by small-scale urban firms (mainly restaurants); and 2% by schools and hospitals for cooking (Ibid.).

Thus, 477,000 t of charcoal were consumed in household cooking in 1980.

Charcoal is primarily a fuel for lower to middle income households, particularly those in urban areas. Rural households often cannot afford to pay cash for cooking fuel. Rural households also have access to crop residuals while urban households may have to pay cash for wood. Urban households (particularly those living in a one-room house) often lack adequate storage space for wood. Charcoal takes little space and does not deteriorate much in storage. Charcoal is a more convenient fuel than wood because it is ready to use without chopping. Furthermore, charcoal is better-suited for urban houses because it burns more cleanly than wood. Charcoal also is perceived to be a more modern fuel than wood. For these reasons, many urban households are willing to pay more for charcoal per unit of effective heat than for fuelwood. Some low-income, urban households collect or purchase charcoal fines from a charcoal seller and mix the fines with a bit of clay to produce charcoal balls that can be used as fuel. Relatively well-off households also use substantial amounts of charcoal.

In most of Kenya, wood branches and twigs are collected by rural users at no cash cost, but in some areas fuelwood is sold (e.g. the Central Province). Most of the collected wood is from nearby locations, but the situation is changing and many households now have to travel farther to collect wood. Charcoal prices vary, but fuel costs may be higher for burning charcoal than for other fuels if a traditional jiko is used (Table 1). However, the capital costs of kerosene (paraffin), liquefied

Table 1

The Price of Common Cooking Fuels Per Unit of Effective Heat in March 1985

| Fuel | Gross Energy MJ[a] | End-Use Efficiency (percent) | Nairobi Market Price (K.S.) | Market Price per Unit of Effective Heat (K.S. per MJ) |
|---|---|---|---|---|
| Wood (kg) | 16.0[b] | 15-25[c] | 0.00-0.50[d] | 0.00-0.21[d] |
| Charcoal (kg) | 33.1[e] | 20-35[c] | 1.70-3.00 | 0.15-0.45 |
| Kerosene (l) | 35.1-38.9[f] | 45-50[g] | 4.37-6.56 | 0.22-0.42[h] |
| LPG (kg) | 45.2 | 55-60[g] | 9.20 | 0.34-0.37[h] |
| Electricity (kwh) | 3.6[i] | 70-75[g] | 1.00 | 0.37-0.40[h] |

---

[a] 1 Mega Joule (MJ) = .238863 kcal

[b] Air-dried hardwood at 15% moisture content (dry basis).

[c] The range pertains to traditional versus improved stoves.

[d] Fuelwood generally is collected for free rather than purchased in most of Kenya.

[e] Fully carbonized wood at 5% moisture content (dry basis).

[f] Varies with the grade.

[g] In typical Kenyan stoves.

[h] If foreign exchange costs are shadow priced at 1.2, the price per unit heat rises to the following in K.S.:

| | |
|---|---|
| Kerosene | 0.25 - 0.50 |
| LPG | 0.41 - 0.44 |
| Electricity | 0.44 - 0.48 |

[i] Excluding losses in generation and transmission.

Sources: Kash et al. 1975; U.S. FEA 1977; Lippert 1983; O'Keefe, Raskin, and Bernow 1984; Baldwin 1985; Chege 1985; Openshaw 1985.

petroleum gas (LPG), or electric stoves are higher than those of wood or charcoal stoves.

A traditional charcoal stove costs about K.S. 35-40 and an improved charcoal stove costs K.S. 85-125.[1] With one burner, the retail price of a kerosene wick stove is K.S. 145-390, an LPG stove sells for K.S. 1,250, and an electric stove sells for K.S. 1,450 (Chege 1985b). For most urban Kenyans, kerosene is the next most common fuel after charcoal. High-income households prefer LPG to kerosene. Foreign exchange comprises a significant share of the costs of these stoves: 58% for kerosene stoves, 57% for LPG stoves, and 53% for electric stoves (Openshaw 1982b). In a social benefit-cost analysis, foreign exchange costs may be assigned a shadow price to reflect their special scarcity.

Most of the demand for charcoal is located in Nairobi, Nakuru, Kisumu, Mombasa and other urban areas (Brokensha and Riley 1978). Rural households usually can collect wood for free from relatively close sources. In the highlands, wood is often used instead of charcoal because space heating is needed at elevations of 1,500 meters (m) or more in Kenya (Openshaw 1980). Sometimes, charcoal stoves are used for space heating as well. Stoves that radiate a lot of heat appear to be inefficient in cooking efficiency tests even though the energy used for space heating is not wasted.

Fuelwood is rarely transported more than 80 km in Eastern Africa due to the lack of markets. Much of the charcoal consumed in Kenyan cities comes from farther distances. About 90% of the

---

[1] In July 1985, there were about 16 Kenyan Shillings (K.S.) per U.S. dollar.

charcoal consumed in the Central Province or Nairobi comes from the Eastern or Rift Valley Provinces. Much of the charcoal sold in Kisumu is from the Western and Rift Valley Provinces. Charcoal is frequently transported to Mombasa from the Northeastern Province (O'Keefe, Raskin, and Bernow 1984) and to Nairobi from as far away as 300 km (Evans 1983). There are some restrictions on interdistrict shipments of charcoal within Kenya, mainly from arid areas.

Although transportation costs are a smaller proportion of the sales price for charcoal than for wood, there is some question about whether charcoal has an advantage over wood in terms of transportation costs per unit of effective heat supplied. Transport loads usually are limited by volume, not weight, and although transport fuel costs are affected by weight, fuel is a small part of total transport costs (Baldwin 1985). However, this may be counterbalanced by charcoal's lower moisture content of about 5% (dry basis) compared to 15% for wood and the higher efficiency of charcoal stoves than wood stoves (Openshaw 1985). In any case, charcoal is more convenient to transport than wood because it is easily packaged, shipments can be combined with other goods, and small units have a higher monetary value relative to transportation costs.

In addition to relative prices of substitute fuels and stoves, four other important factors affecting the consumption of woodfuels are changes in the number of households, degree of urbanization, relative prices of fuels, and household incomes. The number of households is a function of population growth and average household size. Expected changes in both the number of households and the urban share of the population should increase charcoal consumption. As the incomes of rural households rise, some may switch from burning wood to charcoal. When middle-income people become better-off financially, they may switch from charcoal to kerosene, LPG, or electricity.

In mid-1981, Kenya's population was 17.363 million (World Bank 1983). Between 1960 and 1970, the country's population grew an average of 3.2% per year; this rate increased to 4.0% per year between 1970 and 1982 (World Bank 1984). This recent rate is higher than that of any of the other 98 less developed countries (LDCs) compared in that study. At that current rate of increase, the estimated population on July 1, 1985 was 20.312 million. Assuming charcoal consumption has increased in proportion to population growth, 776,000 t of charcoal were consumed in 1985 and 581,000 t of this was for household cooking. If the present population growth rate were to continue, Kenya would have 40 million people by the year 2000. However, it is more likely that the rate of population growth will fall. At a population growth rate of 2.7%, Kenya would have a population of 35 million in the year 2000 (Ibid.). The Beijer Institute's projections of energy consumption for that year assume a total population of 33.96 million (O'Keefe, Raskin, and Bernow 1984).

Since most charcoal is consumed by urban households, the rate of urban population growth is particularly important. In 1981, 14.7% of Kenya's population lived in urban areas (World Bank 1983). Due to a high rate of migration from the rural areas, the urban share of the population has been increasing much faster than the overall population -- 6.4% per year from 1960 to

1970, and 7.3% per year from 1970 tc 1982 (World Bank 1984). Because urbanization has increased faster than overall population growth, the above estimate of charcoal consumption in 1985 is a conservative one.

The Beijer Institute projects an urban population of 10.24 million (7.24% annual growth) and a rural population of 23.72 million (2.88% annual growth) in Kenya in the year 2000. Thus, the urban share of total population would be about 30%. Urban households tend to be smaller than rural ones. The average sizes for both urban and rural households are expected to fall over time because the age-structure increasingly will be skewed toward younger heads of households at an early stage of their child-bearing years, and some extended families will split into nuclear families. As a result, the projections assume that average urban household size will drop from 4.38 to 4.00 while average rural household size will drop from 5.98 to 5.50. This would result in an average overall household size of 5.65 instead of 4.94 (O'Keefe, Raskin, and Bernow 1984).

In 1982, Kenya's per capita GNP was $390; this was in the upper portion of the range for low-income, oil-importing countries. Between 1960 and 1982, Kenya's real per capita GNP increased an average of 2.8% per year, a rate slightly below the average of 3.0% for low-income countries (World Bank 1984) due to Kenya's relatively high population growth despite good GNP growth. Between 1980 and 1983, growth in real GDP kept about even with population growth. The average annual increase in the Consumer Price Index over this period was 15.8% (Central Bureau of Statistics 1984). The Beijer Institute's projections assume a

1.9% average annual increase in per capita GDP between 1980 and 2000. The overall income growth changes the distribution of income which in turn affects charcoal consumption (Table 2).

Accounting for the above four factors, the Beijer Institute projects an annual increase of 6.7% in charcoal consumption between 1980 and 2000. Under the base case assumptions about fuel prices and policies and types of stoves used, total charcoal consumption would reach 76.2 million GJ of end-use energy by the year 2000. About 73% of projected charcoal consumption is by urban households, over 15% by rural households, 6% by informal urban industries, 5% by informal rural industries, and 1% by schools and hospitals. The projected total consumption by all households amounts to 2.1 million t of charcoal per year, the equivalent of 17.5 million t of wood annually if traditional charcoal conversion methods are used. An additional 2.5 million t of wood per year may be required for industrial, institutional, and commercial use of charcoal in the year 2000, for a total of 19.9 million t of wood per year.

Fuelwood consumption is projected to increase 3.6% per year between 1980 and 2000. Total fuelwood consumption would reach 416.9 million GJ in the year 2000. Almost 70% of the projected fuelwood demand is by rural households; 13% by informal rural industries; 13% by large industries; 3% by urban households; and over 1% by schools, hospitals and urban informal industries. A total of 26.1 million t of wood would be burned directly as fuel and another 1.2 million t used for nonfuel industrial purposes per year. Wood for charcoal production will account for over 42% of Kenya's total wood demand for the year 2000.

Table 2

Projected Changes in the
Income Distribution of Kenyan Households
and their Implications for Charcoal Consumption

| Urban | Income Class[1] | Percent of Households 1980 | 2000 (est'd) | Average Annual Charcoal Consumption (Tonnes/Household) |
|---|---|---|---|---|
| I | 0 - 417 | 15 | 6 | 0.24 |
| II | 417 - 1,227 | 28 | 17 | 0.53 |
| III | 1,227 - 2,555 | 29 | 34 | 0.69 |
| IV | 2,555 - 7,365 | 19 | 27 | 0.65 |
| V | 7,365+ | 9 | 16 | 0.38 |

[1]In constant 1980 U.S. dollars at the then prevailing exchange rate of K.S. 7.42 per U.S. dollar.

Source: O'Keefe, Raskin, and Raskin, and Bernow 1984.

In the absence of any technological or policy innovations, the mean annual increment of wood predicted for the year 2000 could meet only 35% of this annual demand (*Ibid.*). The remaining 65% could be met through unsustainable tree cutting rates in the short-run and through decreases in charcoal and wood consumption. The urban demand for charcoal may reduce accessible woodfuel supplies for collection in rural areas and increase rural prices for marketed fuelwood. Part of the shortfall could be eliminated if households adopted more fuel-efficient charcoal or wood stoves. In Kiswahili, the word "jiko" means any stove for cooking food, including an open fire. For clarity, this report will only use "jiko" to mean a charcoal stove, whether of the traditional or improved designs.

About 17% of rural households and 83% of urban households in Kenya owned charcoal stoves in 1980 (O'Keefe, Bernow, and Raskin 1984). Given the current ratio of rural to urban population and the average sizes of rural and urban households, there were 2,887,200 rural households and 695,000 urban households as of mid-1985. If the proportion of households with jikos has remained constant since 1980, 490,900 rural households and 577,400 urban households owned jikos in mid-1985, for a total of 1,068,300 households. Actually, the current proportion of households with jikos is likely to be slightly higher than this due to substitution of charcoal for wood as a result of increases in urbanization and per capita income over this period. Openshaw (1985) estimates that about 630,000 of these households use charcoal as their primary cooking fuel, including 545,000 urban and 85,000 rural households.

Practically all of the charcoal stoves in use in Kenya before 1980 were of the traditional design. If 80% of the improved liner and Umeme stoves produced commercially through March 31, 1985 remain in use and their components are replaced as needed, over 6% of the Kenyan households that cook with charcoal had improved liner stoves by that time. This number would be slightly lower if some households replaced one jiko with another or bought more than one improved jiko.

Many Kenyan households have more than one type of cooking stove because they use several different fuels. Some urban households supplement their charcoal use with kerosene or LPG when they are in a hurry or have to cook extra food for guests. These households use charcoal for foods that take a long time to cook such as "ugali" (a maize meal staple), maize and beans, or cabbage. Charcoal is more likely to be used at dinner and less likely to be used at breakfast. A family using charcoal as its sole fuel source for cooking and heating water by a traditional stove might consume 0.7-1.1 t of it per year. However, the average charcoal-consuming household uses much less than this amount because it also cooks with other fuels. Consequently, the average serviceable lifetime of a jiko at actual use is approximately double what it would be at full use.

Given the total charcoal consumption by households and the number of households owning jikos (whether or not the jikos are used regularly), the average charcoal consumption per jiko-owning household is 0.544 t per year. Disaggregated, this figure is 0.662 t per year for urban households that own jikos and 0.405 t per year for rural households that own jikos.

## The Traditional Technology For Charcoal Combustion

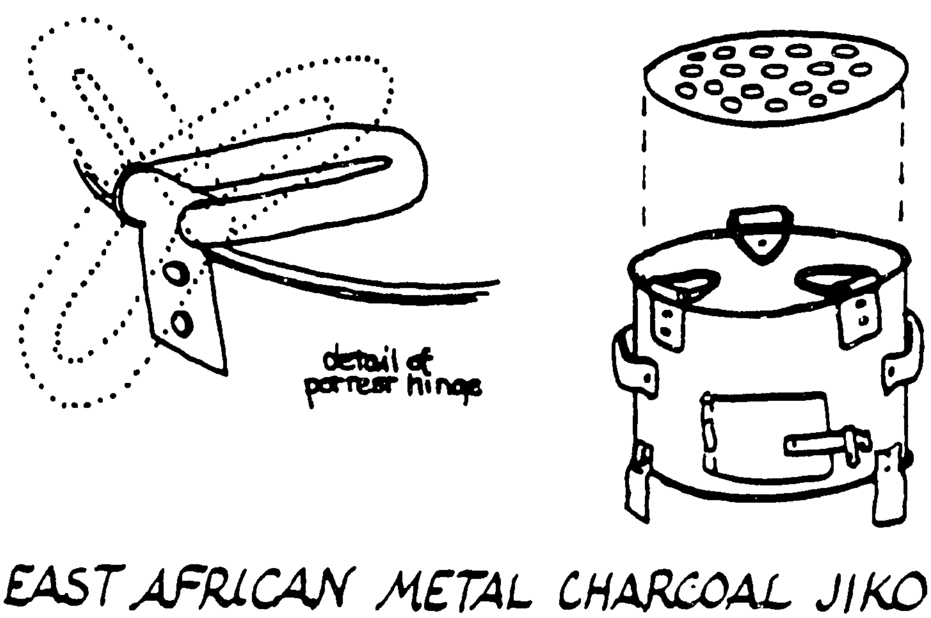
The traditional (established) jiko design was introduced into Kenya, in the early 1900s by Indian laborers working on construction of the railroad. This stove is still used in India. For many years, the Indian population kept the fabrication process as a trade secret in Kenya. As Indians switched from being artisans to merchants, black Kenyans took on this occupation. It took about 50 years for this stove to become the predominant type of charcoal stove in Kenya through market forces. This stove is also commonly used in Tanzania, Uganda, and Burundi (Sambali and Schneiders 1984) and more infrequently found in Malawi.

The traditional jiko is made of scrap metal and is assembled by local tinsmiths on a cottage industry scale. It is shaped like a cylinder and has a door for draft control and ash removal, 3 hinged triangular-shaped flaps that can hold one cooking pot, 3 legs to support the round base, a metal grate, and a handle (Figure 1). Since the traditional jiko is uninsulated, it radiates heat out to the air as well as to the pot.

This jiko is available in various sizes. The size most commonly owned by households has a diameter of 28 centimeters (cm) and a height of 28 cm including the legs. A jiko with a 25 cm diameter is too small for very large families or for roasting maize. The traditional jiko is very portable which is important in urban areas. The most common size for households weighs about 3 kilograms (kg), but commercial or institutional users can buy large jikos that weigh up to 20 kg. The traditional jiko is used for cooking and heating water, but not for baking or lighting.

Figure 1

The Traditional Jiko in Kenya




Source: By Laurie Childers, reprinted from Kinyanjui 1984.

## The Upgraded Traditional Technologies

### Historical Overview of Improved Charcoal Stove Activities

Work on improving charcoal stoves began in Kenya in 1977 in the Physics Department at Kenyatta University College under the auspices of Father Drohan and Dr. Damm, and later Dr. Swift and Raphael Kapiyo. Some early work also was done at Egerton College. The Bellerive Foundation (a Swiss-based group supported by the Aga Khan) began its charcoal stove activities in Kenya in 1979 under Waclaw Micuta. In 1980, Stuart Marwick arrived at the University of Nairobi on loan from York University and played an important organizational role in this area. UNICEF began working on charcoal stoves in 1980, and the Umeme design was developed in 1981 by Philip Hassrick, Eric Brunet, and Frans Claassen. The Beijer Institute of Energy and Human Ecology began studying woodfuel consumption in Kenya in 1980 and an expatriate researcher, Keith Openshaw, arrived to work for the Beijer Institute in 1981. Later, Max Kinyanjui began working on the Kimaki kiln/stove designed primarily for high-income households for barbecueing meats, and on cement/vermiculite stoves although these designs were not adopted in the subsequent AID-funded project.

Around that time, the Environment Liaison Centre carried out a survey which identified 35-40 organizations in Kenya working on energy problems. Soon afterward, the Kenyan Claystoves Working Group (the predecessor of KENGO) was established to organize an exhibition of cooking stoves to prepare a display for the U.N. Conference in Nairobi on New and Renewable Sources of Energy. The key actors in this working group were Marwick, Openshaw, Hassrick, and representatives from a large brick and tile firm, Clayworks Ltd. The Ministry of Energy and Regional Development (MOE) was kept informed of the discussions of the working group, but was not an active participant. Later, Mike Jones of Energy/Development International (E/DI) and Kinyanjui became important participants. The working group also organized a "March on Wood Energy" because the government had not paid much attention to this problem. Marwick also assisted in forming an Interministerial Working Party on Energy within the government, but this forum dissipated after 1982.

Before the U.N. Conference, the Claystoves Working Group tested stoves informally and gave prizes for the most efficient designs. An early version of UNICEF's Umeme stove won as the most energy-efficient stoves at its June 1981 exhibition. One of the Thai stoves (a straight-sided design) that Openshaw brought to Kenya was only a little less efficient than the Umeme. The tests showed that the Bellerive Foundation's three charcoal stove designs were no more efficient than a traditional jiko despite their much higher cost. All of the organizations involved in charcoal stoves work in Kenya, with the exception of the Bellerive Foundation, cooperated on a joint exhibition at the U.N. Conference in August 1981. This display comprised half of the Kenyan stand at the conference.

The Claystoves Working Group played an important role in creating momentum and encouraging communication among key individuals; however since it had no full-time staff or funding, its ability to follow through was limited. As a result, the Kenya Energy Nongovernmental Organizations Association (KENGO) was organized in 1981 and registered in 1982 as a consortium of NGOs. KENGO has a small, but growing core staff.

Following the U.N. Conference, a large number of organizations sponsored or carried out work to develop, promote, disseminate, and commercialize improved charcoal stoves in Kenya. Most of these efforts have been devoted to upgraded versions of the traditional jiko that incorporate design features from engineering principles and experimentation as well as from stoves in use in other countries. The active efforts of a large number of local NGOs and international organizations as well as the government and the media have begun to disseminate this technology faster than the original rate of dissemination of the traditional jiko.

The key organizations involved in these activities after 1981 include U.S. AID, the MOE, KENGO, UNICEF, the Intermediate Technology Development Group (ITDG), Kenyatta University College, Appropriate Technology International (ATI), the National Christian Council of Kenya (NCCK), Kenya's Appropriate Technology Advisory Committee (ATAC), and a large number of private artisans and distributors.

The Kenya Renewable Energy Development Project (KREDP) funded by AID through the MOE began in September 1981. The project included components for improved charcoal stoves and woodstoves, agroforestry, industrial fuel conservation and subsitution, more efficient charcoal kilns, and biogas. The jikos component included 1) applied research and prototype development; 2) training, extension, and demonstration; 3) development of productive enterprises; and 4) monitoring and evaluation. The improved jiko design which has been begun to be adopted in significant numbers mainly in and around Nairobi is an outgrowth of this project. These stoves have a metal shell, a ceramic liner, and an insulating layer of cement/vermiculite that attaches the liner to the shell.

E/DI was the contractor selected by AID for the KREDP. The project director for the first half of the project was Mike Jones and Amare Getahun was the project director for the second half. E/DI hired Kinyanjui as director of the stoves component at the suggestion of Ned Greeley of AID. The project was scheduled for completion in June 1984, but an extension was granted allowing KENGO to spend remaining AID funds from the jikos component until June 1985.

E/DI convinced Kinyanjui and the MOE to focus on charcoal stoves for low-to-moderate income groups which could be built by informal sector artisans rather than the more frequently tried approach of user-built stoves. The NCCK was influential in persuading E/DI that this strategy was appropriate and in making suggestions on how to implement the strategy. In late 1981, the KREDP tested various Thai cookstove designs brought in by Openshaw who had previously examined the potential for these stoves in Tanzania. Another major influence on the KREDP was a 4-week study tour of the stoves industry in Thailand following the suggestion of Openshaw. Three people went on the study tour in early 1982: Kinyanjui, a potter employed by Clayworks Ltd., and Clayworks' marketing specialist. The expenses were covered by AID, the Beijer Institute, and Clayworks respectively.

ITDG and the Appropriate Technology Center at Kenyatta

University College tested the efficiency of various stove designs. ITDG first became involved with Kenyan charcoal stoves in 1981 through Marwick's efforts following the suggestion of Hassrick. Between June and October of 1982, Stephen Joseph and Bill Stewart of ITDG worked closely with Kapiyo in Nairobi. E/DI also hired a skilled potter and trainer, Laurie Childers, from the Aprovecho Institute in mid-1983.

KENGO was the subcontractor for a 6-month stove field testing program supported by the KREDP in late 1983. Achoka Aworry of KENGO and Kapiyo were the key individuals involved. Various NGOs participated in the training, production, and standardized survey work of the field test; the principal ones were Maendeleo ya Wanawake (a group concerned with women in development), the Undugu Society (a social welfare organization that helps orphan boys), the Christian Industrial Training Centre, ATAC in Nairobi, the Baha'i community in Mombasa, and the Diocese of Maseno South in Kisumu.

ATAC was also involved in disseminating another jiko design at Kibera (a shanty area in Nairobi), but after a slow start switched to the KREDP jiko design with support from ATI.

A follow-up project that builds on the achievements of the KREDP began in mid-1985. ATI is providing a grant of over K.S. 4,065,500 to KENGO to accelerate the production and dissemination of the improved household jiko design in areas outside of Nairobi. Nairobi itself constitutes only about one-quarter of the annual demand for charcoal stoves (Burne 1985a). This 3-year project will provide training, technical assistance, and loans covering 75% of the capital costs of establishing production of the improved stove in up to 20 existing informal sector, jiko production units throughout the country. These production units are expected to supply 10% of the annual demand for charcoal stoves. A brick press will be provided to make inexpensive, high-quality bricks to make the kilns used to fire the ceramic liners for the jikos. In addition, some support will be provided for public education, a marketing program, and a quality control certification process.

German Aid (GTZ) is providing a grant of about $6,500 to ATAC in 1985 for production of improved stoves and subsidized distribution of 500-1,500 to households in Kibera at half cost. The bell-bottom stove will probably be the one selected, but ATAC is considering a stove with a metal grate between a two-piece extruded liner made by Clayworks to be fixed in place with cement/ vermiculite. In addition, surveys of charcoal consumption will be included in this project (Krosigk 1985c).

UNICEF's Umeme stove is based on an entirely different design concept. It is an all-metal, double-walled charcoal stove with an insulating layer of air, soil, or ash. UNICEF's Haraka stove is a variant of the Umeme.

Improved woodstoves received little attention in Kenya before the U.N. Conference although UNICEF had done some preliminary work in this area in 1979. Some of the organizations active in charcoal stoves work also have been involved in woodstoves. Since 1981, the Bellerive Foundation has concentrated on woodstoves and it received a grant of K.S. 1.5 million from the United Nations Environment Programme in 1984. Maendeleo ya Wanawake, supported by GTZ, began developing different woodstove designs in 1983. Other key organizations working on household woodstoves include CARE-Kenya, Action-Aid, and the Beijer Institute. IDRC has provided some support to KENGO for the design of improved woodstoves for institutional users.

**Description of the Improved Jikos**

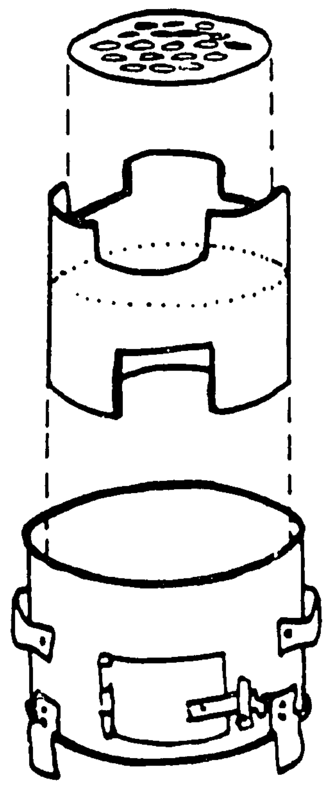
**A. KREDP Liner Stoves**

The most popular improved jiko designs are liner stoves adapted from the all-metal traditional jiko. Following the example of Thai stove designs, the improved Kenyan stoves have three other components: 1) a ceramic liner, 2) an inserted grate, and 3) an insulating layer between the cladding and the liner and also on the bottom of the ash box. The metal cladding protects the liner and supports the pots while the liner reduces heat transfer losses from lateral radiation. The grate aerates the combustion bed and channels heat toward the pot. The insulating layer increases the lifetime of the cladding by reducing its exposure to heat and oxidation. Like the traditional jiko, the improved stoves can cook one pot of food at a time. Both stoves can be used for barbecueing if a grate is placed on top. Neither stove is appropriate for slow drying or smoking of fish or meat for preservation due to the high temperatures generated.

Kenyan liner stove designs have evolved a great deal and are still undergoing further refinement. The first designs developed and tested under the KREDP in early 1982 were "pipeliner" stoves (Figure 2). The pipeliner stove consists of a traditional jiko lined with an extruded fired clay pipe and fitted with a separate ceramic grate. This design was later rejected due to the suscep-

Figure 2

An Early Pipeliner Stove



Source: By Laurie Childers, reprinted from Kinyanjui 1984.

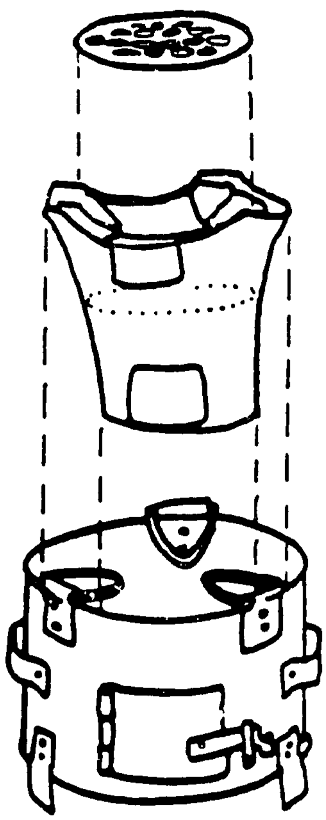
tibility of the liner to cracking, separation of the liner from the cladding, difficulty of holding the grate in place, and the short life of the ceramic pot rests since the pots rested directly on the extruded pipe.

The second major stove type was a Kenyan version of the Thai bucket stove which was developed in mid-1982 (Figure 3). The Kenyan bucket stove consisted of a cylindrical, flat-bottomed clay liner which was molded on a turntable, fired, and then placed in a traditional jiko. This stove differs from the Thai bucket in several ways. First, the sides of the stove are cylindrical rather than sloping. Second, metal pot rests were attached to the cladding because Kenyan cooks use heavy pots which need firm support and because it takes considerable skill to carve clay pot rests out of a ceramic liner. Third, three short legs were attached so that the stove would not rock on uneven floors during the vigorous stirring that is often done for ugali. The shape of the stove also helps keep it stable while foods are mashed or stirred in the pot. Fourth, the air inlet door was made tighter to allow better regulation of the power output for high and low heat. Fifth, the Kenyan stove had a heavier metal casing for greater perceived durability. Nevertheless, this stove was heavy, relatively expensive, and difficult to ignite. In addition, the liner was susceptible to cracking and coming loose because it was not not well-anchored, and the grate tended to break easily.

The third type, the bell-bottom stove, was developed in late 1983 and refined further in 1984. This stove has a waisted shape which is narrowest in the middle (Figure 4). The shape provides

Figure 3

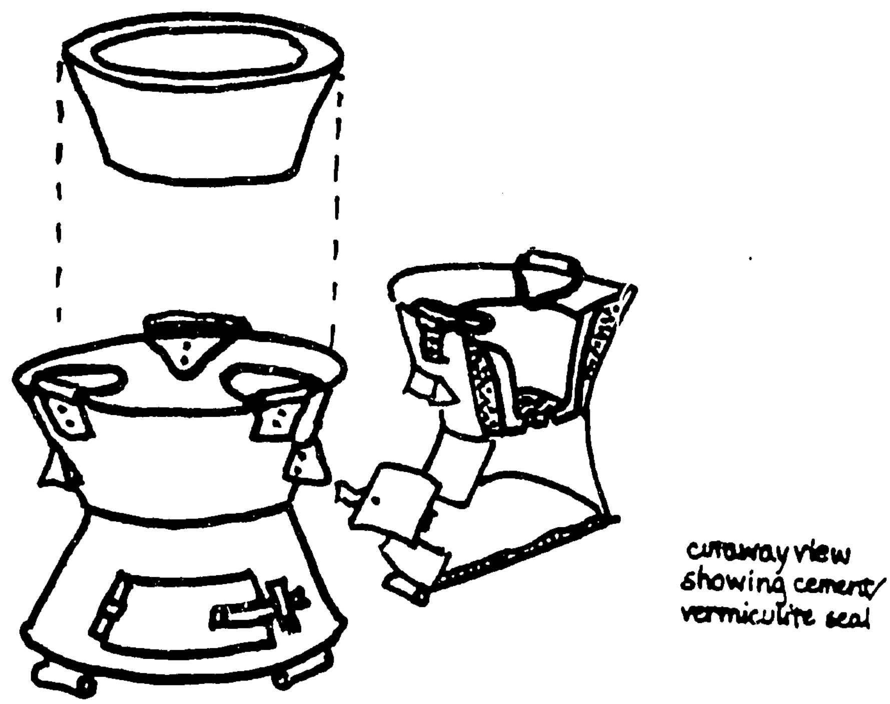
Early Kenyan Version of
Thai Bucket Stove



Source: By Laurie Childers, reprinted from Kinyanjui 1984.

Figure 4

Current Version of the Bell-Bottom
Stove With a Half Liner




Source: By Hugh Allen, adapted from Laurie Childers' diagram reprinted in Kinyanjui 1984.

a firmer assembly because the cladding conforms to the shape of the liner. Gravity and the insulation hold the liner in place. As a result, the liner is less prone to cracking caused by differential expansion in heating. The earlier version of this stove had a full-length liner, but this model was discontinued in November of 1984. The current version has a liner that extends only halfway down the height. The main advantages of having a half liner are that 1) the stove is more portable because it weighs less, 2) the stove has a smaller firebox, reducing the possibility of waste from charcoal overload, 3) the liner is cheaper to produce, and 4) the liner is less prone to cracking. The wide bottom of the stove makes it stable and easy to light. Since the air inlet is bigger in the bell-bottom stove, it can be used for roasting maize. This stove can be constructed out of sections of the circular tops and bottoms of metal drums which are of little use in making most other products.

The earlier version of the bell-bottom stove had a ceramic grate separate from the liner, but it was found that a separate grate was more subject to cracking. At present, most bell-bottom stoves have a one-piece ceramic liner in which the perforated floor of the liner serves as a grate. The ceramic material for the liner may be molded by hand on a turntable. Or alternatively a metal, wood, or concrete mold can be used on a bench, table, or floor. Then the liners are fired in a brick kiln or an earth pit kiln. The bell-bottom stove has strong metal pot rests and a wide base to facilitate stability in stirring. Several types of insulation were tried in these stoves; a cement/vermiculite mixture appears to be best. Over time, the weight and bulk of the cement/vermiculite insulation was reduced and its thickness was made more uniform to protect against cracking and to lower production costs. The bell-bottom stove is available in several sizes; the most popular size is approximately 28 cm in diameter and 28 cm high and weighs 7 kilograms. Some women find the larger sizes to be a bit heavy.

### B. Variants of the KREDP Designs

Some variants of the bell-bottom stove also show promise for particular segments of the market. For example, in Western Kenya, where scrap metal is expensive, there was some experimentation with an all-ceramic version. The all-ceramic stove has a cement/vermiculite layer on its floor to protect it from the corrosive effects of hot coals and falling ash. Although much cheaper, the ceramic stove is less durable than the metal clad liner stoves. Because thin-walled ceramic stoves are prone to cracking from differential rates of expansion, thick walls are required and that reduces the portability of the stove. This stove is not currently being manufactured or promoted.

Another less common variant consists of a cement/vermiculite or cement/diatomite liner in a traditional jiko instead of a ceramic liner in the bell-bottom stove. Cement mix linings are heavy and must be properly cured for three weeks before use. Procurement of vermiculite might be a problem in many areas. The cement/vermiculite lined stove has been tried with some success in Mombasa, Kisumu, and Kibera (Nairobi) and is still being produced in Mombasa. Few clay-lined stoves have been made in Mombasa, where there is less of a tradition of small-scale pottery making and suitable clay is scarcer. Some clay bricks and tiles are made there. The Baha'i Community builds cement/vermiculite lined stoves. Kits for the cement/vermiculite mix could be sold to artisans to accelerate the retrofitting of traditional jikos; however, these kits probably should not be sold directly to consumers who might not let the mix cure for a long enough time. It takes longer to light a cement/vermiculite lined stove than a traditional jiko.

Individual entrepreneurs now are making further modifications to meet local needs. For example, a jiko that can burn charcoal but is particularly suited for burning sawdust, coffee husts, and maize cobs due to the system of flue gas circulation has been developed by an entrepreneur in the Central province (Gonza 1984). Further advances may be possible in castable materials that bind vermiculite for stove liners (Newman 1985).

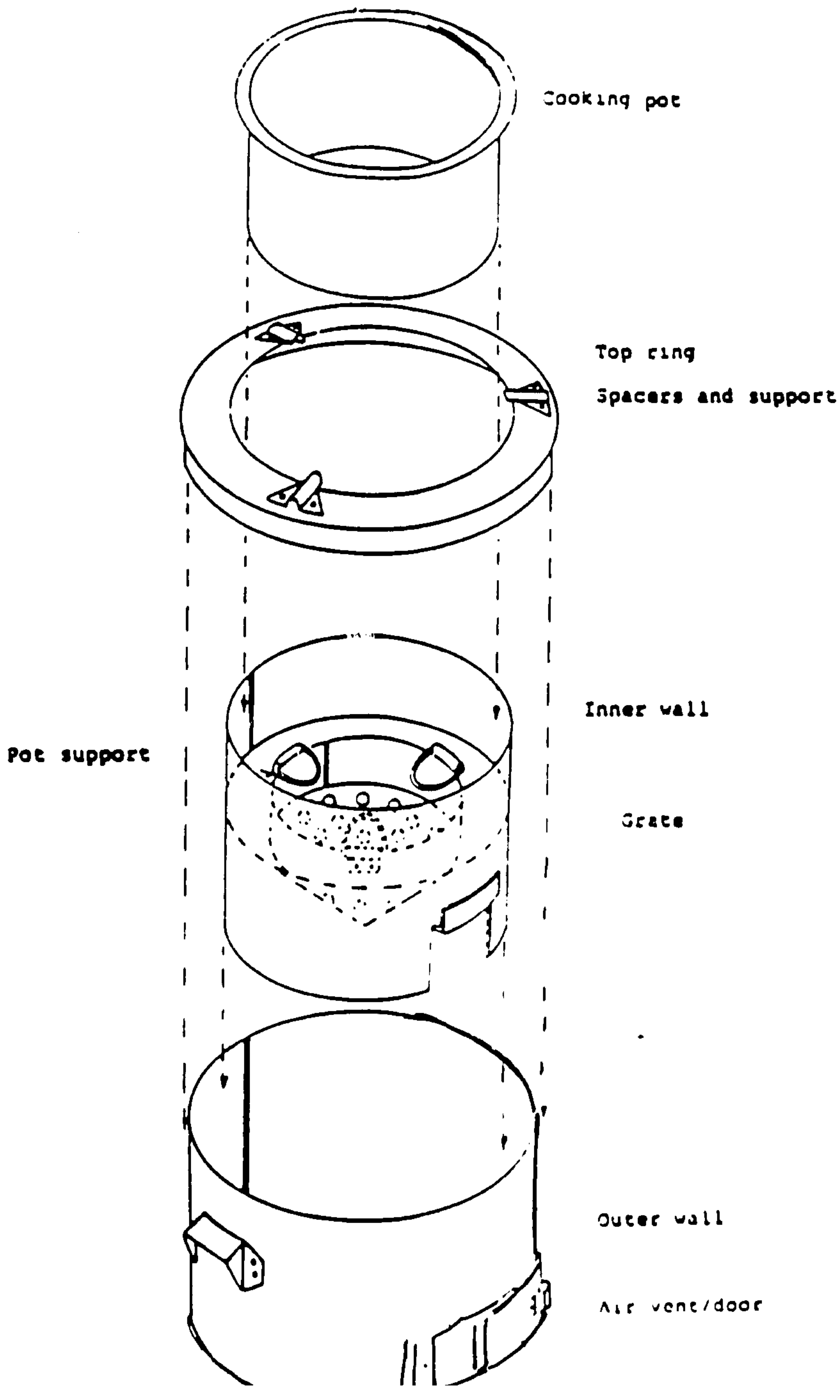
### C. The UNICEF Stoves

UNICEF's Technology Support Section in Nairobi developed two improved charcoal stoves in the Umeme and the Haraka. "Umeme" means "lightning" in Swahili. The Umeme is an all-metal stove with five components: 1) an outer body with a door frame and a sliding door to control the air intake, 2) an inner cylindrical wall body which is the combustion chamber, 3) an inner cone for holding the charcoal, 4) an additional grate for large pots, and 5) a top ring which closes the insulating chamber between the two walls and holds three prongs for the pot rests (Figure 5). The insulating layer may be filled with ash, soil, or just air.

A major difference between the Umeme and the liner stoves is

Figure 5

The Umeme Stove




Source: UNICEF Technology Support Section n.d. c.

that an average-sized pot sits on three prongs inside the Umeme rather than resting on top of the stove. The Umeme is 28 cm in diameter. Spacers limit the size of the pots that can fit inside, but larger pots can be placed on top of the stove. Three legs are attached to the base of the Umeme. Without the insulation, the Umeme weighs 6.5 kg, but the weight may increase to 12.5 kg if soil is used as an insulation. Adding soil as insulation does not increase the efficiency any more than just using air as the insulation (Sambali and Schneiders 1984). However, cooking can continue for up to two hours after the charcoal fire is burned out if the space between the inner and outer walls is filled with damp earth for insulation (UNICEF Technology Support Section, n.d.).

The Umeme has the highest fuel efficiency of the charcoal stoves promoted in Kenya. The efficiency gains are due to the enclosed combustion chamber, greater convective heat transfer to the inserted pot, insulated chamber wall, and regulated air flow. Other advantages are that it remains hot for a long time, cooks fast, and is durable. Also, the large firebox diameter provides stability. It takes only one type of artisan to make the Umeme, since it is all-metal, and this avoids some of the quality control problems that have been experienced with ceramic liners.

The Umeme has several disadvantages. Although production of the stove only requires one type of material, metal is an expensive material. The metal work is more time-consuming for the Umeme than for the bell-bottom stove. The Umeme is also more difficult to use than the traditional stove or the liner stoves.

The Haraka stove is a variant of the Umeme with a single wall (Figure 6). "Haraka" means "fast" in Swahili. The two stoves have the same inner diameter, but the Haraka is a little smaller. The inner wall of the Umeme forms the outer wall of the Haraka's cylindrical shape. The insulating second wall for the combustion chamber and pot are raised only up to the grate which rests on the half wall. Small pots are only surrounded by one wall when partly inserted in the stove while large pots sit on the rim. The Haraka has a handle that can be used to swing the stove for air circulation to speed up lighting. The Haraka is cheaper to produce than the Umeme because it requires less metal and labor. The Haraka weighs 4.5 kg (Sambali and Schneiders 1984).

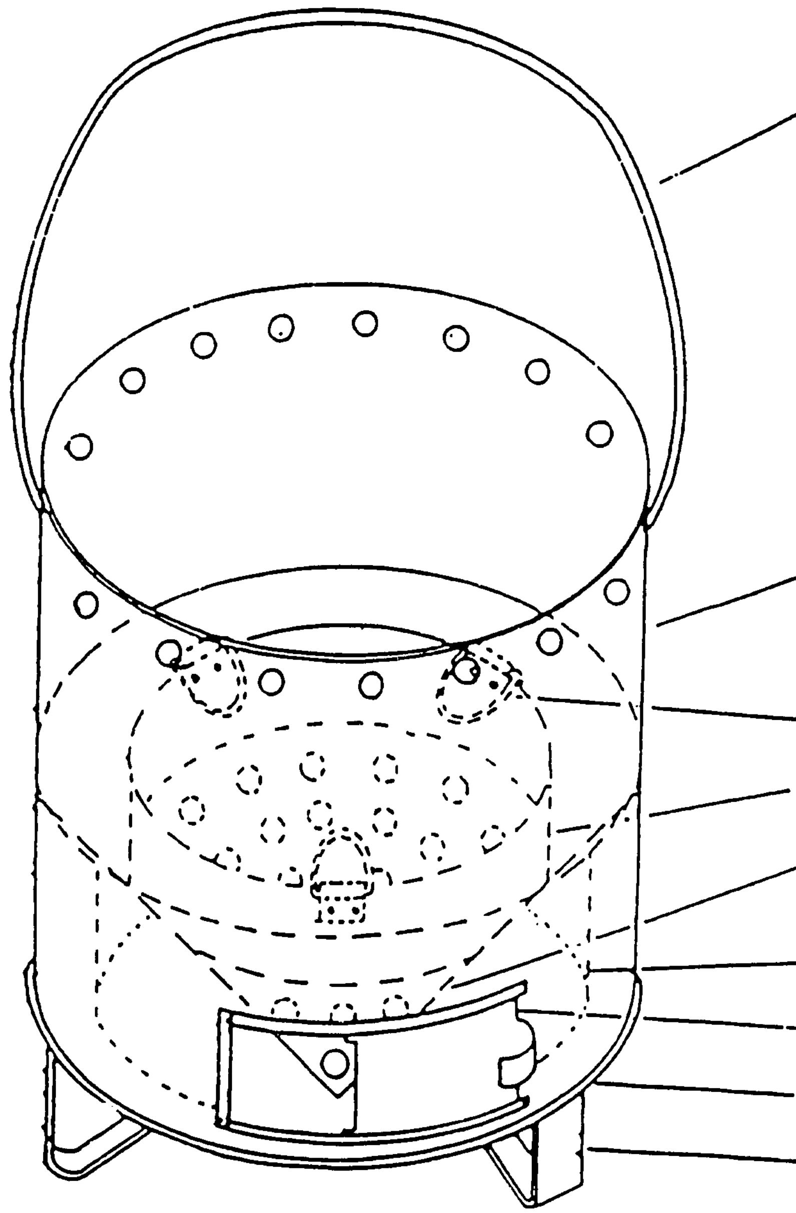
**Cost and Expected Lifetime of Improved Jikos**

The traditional jiko has one advantage over the improved designs, its low initial cost. Depending on size and location, this stove retails for K.S. 35-45. The size with a 28 cm diameter sold for K.S. 40 in Nairobi in mid-1985. With full use, the traditional jiko has an expected lifetime of about 1 year, but the metal grate may need replacement after 3 months. A replacement metal grate wholesales for K.S. 6 and retails for K.S. 10-15.

When it was first introduced, the wholesale price of the bell-bottom stove was K.S. 85-125, and the retail price was as high as K.S. 125-250. Since the quantity of stoves produced was much lower than the potential demand, producers and distributors were able to charge high prices for them. These prices provided good incentives for existing producers to expand their output and to encourage entry of new producers, but at the expense of consumers. As the novelty

Figure 6

The Haraka Stove




Source: UNICEF Technology Support Section n.d. a.

aspect of the stoves began to wear off and output expanded, competition has forced producers and vendors to lower their profit margins, and this process is continuing.

In mid-1985, the factory price of the 28 cm bell-bottom stove in Nairobi was K.S. 60-85. The factory price in Kakamega (western Kenya) was K.S. 125. Retailers as well as individual consumers can purchase the stoves directly from the factory at these prices. Even at the factory price, the stove costs more than most low-income Kenyans are willing or able to pay despite the eventual savings in charcoal costs. The retail price is higher at other sales outlets. The stove retailed for K.S. 90 in the Kenyan Grain Growers Union (KGGU) cooperative shops in Nairobi and K.S. 110-125 in privately-owned shops. The KGGU shop in Kisumu (western Kenya) sold the stove for K.S. 145.

As the market for bell-bottom stoves becomes saturated, the profit margin should fall further. Eventually, a factory price of K.S. 50-60 is expected; the retail price might then drop to K.S. 55-70. Factory prices are most likely to drop if the metal claddings and liners are made in integrated production units that actually produce at least 50-100 jikos per day. Some additional cost savings could be achieved through more systematic marketing. A major promoter of the bell-bottom stove, Kinyanjui, has wholesaled some stoves at production costs to try to force down the factory prices charged by other large producers. Profit-making entrepreneurs cannot match this price over the long-run and stay in business without subsidies and this strategy may have an undesirable side-effect of blocking entry by additional small producers.

In early 1985, the factory price of an all-ceramic improved jiko would have been about K.S. 30. A new cement/vermiculite lined jiko cost K.S. 40 in the 25 cm size and K.S. 50 in the 28 cm size. Alternatively, a household could have its own traditional jiko retrofitted with a cement/vermiculite lining at a cost of K.S. 15. Cement/vermiculite retrofitting of traditional stoves may deserve more attention to allow low-income households to save money on fuel right away and for a faster reduction of tree cutting for charcoal making.

The Umeme stove wholesaled at K.S. 70 and retailed at K.S. 85 at the workshops in Nairobi in early 1985. The price was K.S. 97 in the KGGU shop and K.S. 125 or more in private shops in Nairobi. Production costs for the Umeme were estimated at K.S. 52 in 1984 including materials (Claassen 1985). Adjusted for inflation, production costs would be about K.S. 60 in 1985, including K.S. 20 for labor. The Haraka is about K.S. 15 cheaper to produce than the Umeme (Ibid.). Since UNICEF arranges for direct purchases of metal from large companies, the Umeme artisans are able to buy metal at a 40% cheaper price than they would be able to arrange for themselves through middlemen. This assistance can be helpful in accelerating production and consumer acceptance, but it does mean that the current production costs of the Umeme are lower now than they might be when UNICEF eventually withdraws its support. If the artisans had to rely on informal sector sources of metal, the Umeme might wholesale for K.S. 95 and retail for K.S. 120.

Since improved jikos have been in production for a relatively short time, little data exists on their actual useful life.

With full use, it is expected that the metal cladding on a liner stove will last for 2 to 3 years and possibly 4 to 5 years or more if carefully handled because the liner and insulation keep heat away from the metal. All estimates of the lifetimes of relatively new stoves should be considered speculative since insufficient time has elapsed to confirm the estimates. Since the metal cladding is the most expensive part of the stove, its lifetime is the stove's maximum lifetime. At full use, the ceramic liner and attached grate for this stove may need replacement after 8 to 12 months when the grate burns out. The insulating material must be replaced every 6 to 12 months (Kinyanjui 1985). Because their lifetime falls within recent experience; the data are better for estimates of liner/grate lifetimes. Replacement of the liner/grate and the cement/vermiculite insulation should cost no more than K.S. 30 in Nairobi. At present, the availability of replacement liners is limited outside of Nairobi, but this is expected to change with the establishment of production units throughout the country.

The all-ceramic stove has a lifetime of only 6 months with full use because of cracking or breakage. A cement/vermiculite liner for a metal stove is subject to hairline cracks with the initial firing, but these do not necessarily decrease performance (Kinyanjui 1984). There are some reports of problems with cement/vermiculite liners falling out of metal stoves. A cement/vermiculite lined stove has an expected lifetime of at least 9 months (Ibid.), but anecdotal evidence indicates that they can last for 2-3 years if carefully used. If it gets wet, the cement/vermiculite lining can erode from the cladding. A replacement cement/

vermiculite liner would cost K.S. 15.

The Umeme stove body can last 3-4 years or more. Metal workers found in most urban areas can repair the Umeme. The metal grate for the Umeme may need to be replaced after 6-12 months at full use (Allen 1985; Schneiders and Mkallatta 1985); it cost K.S. 15-20 in 1985.

More attention needs to be paid to durability as a design criterion rather in addition to thermal properties. Users may reject an improved jiko when the first part breaks or may replace a ceramic liner with a cheaper and less efficient metal liner. David Newman at Kenyatta University College is now carrying out accelerated testing of the durability of materials for jikos.

**The Efficiency and Use of Improved Jikos**

The fuel efficiency of a charcoal stove depends on a large number of factors: the width and length of the channel between the pot and the wall; use and placement of insulation; type of grate and its hole density, form, mass, and thermal isolation; grate-to-pot height; and whether a bellows is used to reach high power more rapidly. A tightly-fitting door of suitable size to regulate oxygen flow is important in a charcoal stove. Most paint, even white paint, or a coating of soot or rust on the outside, increases radiant heat loss from a stove, but these losses are less important if the stove has a double wall or layer of insulation (Baldwin 1985). Since the design and construction specifications can vary even across similar stoves, the dimensions should be recorded for each stove tested.

Laboratory tests on Kenyan jiko fuel efficiency were per-formed at Kenyatta University College and ITDG's Test Centre at Reading University. These $PHU_2$ tests measured the percent of the heating value of charcoal utilized in boiling and evaporating 2.0 liters (l) of water for 60 min. The following factors are held constant in these tests:

1) Type and weight of charcoal charge,
2) Type and size of pots,
3) Weight of water evaporated,
4) Initial temperature of the water,
5) Initial temperature of the stove,
6) Method of igniting the fire,
7) Method of operating the stove, and
8) Accuracy of the test equipment.

The calculation must account for the calorific value of the charcoal and ash remaining after combustion because this can exceed that of unburned charcoal with a high volatiles content and a high moisture content. Efficiency tests should be conducted under a fume hood to avoid the build-up of carbon monoxide which can distort the perceptions of the tester. Laboratory tests have shown that the $PHU_2$ was 20-22% for the traditional jiko, 25-30% for the pipeliner stove, 29% for the Kenyan bucket stove, 32% for the bell-bottom stove with a full liner, 33-36% for the Umeme stove, and 28-31% for the Haraka stove (Joseph, Shanahan, and Young 1982a; Sambali and Schneiders 1984; Stewart 1984; Claassen 1985). The bell-bottom with a half-liner should have an efficiency similar to that of the version with the full liner (Young 1985). Thus, in laboratory tests, use of the most popular improved jiko results in a 34% fuel savings over the traditional jiko [1 - (0.21/0.32)]. However, a 25% fuel savings would be a more conservative estimate of what users are likely to achieve in practice. A cement/vermiculite lined, metal stove has about the same efficiency as the ceramic-lined, bell-bottom stove, but an all-ceramic stove is likely to be significantly less efficient.

In general, as $PHU_2$ increases, the time it takes to boil water decreases although this relationship is not uniform. Also, the difficulty of lighting a stove varies; for example, the bell-bottom stove is easier to light than the traditional jiko which, in turn, is easier to light than the Umeme. Tests have found that the total time required for ignition and boiling of 2 l of water was 28-32 min for the traditional jiko, 25-28 min for the pipeliner stove, 19 min for the Kenyan bucket stove, 20 min for the bell-bottom stove with a full liner, and 22 min for the Umeme (Joseph, Shanahan, and Young 1982; Stewart 1984). These differences should be considered relatively.

The $PHU_2$ test does not distinguish differences in the efficiency of a stove at high versus low power output. In the low power phase, a large difference in efficiency may save only a small amount of charcoal because less is being burned. Another complication is that the heating value of charcoal varies during combustion as the volatiles are burned off. The formula for calculating $PHU_2$ does not account for this variation and this will skew comparisons of the relative efficiency of stoves that take different-sized fuel charges (Baldwin 1983).

Specific fuel consumption (SFC) tests measure the weight of charcoal burned per unit weight of water boiled in laboratory tests. For an SFC test, the volume of water must be standardized and the high power phase is stopped as soon as the water reaches a vigorous boil. In some cases, $PHU_2$ and SFC tests may give different rankings of charcoal stove efficiency. SFC tests are a more direct measure of fuel savings than $PHU_2$ tests (Ibid.).

Most Kenyan cooks place the full charge of charcoal in the jiko at the start to reach a high cooking temperature (Kinyanjui 1982). Often, the cooking water is boiled first before the food is added for further boiling or simmering (Joseph, Kapiyo, and Kinyanjui n.d.). In order to achieve the full efficiency gains, improved jikos require more careful use than is customary. Although they can provide high heat, the liner stoves are optimized for slow cooking.

For short periods of cooking, the firebox of liner stoves should only be partly filled with charcoal. Before the stove is lit, left-over ashes should be removed by hand or with a scoop. It is best to light the stove outside to reduce smoke in the kitchen. Small crumpled wads of paper are placed in the fuelbox and lit until the charcoal is ignited. When small blue flames appear at the side of the charcoal bed, the stove may be brought to a sheltered area in the house (Kimani 1985). After the boiling point is reached, the inlet door should be closed to decrease charcoal use. When recharging is necessary, 2 or 3 pieces of charcoal should be added. In addition to charcoal, other fuels that can be burned in these stoves include wood chips, maize cobs, and coconut shells, but these fuels produce a lot of smoke. Flat-bottomed pots with lids should be used for maximum heat transfer and retention; metal pots have better thermal properties than clay pots. The stove should be located away from drafts. If exposed to rain, the stove must be dried out before it is usable.

Periodic replacement of the grate and liner are necessary to maintain the stove's efficiency. When operated at high power continuously to heat large institutional pots, the grate and cement/vermiculite insulation may burn out quickly (Kernan, Little, and Evans 1984). Users may reduce the serviceable life of the liner/grate or insulation by dousing the stove with water instead of removing the charcoal before it is quenched, shaking the stove to get the ashes out, or using too much kerosene to ignite the charcoal.

The Umeme stove is more complex to use than the liner stove. While the charcoal is burning, the pot should be placed inside the Umeme so that the brim of the pot rests on the three supports on top of the stove. To fit inside the Umeme, a pot must have a diameter of 15-27 centimeters. Kenyan households mainly use pots that are 18 or 25 cm in diameter (Hassrick 1985). When larger pots are placed on top of the stove, the fuel efficiency drops to a level comparable to that of the liner stoves. Small pots can move around on the inner grate and may have to be held. Users should not overfill the entire grate with charcoal. If a grate is not used and the stove is overfilled with charcoal, the stove might not light and, if it did, the metal could burn out. The Umeme is more difficult to light than the traditional jiko when lit from below, as is the usual practice in Kenya, because the grate can become clogged when newspapers are stuffed below. Instead, this stove should be lit from above with a few sticks of wood. Nevertheless, the Umeme cooks faster than a traditional jiko. Users can adjust the sliding door on the side to control the power. Because the Umeme has a small door, it is more difficult to remove ashes from it than from traditional stoves.

Controlled cooking tests and field tests may provide more meaningful information on how much fuel is saved in actual cooking of foods than laboratory $PHU_2$ or SFC water boiling tests. There may be a substantial difference between fuel efficiencies under ideal and actual cooking conditions. The size of the difference depends on how complex a stove is to use and how sensitive its fuel efficiency and durability are to incorrect handling.

Controlled cooking tests measure specific fuel consumption in the preparation of common foods. Care is taken in controlling the amount, mix, and preparation of ingredients; the way the fire is tended; and the degree to which the food is done. The traditional jiko has a fuel efficiency of about 18% in controlled cooking tests (Kinyanjui 1984). Controlled cooking tests have not yet been conducted for the bell-bottom stove or the UNICEF stoves, but are now being carried out as part of the ATI project.

Field tests can provide useful information on the fuel savings households actually achieve with improved stoves; how often households use the improved stoves and their techniques of use; operating, maintenance, and replacement costs; durability; monetary savings; and other perceived advantages and disadvantages. Time should be allowed before the beginning of a field test to allow consumers to get accustomed to use of a new stove.

Field tests are more likely to give accurate results if technicians periodically measure how much fuel is consumed rather than relying on the imprecise reports of households in a survey. One problem with field tests is the "Hawthorne Effect"-- knowing that they are the subject of a study, users may change their cooking practices to conserve fuel. If this effect occurs, it is difficult to attribute measured or reported fuel savings to the design of an improved stove unless laboratory tests are also carried out. Other complications in a field test include variations in the number of people taking meals in the household, seasonal variations in the availability and quality of fuels, and fuel loaned to other people.

A field test confirmed the energy savings and consumer acceptability of the Kenyan bucket stove. It found that 80% of the 450 stoves disseminated in late 1983 remained in use after 8 months. Fifty of these households with improved stoves were monitored intensively and compared to a control group of 50 households using traditional jikos; the rest were monitored less closely. Households reported that the improved stoves produced an average charcoal savings of 40% (KENGO 1984). Several design deficiencies that reduced the durability of the stove were noted in the field test and led to design modifications. The bell-bottom stove has not yet been formally field tested. UNICEF carried out a small field test for the Umeme, but this stove has been less thoroughly field tested than the liner stove.

**Inputs for Production of Improved Jikos**

Traditional jikos are made by small-scale metal artisans in the informal sector. The informal sector continues to be involved in production and distribution of the bell-bottom stoves. Small-scale artisans make the metal claddings, assemble the jiko and add the insulation, and sell it to households directly or through middlemen. Since production of the ceramic liners is more exacting, a few larger scale production units have dominated this aspect of jiko production. The products made by traditional potters do not meet the tolerances for thermal and physical stress required for improved jiko liners. With proper training, small-scale potters are capable of making the liners.

In addition to labor, the main inputs for bell-bottom stoves are clay, scrap metal, and insulating material. Where clay is purchased, it should be ordered in bulk and stored to obtain the best price. The characteristics of clays vary enormously between and even within deposits (Allen 1985). A mix of one or more types of clay with sand and cowdung is desirable for proper plasticity, resistance to cracking and shrinking, binding strength, hardness after firing, and resistance to thermal stress. The precise mixture must be formulated individually through trial and error because it will vary with the type of clay. If the ingredients are not mixed well, the liners are more likely to crack because there will be places where the material shrinks at different rates (Childers 1983). More research to help standardize suitable clay mixtures, better training, and quality control monitoring could help avoid problems with the clay mix.

After the clay/sand mixture is prepared, ash (or silica, soapstone powder, or mica) and water are added before the mixture is shaped for better binding. Sometimes, grog (crushed fired clay) is added to improve the structure of the mix. Few existing manufacturers of liners are using tooling and wooden or metal molds to ensure consistency and quality despite the low cost of doing so, approximately K.S. 100 per liner maker (Allen 1985).

If molds are used with too little ash sprinkled on their surface or too much water in the mixture, or if the liner is formed too slowly, the clay will bind to the mold making it difficult to remove the liner without damaging it. If the liners are too thin, they will slump and if they are too thick, it will take too long to make them. After the liner is formed and dried for 1 day, the grate holes are punched out of the liner floor. The grate holes should cover 30% of the grate area and each should be 1.5 cm in diameter (Kimani 1985). If there are too few grate holes, the stove will be difficult to light and if there are too many grate holes, charcoal will burn out too fast. Usually, the holes are made with an irregular piece of metal or plastic, but a simple punch could be used to make them more uniform. Uneven drying or handling the liners too soon can cause cracking (Childers 1983). After drying, the liners must be fired in either a traditional earth pit kiln or a masonry kiln. The liner should be an even red color with a thickness of 3.2 cm after firing.

From bottom to top, the traditional earth pit kiln consists of layers of ash and stones; closely-spaced fuelwood; the unfired clay products; and wood chips, twigs, bamboo, rice husks, coffee husks, or sawdust. This kiln must be rebuilt after each use. A common size for the inside dimensions of the mound kiln is 1.5 x 1.5 x 1.5 cm, allowing about a 100 liners to be fired in a cycle. Each cycle requires about K.S. 65 worth of fuelwood. After the fire has started, green grass which resists burning is added to the top.

A traditional kiln usually operates at around 600°C, but can reach temperatures as high as 900°C. Firing temperatures of at least 900°C are best for the liners' structural strength and resistance to thermal stress (Childers 1983; Allen 1985). When the firing temperature is too low, pottery becomes porous and tends to crumble. At too high a temperature, the surface vitrifies so that it expands and contracts at a different rate from the inside, causing flakes to chip off. If traditional kilns are not properly controlled, many of the liners will be burnt, underdone, or susceptible to cracking. After firing, a good quality liner is symmetric in thickness, has smooth walls near the top, does not have vertical cracks in the walls, and only has insignificant cracks in the liner floor.

More consistent results can be obtained with a masonry kiln. A masonry kiln is free-standing and made of fired bricks. Although two-thirds of the establishments making liners use a traditional kiln (Khamati 1985), these are the smallest producers so the bulk of production is fired in a masonry kiln. A shed is often built to protect a masonry kiln from the weather. The shed roof must be out of reach of the fire and should be made of nonflammable materials. These kilns may be built in different sizes. About 350 liners that are 30 cm in diameter or 400 25-cm liners can be fired in one cycle in a masonry kiln 1.2 m high and 1.5 m in diameter (Ongai 1985).

A masonry kiln also uses fuel more efficiently because it is better insulated than a traditional kiln. Each cycle for the masonry kiln size described above requires thirty sticks of fuelwood costing K.S. 1 each as well as two bags of charcoal fines that cost K.S. 6 each (Ongai 1985). The wood is set below the metal grate, the liners are stacked on the grate, and the charcoal fines are placed above the liners. Sawdust can a substitute for part of the wood, lowering the fuel cost but increasing the carbonization time.

Two of the large companies that make liners as well as other pottery products rely on electric kilns. It is easier to control the firing temperature in an electric kiln. Although the capital costs of an electric kiln are very high, the fuel cost per liner is lower than for a wood-fired kiln.

Under the traditional Kenyan apprenticeship system, there is little specialization of skills in a small pottery, in contrast to Thailand. From clay mixing to punching of grate holes, an average worker can make 15 liners per day by hand or 20-25 per day on a hand-operated turntable. A skilled worker could prepare the clay and make 60-70 liners in a day. Drying and firing takes a small amount of additional labor per jiko. Increasing competition in mid-1985 has been pushing down the wholesale price of liners from K.S. 20 to between K.S. 10-15, excluding transportation costs and in orders of 10 or more.

The cladding is fabricated by small-scale metal artisans. Scrap from split and flattened oil drums is one possible source of the metal; it is usually 1.0-1.5 cm thick. About 5 28-cm bell-bottom jikos can be made from a single oil drum. Sometimes, only the tops and bottoms of an oil drum are used for jikos because these parts are less versatile for construction of other products. Middlemen obtain the drums from oil companies and chemical manufacturers and sell them at high mark-ups. The price of a whole drum is K.S. 65-75 in Nairobi, and when available, it is K.S. 160 at Kisumu in western Kenya. There is an extra charge of K.S. 15-25 for dismantling and cutting a drum into metal sheets. Since most artisans lack the advance capital and storage space necessary, they cannot purchase the drums in large quantities directly from the source.

Artisans have experienced some problems with the cost and unreliability of metal drums. As a result, most metal artisans in Nairobi are now using thinner 18-gauge, scrap, galvanized iron sheets instead of metal drums for the jiko body, handles, doors, latch, legs, and pot rest hinges. In early 1985, the scrap metal sheeting for one jiko cost K.S. 10-12 in Nairobi and K.S. 35 in Kisumu. In Mombasa, metal prices are cheaper than in Nairobi and consumers prefer to buy jikos made of heavier gauge scrap metal. Jiko makers in Thika have an inexpensive source of new metal from the discards of the Metal Box Co. factory at a cost of K.S. 12.5 per jiko. A producer in Ruiru uses scrap metal from old cars to make claddings for bell-bottom stoves.

In addition to the drums or metal sheets, round metal bars (6-8 cm in diameter) are needed for the pot rests and flat iron bars (2 cm x 1 cm) are used for the hinges and handles. The firebox door, legs, and pot rests/handles are attached to the jiko body by rivetting.

An experienced metal artisan can produce an average of 5-7 claddings for bell-bottom stoves or traditional jikos in a day. The traditional jiko also requires fabrication of a metal grate, but more folding and riveting is needed for the bell-bottom stove. Additional labor time is required to prepare the ceramic liner and insulation, and assemble the bell-bottom stove. One artisan usually makes 4 Umeme stoves in a day. These metal artisans need only simple hand tools such as hammers, cold chisels, tin snips, plyers, pipes, and pieces of nails. A short length of old railroad line is nearly always used as an anvil.

The cladding for the bell-bottom stove is made in the same way as the body of the traditional jiko except that the walls are formed in two parts which are narrowest in the center to produce the waisted shape. The joint at the center of the cladding is folded similar to the way in which the bottom of the traditional jiko is attached. Only a small proportion of artisans use templates in cutting the metal for the jiko body although this would result in more uniform stoves. In mid-1985, the wholesale price of a metal cladding in Nairobi was K.S. 20-25 for the 25-cm stove and K.S. 35 for the 30-cm stove, excluding transport costs. Corresponding prices for these claddings in Kakamega were K.S. 35 and K.S. 55.

The layer of insulation should be 1 cm thick. A 1:3 mixture of cement/vermiculite appears to be best as the insulation. In Nairobi, cement cost K.S. 72 for a 50-kg bag in 1985. Vermiculite is mined near Sultan Hamud in Machakos District and processed at Ongata Rongai which is 15 km from Nairobi. Although it is relatively low-quality vermiculite, it is satisfactory as jiko insulation. A bag containing 15-20 kg of vermiculite cost K.S. 81 in Nairobi and K.S. 105 in Kakamega. At present, vermiculite is not routinely available in most other parts of the country without the assistance of NGOs such as KENGO and CARE-Kenya. Where vermiculite is not produced locally, diatomite can be substituted if available. Diatomite has the advantage of being very light. The only commercially-mined diatomite is between Gilgil and Naivashu (near Nakuru), but deposits also exist in the Ngong Hills. A 30-kg bag of diatomite sold for K.S. 50 in Nairobi in 1985. There is a risk that liner stoves will be built without proper insulation after external support is withdrawn due to the cost and limited availability of vermiculite or diatomite. A 1.5:4 cement/white ash mix or a 1:2 cement/carbonized coconut husks mix can be used as a substitute for vermiculite, but these substitutes are less effective. The insulation should be cured for 2-3 weeks before use, or it is likely to crack.

After all of the components have been prepared, it only takes 5-10 min to put the jiko together. Sometimes, the outside of improved jikos are painted for greater aesthetic appeal. One worker can paint the exterior of 35-50 jikos in a day. In a few cases, the inside of the liners has been painted red, but this may pose a health risk.

Table 3 lists the average variable costs for materials, labor, and distribution of a bell-bottom stove with a 28 cm diameter. It also lists the prorated fixed costs for depreciation, maintenance, the proprietor's salary, and interest charges for financing the investment costs and working capital. Average unit costs (excluding profit) range from K.S. 44-56 depending on the capacity of the enterprise and the production rate. Materials amount to 52-66% of total costs, compared to 14-18% for labor.

The Umeme stove is more expensive to make than the traditional jiko because it requires four times the amount of metal

Table 3

Production Costs Per
Bell-bottom Jiko With a 28 mm diameter
in March 1985
(K.S.)

I. **Variable Costs**

| **Materials** | **Cost**[a] |
|---|---|
| Sheet Metal | 10.0 |
| Round bars | 2.7 |
| Rivets | 1.0 |
| Clay | 3.1 |
| Sand | 2.5 |
| Cement | 3.5 |
| Vermiculite | 2.5 |
| Paint | 3.8 |
| Fuel for Firing | 0.1 |
| **Subtotal** | **29.2** |
| **Labor** | **8.0** |
| **Miscellaneous** | |
| Packaging of jikos | 0.3 |
| Transport of jikos | 1.3 |
| Marketing of jikos | 1.3 |
| **Total Variable Costs** | **40.1** |

II. **Fixed costs prorated per jiko produced**[b]

| | **Daily Capacity** | | | | | |
|---|---|---|---|---|---|---|
| | **15** | | | **100** | | |
| | **Capacity Use Rate** | | | | | |
| | **50%** | **70%** | **100%** | **50%** | **70%** | **100%** |
| Depreciation[c] | 4.0 | 2.9 | 2.1 | 2.3 | 1.6 | 1.2 |
| Maintenance[d] | 1.5 | 1.1 | 0.8 | 1.6 | 1.2 | 0.7 |
| Proprietor's salary[e] | 6.7 | 4.8 | 3.5 | 1.0 | 0.7 | 0.5 |
| Interest[f] | 3.5 | 2.7 | 2.1 | 1.8 | 1.4 | 1.2 |
| **Total**[g] | **15.7** | **11.5** | **8.5** | **6.7** | **4.3** | **3.6** |

III. **Total Unit Costs**

| | | | | | | |
|---|---|---|---|---|---|---|
| Excluding profit | 55.8 | 51.6 | 48.6 | 46.8 | 44.4 | 43.7 |
| Including minimum profit[h] | 65.8 | 61.6 | 58.6 | 56.8 | 54.4 | 53.7 |

| | Daily Capacity | | | | | |
|---|---|---|---|---|---|---|
| | 15 | | | 100 | | |
| | Capacity Use Rate | | | | | |
| | 50% | 70% | 100% | 50% | 70% | 100% |
| IV. **Expected unit profit** | | | | | | |
| At a wholesale or factory price of K.S. 70 | 14.2 | 18.4 | 21.4 | 23.2 | 25.6 | 26.3 |
| At a wholesale or factory price of K.S. 85 | 29.2 | 33.4 | 36.4 | 38.2 | 40.6 | 41.9 |

---

[a] Including transport or delivery costs.

[b] A+ 300 working days per year.

[c] Depreciation of tools and kiln over 3 years and buildings over 5 years. For the smaller unit, capital costs are K.S. 30,000 for buildings, K.S. 7,500 for equipment, and K.S. 2,500 for a kiln. For the larger unit, capital costs are K.S. 45,000 for buildings, K.S. 63,000 for equipment, and K.S. 17,500 for kilns.

[d] K.S. 300/month for the smaller unit and K.S. 1,750/month for the larger unit.

[e] K.S. 1,300/month for both units.

[f] At a 15% interest rate over 3 years. Loan covers 100% of initial capital investment and working capital (fixed costs less depreciation + variable costs) for 1.5 months. The loan size is K.S. 54,000 for the small unit at the lower capacity use rate and 59,000 at the higher capacity use rate. Corresponding figures for the larger unit are K.S. 183,000 and K.S. 204,000.

[g] Excludes rent since few jiko-making enterprises pay rent.

[h] Profit at K.S. 10 per unit.

Sources of data: Allen 1985; Kinyanjui 1985.

and five times the amount of labor (Sambali and Schneiders 1984). Although thin metal can be used for the stove walls, heavier gauge metal is required for the inner grate, pot rests, and upper grate (Schneiders and Mkallatta 1985). Although traditional metal working techniques are used in making the Umeme, the work must be done more carefully. For example, the number and location of rivets and air inlets in the Umeme is especially critical to the stove's efficiency. However, only one type of artisan is required for the Umeme and this stove avoids the quality control problems that are common with the ceramic liners. Most Kenyan metal artisans can produce metal products in the traditional way accurately even without using templates. The Haraka stove requires less metal and labor than the Umeme.

## Production Achievements

The KREDP originally set as a goal the manufacture and sale of 5,000 improved jikos in 2 1/2 years. This project is one case in which the achievements have far surpassed the goal. By December 1983, private workshops had produced more than 13,000 liner stoves as a result of the project. Total production rose to 66,000 by the end of 1984 and 84,000 after the first quarter of 1985 (Table 4). The production rate increased dramatically from 2,000 in the third quarter of 1984 to 5,600 in the fourth quarter of 1984 to 18,000 in the first quarter of 1985. If 80% of these stoves remain in use by average-sized urban households, over 357,000 people now benefit from use of this technology. Production of the liner is the limiting factor in the manufacture of these stoves.

Table 4

Total Production of Liner Stoves[1]

| Company | Location | Total Production Through March 31, 1985 | Average Monthly Production 4th Qtr. 1984 | 1st Qtr. 1985 |
|---|---|---|---|---|
| Clayworks | Nairobi | 8,000 | 0 | 0 |
| Githurai | Nairobi | 190 | 63 | 0 |
| Ilesi, Chevakali, and others | Kakamega | 2,915 | 330 | 283 |
| Jerri International | Nairobi | 42,710 | 2,033 | 237 |
| Kibera (ATAC and others) | Nairobi | 10,145 | 1,858 | 500 |
| Maragua | Maragua | 60 | 0 | 20 |
| Nyalenda and others | Kisumu | 2,835 | 265 | 403 |
| Nyeri | Nyeri | 70 | 0 | 23 |
| Miaki | Riruta (Nairobi suburb) | 11,550 | 358 | 3,367 |
| Ruiru | Ruiru | 645 | 0 | 215 |
| Shauri Moyo | Nairobi | 3,780 | 630 | 630 |
| Siaya | Siaya | 195 | 65 | 0 |
| Thika | Thika | 778 | 0 | 259 |
| Karatina | Karatina | 75 | 0 | 25 |
| Embu | Embu | 90 | 0 | 30 |
| **TOTAL** | | **84,038** | - | - |

---

1 Excludes production at some very small workshops and at the agroforestry centers' training courses. Data for first quarter 1985 refers to sales rather than production.

Source: E/DI Quarterly Progress Reports.

The project also set a goal of creating at least 20 self-sustaining enterprises producing improved jikos. To date, most liners have been made by three relatively large enterprises. The first enterprise involved in improved jikos, Clayworks, Ltd., has stopped making liners, but still sells them from its inventory. Jerri International and Miaki Jikos remain active in liner production in the Nairobi area.

Metal claddings for the bell-bottom jiko are made by about 100 informal sector artisans; half of these artisans are located in Nairobi (Opole 1985). Jikos are assembled by the liner manufacturers as well as by metal artisans. Nearly all Kenyan towns with a population of 2,000 or more have metal artisans with suitable facilities for making claddings.

Clayworks is the largest brick and tile producer in Kenya. This company made the liners for all of the early pipeliner stoves and later made liners for bucket stoves and bell-bottom stoves. In 1983, the MOE decided not to provide any assistance to Clayworks in order to protect fundis (small-scale, informal sector metal artisans) from unemployment, but also due to the political and tribal affiliations of its owners. A production run has to be large to be commercially viable for Clayworks. Clayworks uses a kiln fired with electricity and coffee husks.

Since Clayworks made liners from the same clay mixture it used for bricks, these liners are brittle and withstand thermal stress poorly. The grates made by Clayworks are separate from the liners and tend to burn out quickly. Since Clayworks does not use cement/vermiculite insulation, the liner and grate on their stoves can fall out and break easily. Several former

Clayworks employees who were most skilled at making jikos left the company for Jerri International several years ago. Due to quality control problems, Clayworks stopped producing liners in mid-1983. It still sells liners from its inventory as orders arise and has about one-quarter of its last production run of 800 units in stock. On order, Clayworks will supply a whole jiko at K.S. 60. Because of the size and profitability of its other domestic and export operations, Clayworks is not very interested in jiko sales, but it does claim that it may resume liner production in the future. If it were serious about jiko production, Clayworks could be a major competitor of Jerri International.

Jerri International is owned by Richard Kimani, one of the key people originally involved in improved jikos in Kenya. Kimani's large investment in jiko production and marketing savvy accelerated the dissemination of the bell-bottom stove. Jerri now has a pug mill, electric potter's wheels, and two top-loading electric kilns.

By the end of the first quarter of 1985, Jerri International had manufactured almost 51% of the total number of liner stoves produced. The dominance of the market by such a large producer has tended to keep profit margins high. Jerri purchases metal claddings from small-scale artisans and sells assembled stoves to individuals at the factory and to retailers in and outside of Nairobi. It does not sell liners to metal artisans or middlemen. These stoves are painted grey for brand recognition. For greater aesthetic appeal, Jerri has been using a more expensive clay that fires white.

According to several reports, quality control for liner production has slipped recently at Jerri as key employees have left the company to start their own enterprises. The design used by Jerri has a deeper firebox than is recommended. Although this makes the stove easier to construct and requires less cement/vermiculite mix, it increases clay costs, reduces the efficiency and lifespan of the jiko, and may result in waste of charcoal. The grate is too thick and susceptible to cracking, the sizes and shapes of the liners are sometimes irregular and grate holes are punched improperly. Jikos comprise only a small portion of the business of Jerri. As of early 1985, Jerri was holding an inventory of over 3,000 liners because sales dropped due to the relatively high price and declining quality of their jikos (Chege 1985b). It appears that Jerri might withdraw from the market as competition increases further.

Miaki Jikos Co., formerly located in Riruta, has moved to Nairobi. It is owned by Kinyanjui, who has been instrumental in the design and promotion of the bell-bottom stove. This company makes high quality liners following the recommended design. It now has a pug mill. Miaki makes some claddings, but mostly buys them from fundis at Shauri Moyo. Miaki sells completed jikos to households and also wholesales liners to metal artisans. Miaki has made almost 14% of the bell-bottom stoves produced through March 31, 1985. Some metal artisans who buy liners from Miaki report that supplies are sometimes erratic when the proprietor is providing technical assistance in other countries. Miaki has recently begun marketing a cement/vermiculite mix for other jiko makers.

A new large-scale liner manufacturer, Mwangaza Pride International, began operations in mid-1985. It is owned by the

M.P. for Limuru. These liners have been sold at lower prices, forcing the competition to reduce their prices. This firm appears to have gained half of the Shauri Moyo market for liners. The quality of these lines is adequate (Kinyanjui 1985).

Shauri Moyo is a public market in Nairobi with a large number of fundis in open-air workshops. Since the fundis at Shauri Moyo do not own the land they occupy and are not supposed to build permanent structures, they lack adequate storage facilities for jikos, and many are unwilling to construct enclosed work areas which would allow production to continue when it rains.

Kibera is the location of the ATAC workshop and another jiko workshop. ATAC has experienced serious management problems because it tries to do too many projects at one time that it cannot handle. Jiko-making was just one sideline for the organization. The jikos made by ATAC were of inferior quality due to poor materials and failure to master the technical principles. ATAC employees damaged its masonry kiln by overloading it with firewood, melting some of the bricks. As of early 1985, the kiln had not been repaired for at least 5 months. Consequently, ATAC has nearly stopped producing liners and jikos except on order although it intends to resume jiko activities with grant support from GTZ.

Cement/vermiculite lined stoves have been produced in small numbers in Mombasa by the Christian Industries Training Center and students in the Baha'i community. These straight-sided stoves are made of heavier gauge metal than is used elsewhere for jikos.

Informal sector artisans often make changes in the recommended designs and some of these changes may reduce the stove's fuel efficiency. Some inferior quality liner stoves are being sold as improved jikos at high prices by artisans who have not been trained properly or are trying to cut corners in construction. Most of the quality control problems are with the liners and insulation, rather than the claddings. Some of the problems with these stoves include an irregular thickness or shape, which results in a mismatch between the cladding and liner; a poorly joined upper and lower cladding; loose handles; weak legs that are not riveted securely; cracking of liners and grates; pot rests that are weak, badly hinged, or resting on the liner; doors or latches that are not properly riveted or do not work well; weak seam joints; a grate that is not level with the seam joining the upper and lower parts of the cladding; misproportioned door and ashbox depth; irregular grate holes; lack of insulation; or insufficient curing or rain damage to the insulation (Kimani 1985). Sometimes, these stoves are painted for greater aesthetic appeal, but their fuel efficiency and durability are poor.

Design guides for producers and consumers could reduce the prevalence of poor quality stoves. Most Thai consumers know what to look for in the fabrication of a charcoal stove; Kenyan consumers have had less experience with the improved technology and need to be educated. The Kenyan Bureau of Standards has developed performance standards for many products, but it is not interested in doing so for jikos now on the grounds that this is not yet a mature technology. Product certification is not one of the functions of the Ministry of Energy.

In the meantime, it would be desirable for KENGO to establish a quality control certification procedure. KENGO could randomly sample stoves made by producers who agreed to participate in the program. If the sample proved satisfactory, KENGO could allow a seal of approval to be stamped into the liner. Counterfeiting of the seal of approval could be a problem as would getting the seal back from jiko manufacturers that no longer met the standards. A quality control certification process worked well in a stoves project in Botswana although only a small number of stoves were produced there. Other possibility would be for producers to offer warranties to replace defective stoves. Presumably, customers would be willing to pay more for jikos with a certification of quality or a warranty. Quality control may be a simpler task for stoves such as the Umeme and Haraka which are built by a single type of artisan.

The government's goal of encouraging small-scale production has been compromised by the army's initial purchase of 25,000 bell-bottom stoves and contract for an additional 2,000 replacement stoves every 18 months from Jerri International.

It is important that no single firm obtain a monopoly in liner production, or the manufacture of claddings. Fortunately, the degree of concentration in bell-bottom stove production has begun to decline. Due to high transport costs and profits to middlemen, centralized production of jikos is likely to become less competitive over time as increasing numbers of small, local producers gain the skills to enter the market. As the prices of bell-bottom jikos drop, the gross margin for jiko makers may be driven down toward subsistence levels and the large, diversified producers might switch to producing other things.

There is also a need to increase production of bell-bottom stoves in other urban areas besides Nairobi. At present, it is inconvenient for these users to take improved jikos back for repair, and as a result, households either will return to using traditional jikos or will have to buy a new improved jiko prematurely. Centralized production of liners might result in large breakage losses in transport to distant parts of the country. Decentralized production would make it easier for a consumer in other parts of the country to have the liner/grate and insulation replaced and would also generate some additional employment outside Nairobi for fabrication and repairs. It would also facilitate adaptation of designs and materials to match local preferences and available resources. An intermediate production strategy might be feasible: centralized fabrication of claddings in Nairobi, Mombasa, or Thika where metal prices are low and decentralized production of liners and assembly of jikos. Alternatively, metal could be purchased in bulk by a cooperative of metal artisans and transported to decentralized units.

The Umeme stove is being produced at two workshops in Nairobi. According to the entrepreneurs, the Likoni Road workshop currently produces 30 Umemes per month and a workshop at Shauri Moyo produces 25 per month. There are also reports of spontaneous production of Umeme stoves by artisans is Nyeri, Murang'a, and Kisumu (Hassrick 1985). An estimated 4,000 Umeme stoves have been produced in Kenya through early 1985 (Claassen 1985). Production of the Umeme has been demand-limited because UNICEF has not carried out an extensive promotional program for this stove. These same two workshops have made a few examples of the Haraka stove, but not in commercial quantities. Middle-income households often are willing to pay a little more for an Umeme than a Haraka, but the latter may be more attractive to low-income households.

**The Dissemination and Promotion Strategy**

Since the major share of the improved charcoal stoves produced and distributed in Kenya has taken place through the KREDP, this project's strategy for dissemination and promotion of the technology deserves attention. The project benefited from the efforts of Kinyanjui, an enthusiastic national who has a thorough understanding of how small-scale producers operate and how to communicate with them and also with technicians. The project's approach was based on three assumptions.

First, it was assumed that the efforts of government and nongovernmental organizations could be most effective and efficient if they built on Kenya's strong private sector. Consequently, the potential for profit provided the incentives for the production and distribution of goods. The costs also were minimized by relying on the informal sector to produce the metal components of the stove. The informal sector has low overhead, pays little or no rent, relies on inexpensive labor, and has access to cheap sources of scrap metal. The project emphasized working with small-scale artisans who already were producing metal products or pottery on the grounds that these artisans have the basic skills and raw materials needed for jiko production. Recognizing that informal sector artisans are competent at producing stoves when given simple designs, the project provided them with some training on the principles of efficient stove design as well as step-by-step instructions on construction. Some important lessons on how to organize the production of charcoal stoves and train artisans were learned during the field visit to Thailand early in the project.

Second, since the initial cost of an improved jiko exceeds that of a traditional jiko, it was assumed that households would be willing to pay the higher price if they could be shown the benefits of doing so. Thus, emphasis was placed on demonstration of the improved jiko to a wide range of potential buyers. Existing private sector channels of distribution with access to a broad spectrum of urban households were used to sell the jikos. In early 1985, at least 22 wholesalers distributed the jikos; 40% of the wholesalers were in Nairobi. There were over 73 retail distribution points in Kenya for the bell-bottom stove including workshops, open air markets, food stores, hardware stores, and appliance stores. These outlets also helped demonstrate the technology (Opole 1985). Nevertheless, most of the purchasers of bell-bottom stoves to date are middle-income households. Low income households are less willing to take risks on a new technology and may have trouble accumulating the cash to purchase a new product.

Third, it was assumed that households would maintain their same basic cooking practices in judging the improved jikos. Thus, the stove designers sought user feedback in the course of the project on how the technology could be modified.

Table 5 lists the administrative costs of the jikos component of the KREDP including those borne by other organizations.

Table 5

Estimated Administrative and Technical Resource Costs (K.S.)[1]

| | |
|---|---|
| **A. Salaries and fringe benefits for staff** | |
| 1. Senior-level (project and MOE) [2] | 615,000 |
| 2. Intermediate-level [3] | 47,000 |
| 3. Junior-level trainers [5] | 42,000 |
| **Subtotal** | **704,000** |
| **B. Travel and per diems for staff** | |
| 1. Senior-level | 60,000 |
| 2. Intermediate-level | 16,000 |
| 3. Junior-level | 0 |
| **Subtotal** | **76,000** |
| **C. Salaries for foreign consultants** | |
| 1. ITDG staff (provided free to project, costs inputed at $100/day for 18 person-weeks) | 144,000 |
| 2. Others | 72,000 |
| **Subtotal** | **216,000** |
| **D. Expenses for foreign consultants** | |
| 1. Air travel (5 trips borne by ITDG, 1 by project) | 118,000 |
| 2. Per diems (15 person-weeks borne by ITDG at $5/day; K.S. 12,000 borne by project) and equipment provided by ITDG ($1000) | 112,000 |
| **Subtotal** | **230,000** |
| **E. Salaries for local consultants** | **14,000** |
| **F. Expenses for local consultants** | **12,000** |
| **G. Project management and support Salaries and fringe benefits** | **772,000** |
| **H. Overhead (except where indicated, at 36% administration + 8% profit on salaries and expenses)** | |
| 1. Senior-level project staff (excluding MOE) | 260,000 |
| 2. Intermediate-level staff | 30,000 |
| 3. Junior-level staff | 20,000 |
| 4. ITDG (35% fringe benefits and administration) | 50,000 |
| 5. Other foreign consultants (included in salaries) | 0 |
| 6. Local consultants | 12,000 |
| 7. Project management and support staff | 362,000 |
| **Subtotal** | **734,000** |

| | | |
|---|---|---|
| **I.** | **Technology transfer (Trips for 3 to Thailand -- 1 borne by project, 1 by Beijer Institute, and 1 by Clayworks)** | **179,000** |
| **J.** | **Structures** | |
| | 1. Agroforestry centers (6) | 120,000 |
| | 2. Ilesi (kiln and shed) | 35,000 |
| | 3. Kibera (shed) | 12,000 |
| | 4. Thika (shed) | 3,000 |
| | 5. Riruta (start-up costs) | 16,000 |
| | **Subtotal** | **186,000** |
| **K.** | **Training** | |
| | 1. Tools (3 sets per agroforestry center) | 36,000 |
| | 2. Supplies (metal and clay) | 20,000 |
| | **Subtotal** | **56,000** |
| **L.** | **Demonstration at agricultural exhibitions** | |
| | 1. Kakamega (2) | 14,000 |
| | 2. Meru (1) | 6,000 |
| | 3. Mombasa (1) | 6,000 |
| | 4. Nairobi (2) | 16,000 |
| | 5. Nyeri (1) | 6,000 |
| | **Subtotal** | **48,000** |
| **M.** | **Dissemination** | |
| | 1. Field test | 136,000 |
| | 2. Other free distributions of stoves (250) | 20,000 |
| | **Subtotal** | **156,000** |
| **N.** | **Evaluation and documentation** | |
| | 1. Foreign consultant salary, expenses, and overhead | 174,000 |
| | 2. Documentation | 100,000 |
| | **Subtotal** | **274,000** |

---

| | |
|---|---|
| **Administrative Costs to AID** | **3,083,000** |
| **Total administrative costs to all organizations** | **3,652,000** |

**Total administrative costs per stove = K.S. 43**
(84,000 stoves produced through 3/31/85)

---

[1] Except where noted, the costs were borne by AID. The costs are based on the current exchange rate of K.S. 16 per U.S. dollar.

Sources: Mike Jones and Amare Getahun (E/DI); Yvonne Shanahan (ITDG).

These administrative costs amounted to K.S. 3,680,000, including evaluation and documentation. The bulk of the costs were incurred for salary, fringe benefits, and overhead for staff. Prorated over the number of improved jikos produced by commercial enterprises through the first quarter of 1985, the administrative costs were only K.S. 43 per jiko. Over time, the total administrative costs can be amortized over a larger number of jikos as production by units assisted under the project continues.

The project also authorized an Energy Development Fund designed to be flexible to allow a rapid response to opportunities that support the objectives of the project. Unfortunately, there were considerable delays in obtaining permission from the MOE to use this money for any purpose because one former official did not support a private sector charcoal stoves program, preferring instead production at the agroforestry centers. Later, some questions arose about the legality of allocating uses for such a fund without the approval of Parliament. As a result, hardly any of this money was spent, and it is reverting to AID for reprogramming within Kenya.

**Training**

The project recognized that different forms of training are necessary to meet diverse needs. Training was provided to artisans, trainers and managers in the form of seminars, lectures, and hands-on workshops. The first priority in training was to reach some artisans who already were involved in jiko making so that production of the improved models could begin; this started in 1982. Experienced metal workers can learn to fabricate the cladding for the bell-bottom stove in 3 to 4 training sessions. Production of the ceramic liners is more complicated, requiring a month of intensive training for informal sector potters (Kinyanjui 1984). Some of this initial training took place on the sites where the artisans usually work, but later most of the training was done at the government's agroforestry centers. Some village polytechnics were involved in training, but these efforts were limited and eventually dissipated. Since the polytechnics generally lacked adequate tools and materials, they generally made substandard claddings and liners (Opole 1985).

Some follow-up visits were conducted to ensure that these artisans retained what they learned. To stimulate production for the field test and ensure that their newly-acquired skills were not forgotten before they could be applied, the project ordered metal claddings from qualified artisans shortly after they completed the training. The large order generated by the field test allowed production bugs to be worked out. In addition, it gave jiko makers the motivation, experience, and cash needed to expand their production later. At the time when Jerri International received the contract to make the liners for the Nairobi field test, it was a small, formal sector, pottery firm just getting started in jiko making. Several small producers in Mombasa made the liners that were field tested there.

Mobile training units that travel to the work sites of the artisans were planned from the beginning. Each mobile training unit consists of two trainers equipped with stove prototypes at different stages of production plus one set of templates, tools, and materials. However, the first of these units was not operational until mid-1984 when project funds for this purpose were provided to KENGO. A second vehicle was purchased for the Ministry of Energy in early 1985.

It was hoped that a network of trainers could train large numbers of additional artisans. Since many of the artisans are semi-literate or illiterate, it was important to reach them through their peers. Special attention was paid to identification of skilled artisans who could become good trainers.

Instructional facilities for the trainers were built at the regional agroforestry centers in 1983. Most of these courses were held at the centers near Nairobi (Jamhuri) and Mombasa (Mtwapa), although some were held at other centers. The locations of the agroforestry centers are more appropriate for the tree nurseries component of the project than for the stoves component because the centers are far from the locations of the artisans and major markets for jikos.

As of November 1984, 13 trainers had participated in the 5-10 day workshops, but only 3 of these trainers were effective. Another problem was that trainers often quit their jobs after a short period of time because of the low pay. Some of these former trainers started their own jiko-making businesses and although this slowed the progress of training other artisans, it did indicate the income-generating potential of improved stove manufacturing.

In general, the training sessions for artisans had only limited impact because after the training most continued making traditional jikos and other metal products rather than improved jikos. The artisans who received the training (especially those outside of Nairobi) often complained that they could not obtain ceramic liners, sufficient capital, or orders to produce improved jikos. Few had sufficient management skills or experience in bookkeeping, analysis of cashflows, or marketing. It might have been better to give more emphasis to training of entrepreneurs and to promotion of improved jikos among consumers.

The third type of training was aimed at building technical and management skills among managers in the national and local government and nongovernmental organizations, and also private entrepreneurs. Three-month training sessions on enterprise management were conducted for groups of 5 to 7 at the agroforestry centers. As of early 1984, 10 participants had completed the course in enterprise management and 6 more were taking the course. A 6-month course in production line techniques was given to 15 people as of early 1984 (EDI Progress Reports). The impact of the training courses for decision makers is unclear.

**Demonstration**

As the experience in other countries shows, it is more difficult to encourage households to accept new stove designs than it is to train artisans to produce the stoves. Few small enterprises can take the risks of producing a new product before the market is established. A thorough demonstration program requires strong backing by government or nongovernmental organizations and a substantial amount of resources to inform people about the benefits and costs of the stoves.

The KREDP mostly confined its demonstration activities to a field test and displays at exhibitions. The field test distributed about 450 Kenyan bucket stoves to households in Nairobi and Mombasa in late 1983 (KENGO 1984). In addition to providing important information on the efficiency and durability of the stove in use, the field test had a secondary goal of fostering demonstration effects so that relatives, friends, and neighbors of the users would hear about the stoves. Information gained during the field test led to important design modifications that resulted in the bell-bottom stove. Later, the KREDP gave away about 250 bell-bottom stoves to households. UNICEF distributed about 50 free Umeme stoves to households to demonstrate that design (Hassrick 1985).

In early 1984, the Kenyan army began a large program to distribute bell-bottom jikos to soldiers. Kenyan soldiers prepare their own food and carry their fuel. In addition to saving money on charcoal rations, this program could have important demonstration effects as local people observe the use of the new stoves by soldiers and as soldiers inform their relatives and friends. It was discovered that some soldiers damage their jikos through rough handling, so some consideration is now being given to design modifications for army jikos such as reinforcing the liners with chicken wire.

Eventually, users spread information on the new jikos by word-of-mouth and households began to buy them at market prices. Although most households mainly buy improved jikos for the energy savings, the greater prestige of having a modern device also may be important. A metal stove can be a status symbol, particularly in rural areas where it is seen as a step up from an open fire. The bell-bottom stove seems to sell best at the beginning of the month, due to workers who receive a monthly wage and like to buy a present for their wives or possibly their mothers (Burne 1985b). Consumer subsidies were not necessary to stimulate a significant number of middle-income households to purchase the stoves. Many low-income households are not aware of the existence or benefits of improved jikos, or cannot afford the extra initial cash cost. A mid-term evaluation (Kernan, Little, and Evans 1984) suggested that the government or NGOs support an arrangement allowing the poor to exchange their old traditional jikos for new ones, but this recommendation was never implemented.

Liner stoves and traditional stoves were compared in cooking tests at seven major agricultural fairs in different parts of the country. Members of the audience were involved in the demonstrations. Early on, it was learned that the public became frustrated if improved stoves were not available for sale immediately after a demonstration.

Other than the exposure through the field tests and displays at the agricultural shows, only modest efforts were made at demonstrating improved jikos at public markets or through local institutions. Project management was concerned about creating a potential demand that could not be met before production could be expanded sufficiently. Although this strategy reflected the reality of the early situation, a stronger demonstration and marketing program would be timely now. Promotional efforts should go beyond just influencing the decision to purchase an improved jiko because users must understand the importance of having the stoves repaired properly and must be able to identify when repairs are needed. This should not be too difficult because households already are accustomed to frequent replacement of the metal grate in a traditional jiko.

Since the literacy rate in Swahili or English is relatively high in Kenya and the national newspapers have large circulations, a press campaign could help publicize improved jikos. The KREDP printed 5,000 booklets describing the improved jiko, but these were not really aimed at households. More could also be done to publicize improved jikos through radio announcements.

Promotional efforts could be expanded through greater coordination with church groups and women's groups. Existing governmental programs, such as the Family Life Training Centers and women's affairs programs of the Ministry of Housing and Social Services, and the Farmer's Training Centers and home economics programs of the Ministry of Agriculture might be able to provide some assistance. Promotional campaigns at schools may be quite effective because children often bring information to their mothers. Recently, the construction of a traditional jiko and measurement of its charcoal consumption was made part of the seventh grade curriculum.

Each production unit should have a sales manager paid solely on commission to have an incentive to market jikos effectively. Forward-thinking producers could let people borrow improved stoves for a short trial period or allow them to return purchased stoves if they did not like them.

A government loan program to enable consumers to buy jikos probably would not be appropriate because there are many other things people would rather buy first before jikos and many households are wary of government loans. Jerri International has had some success with an interesting approach of arranging for large employers to provide jikos for their employees and recover all or part of the cost gradually through payroll deductions. One seller in Chevakali offers a rent-purchase agreement to customers, whereby rent payments for a jiko can be credited to the purchase price (Opole 1985). AID's regional housing office for Africa is considering including jikos in its housing programs and this could have important demonstration effects.

More follow-up to ensure proper use and maintenance of the stoves within households would be desirable. Key questions for this follow-up include the extent to which households replace liners when they break or buy another improved jiko when their first one burns out. Since the initial purchase of an improved stove may be on impulse, maintenance and replacement expenditures may be a better indicator of eventual consumer acceptance than the initial purchase. Nongovernmental organizations are probably the most appropriate vehicle for this monitoring function.

**Production Assistance**

The project provided grants to 4 entrepreneurs for start-up costs and/or construction of a kiln and shed. One entrepreneur was provided with an indoor masonry kiln for free, but only uses it during rainy season because he worries that the heat will damage the iron sheet roof of his workshop. The rest of the year he uses a traditional earth pit kiln outdoors. The ill-fated Energy Development Fund was supposed to provide money to additional production units for start-up costs. In its absence, K.S. 500-3,000 per artisan was provided out of other budget line items to about 30 artisans for partial financing of the costs of tools and initial materials. These artisans were selected from those who had received training through the project. The start-up assistance was supposed to be repaid after a commercially viable business has been set up, but the repayment record is poor, and there is no effective mechanism for ensuring repayments.

Clayworks, Ltd. submitted a proposal to the MOE for a large sum of money to produce charcoal stoves, but Minister Leakey rejected this as inappropriate government subsidization of a large firm. Jerri International did not receive any financial assistance from the project, but it did receive technical assistance. Jerri submitted a proposal to ITDG for upgrading their pottery production process through purchase of an electric kiln, pug mill, and improved molds, but the proposal was not funded and Jerri later obtained this equipment on its own. Jerri also had tried to obtain government support for a monopoly in liner stove production, but was unsuccessful.

Miaki Jikos had proposed a franchising approach to establishment of small production units throughout the country. A franchise would allow full recovery of the costs of training, structures, equipment, and materials. However, franchises can be exploitative to participating firms if royalties continue indefinitely beyond the point of cost-recovery, and this idea was not accepted.

A few artisans received assistance in obtaining access to water and power through KREDP staff. Project staff also interceded unsuccessfully with local officials to try to stop the harassment of metal artisans over land squatting in Shauri Moyo and Mombasa.

A wide variety of organizations are involved in the distribution of improved jikos: retail shops, market vendors, some of the jiko factories, government field extension centers, churches, and chief's camps. In the early stages, retailers were encouraged to stock improved jikos by arranging their first deliveries on consignment so that they would not have to risk their own cash in advance on a new product that might not sell. The Kenyan Grain Growers Union cooperative stores are selling improved jikos now.

## Financial and Economic Analysis

This section contains a financial and economic analysis of the jikos component of the KREDP, the follow-up ATI project aimed at expanding production to the take-off stage, and their combined effects. Table 6 lists the assumptions behind the financial and economic analyses.

Although laboratory tests show that a 34% fuel savings is feasible, households often do not use or maintain stoves properly, so it is more prudent to assume a 25% fuel savings. Another factor that results in a conservative estimate of net benefits here is the assumed charcoal consumption rate. Although a household that uses charcoal as its fuel for cooking and heating water might consume 700-1,100 kg of it per year, the average urban household that owns a jiko only consumes 662 kg of charcoal per year. If the heavy users of charcoal buy improved jikos before the average users, the net benefits to the household and to society would be even larger than those estimated here.

Table 6

Assumptions For the Economic Analysis of the Jiko Projects

* **Time horizon of analysis** -- 1984-1994 (11 years).

* **All costs and benefits** in 1985 monetary units, discounted to 1984 values at 15% per annum.

* **Administrative costs for KREDP--** K.S. 3,652,000 (1/3 spent each year 1982-84).

* **Administrative costs for the ATI project--** K.S. 1,331,000 in year 1, K.S. 1,534,000 in year 2, and K. S. 1,060,000 in year 3, for a total of K.S. 3,925,000. These figures include the capitalization of a loan fund for producers, but exclude costs of the Kuni Mbili woodstoves field test. Loan repayments may be subtracted from these costs (including a 13% per annum simple interest rate and 60% repayment rate after 1 year). Expected loan repayments are K.S. 225,000 in year 2, K.S. 293,000 in year 3, and K.S. 127,000 in year 4, for a total of K.S. 645,000.

**Costs to each household:**

| | | **Nairobi** | **Other Urban** |
|---|---|---|---|
| i. | Initial purchase of improved jiko | 85 | 120 |
| ii. | Replacement cost for an improved jiko after 2 years of use | 85 | 120 |
| iii. | Replacement cost for a traditional jiko after 2 years of use | 40 | 40 |
| iv. | Replacement of liner/grate for an improved jiko after 1 year of use | 30 | 40 |
| v. | Replacement of 2 grates for a traditional jiko each year | 20 | 20 |

* **Number of urban households using improved jikos as a direct effect of the projects:**

  i. Estimated to have resulted from KREDP at 80% of commercial production through March 31, 1985

| | Nairobi | Other Urban |
|---|---|---|
| | 47,061 | 20,169 |

  ii. Expected from planned ATI project (50% capacity utilization of new production units)

| | Nairobi | Other Urban |
|---|---|---|
| a. New purchasers in 1985 | 2,340 | 9,360 |
| b. New purchasers in 1986 | 7,800 | 31,200 |
| c. New purchasers in 1987 | 10,530 | 42,120 |
| **Total** | **20,670** | **82,680** |

  It is assumed that rural households will adopt the stoves later than urban households.

* **Gross benefits to urban households if improved jikos are used through 1994:**

  i. Average previous charcoal consumption of 662 kg per jiko-owning household per year.

  ii. The price of charcoal in small tins (1-4 kg) is K.S. 3.0/kg in Nairobi and K.S. 2.0/kg in other urban areas. In 30 kg sacks, the price is K.S. 1.8/kg in Nairobi and K.S. 1.2/kg in other urban areas.

  iii. Fuel savings of 25% with the improved jiko.

A household in Nairobi currently can purchase an improved jiko directly from the producers. In other urban areas, allowance is made for the profits of middlemen. The estimates of the lifetime of the cladding, liner/grate, and insulation are conservative; with careful use, the replacement and repair costs should be lower than those assumed. Since it is assumed that a household that adopts an improved jiko for reasons of fuel efficiency discards a traditional jiko that is still serviceable, the whole cost of the initial purchase of an improved jiko is counted. At the end of the expected lifetime of the traditional jiko, only the incremental cost of the improved jiko over the cost of replacing a traditional jiko is relevant.

There is considerable variation in the price of charcoal by season, location, and volume of purchase. Retailers usually specialize in selling charcoal, buying it in sacks from wholesalers who deliver it to them in trucks. Transportation costs vary with distance from the source of the charcoal. A truckload may contain 200 sacks of charcoal (Dewees 1985). The price of charcoal is controlled in Kenya by the Ministry of Finance and periodically published in the Kenya Gazette Supplements. Although the price controls are not rigorously enforced, there has been no change in the official price of charcoal since late 1982.

Charcoal is scarcest in the rainy season for several reasons. Wood is harder to collect at that time, and the weather may interfere with charcoal conversion in outside earth pits or mounds. In addition, more labor is needed for agricultural activities in the rainy season. During the dry season, charcoal makers may have a greater need for cash. Transportation and storage of charcoal also are more difficult in the rainy season. However, the price ceilings do not allow for seasonal variations because that would be more difficult to administer. In the rainy season, the price stays the same, but the size of the sack decreases.

Table 7 shows the variation in contrlled and actual retail prices of charcoal sacks in different urban areas. Although a sack used to contain 40 kg of charcoal, it now contains about 30 kg of charcoal and another 2-3 kg of charcoal fines, twigs, and sometimes stones which are deliberately added. A reduction in weight is one way charcoal sellers try to circumvent the price ceilings. When purchased by the sack, charcoal costs K.S. 1.7-2.0 per kg in Nairobi and an average of K.S. 1.2 per kg in other areas.

Many households cannot afford to buy a sack of charcoal at a time due to insufficient cash and the possibility that stored quantities of charcoal will be stolen. As a result, most households buy charcoal in metal tins ("debes") or gourds or in piles. Although sold by volume, these units usually weigh between 1 and 4 kilograms. Sometimes, the metal tins have punched-in sides, reducing the volume. No effective controls exist on the retail price of charcoal in tins or piles. To find out the actual retail prices, it often is necessary to ask the customers and not the sellers. By the tin, charcoal costs K.S. 3 per kg in Nairobi and an average of K.S. 2 per kg in other areas. A small charcoal seller may sell 20-30 tins per day and therefore has to have a large mark-up over the wholesale price to earn a living. A vendor selling charcoal would earn about K.S. 35 in Nairobi or

Table 7

The Price of Charcoal By
Location in 1985
(K.S. per 30-kg Sack)

| Location | Controlled Price | Actual Retail Price |
|---|---|---|
| Kakamega | 25 | 45 |
| Kericho | 23 | 35 |
| Kininaga | 21 | 30 |
| Kilifi | 23 | 35 |
| Kisii | 25 | 38 |
| Kisumu | 25 | 36 |
| Kitale | 21 | 24 |
| Meru | 23 | 37 |
| Mombasa | 25 | 45 |
| Nairobi | 35 | 50-60 |
| Nyeri | 23 | 40 |

Sources: Maingi 1985; Openshaw 1985.

K.S. 25 outside of Nairobi for each sack broken up into debes.

The average traditional jiko user in Nairobi who buys charcoal in small volumes spends K.S. 166 per month for this fuel. Since a laborer in Nairobi may earn about K.S. 700-800 per month, charcoal purchases account for 21-24% of the laborer's cash income if there is only one wage-earner in the household. By comparison, a household might pay K.S. 150 per month to rent a one-room dwelling in Kibera (Chege 1985b). In other urban areas where the price is lower, the average expenditure on charcoal is K.S. 110. The average rural charcoal user consumes a smaller quantity of charcoal and spends K.S. 68 per month. Although the price of charcoal is lower in other urban areas and in rural areas, charcoal purchases could amount to an even larger share of household income in these areas because wages are much lower.

Table 8 shows that the payback period for an improved jiko is relatively short, especially if a household is replacing a worn-out traditional jiko. The payback period is shorter in Nairobi than in other urban areas and is longest in rural areas. On average, it is reasonable to assume that a household has a traditional jiko that is half worn-out. In that case, the payback period will be somewhere between the times shown here.

Table 9 lists the the present value of net benefits (PVNB) over a 2-year period to a household adopting an improved jiko. Unlike the payback analysis, this calculation includes incremental repair and replacement costs over the full period and it accounts for the time value of money. When aggregated over a large number of households, the total PVNB is substantial.

Table 10 contains an ex post economic analysis of the jikos

Table 8

Payback Period for an Improved Jiko (months)[1]

| Location of Household | Charcoal Purchased In Tins | Charcoal Purchased In Sacks |
|---|---|---|
| **A. Household discards a serviceable traditional jiko** | | |
| Nairobi | 1.8 | 3.0 |
| Other urban areas | 4.0 | 6.7 |
| Rural areas | 6.5 | 11.0 |
| **B. Household replaces a worn-out traditional jiko** | | |
| Nairobi | 0.8 | 1.4 |
| Other urban areas | 2.5 | 4.2 |
| Rural areas | 4.1 | 7.0 |

---

[1] See Table 6 for the assumptions. Since one grate probably would have to be purchased during this period if a traditional jiko were used, its costs are subtracted from the incremental costs of the improved jiko.

Table 9

Present Value of Net Benefits Over a Two-Year Period to Each Household Adopting an Improved Jiko (K.S.)[1]

| Location of Household | Charcoal Purchased In Tins | Charcoal Purchased In Sacks |
|---|---|---|
| **A. Household discards a serviceable traditional jiko** | | |
| Nairobi | 844 | 478 |
| Other urban areas | 496 | 251 |
| Rural areas | 257 | 109 |
| **B. Household replaces a worn-out traditional jiko** | | |
| Nairobi | 884 | 518 |
| Other urban areas | 536 | 291 |
| Rural areas | 317 | 149 |

---

1 See Table 6 for the assumptions.

component of the KREDP and an ex ante analysis of the expected economics of the ATI project, accounting for administrative costs. The total PVNB of the two projects is estimated at K.S. 288,571,000 in the most likely case (charcoal purchased in tins). The total PVNB would be 45% lower if charcoal were purchased in sacks, but it would still be high. The PVNB would be 45% higher if the fuel savings were 35% and charcoal were purchased in tins. It would be 55% lower than in the base case, but still sizable if the fuel savings were only 15%. A low fuel savings rate might occur if households do not use or maintain the stoves properly (Foley and Moss 1983). The assumed rates of market penetration may be optimistic, but even if they were 50% lower than expected, the two jikos projects still have a large PVNB, K.S. 140,882,000 (assuming charcoal is purchased in tins).

## Other Social Effects

The employment and income-generation effects of an improved jikos program vary with the way in which production is organized. To date, production of the metal claddings has been labor-intensive. Although mechanized production of the claddings in the future is possible, it is not likely. The traditional jiko would be even easier to produce by machine, but that this has not happened yet. There may be a conflict between employment goals and energy conservation goals because mass production could lead to faster dissemination of the improved technology.

At present, the employment and income distribution effects of the traditional and improved technologies are roughly comparable. It takes slightly less time to fabricate the metal clad-

Table 10

Economic Analysis of Improved Jiko Projects, 1984-1995 (K.S.)[1]

| | KREDP | ATI Project | Total |
|---|---|---|---|
| | **All cases** | | |
| Present value of administrative costs | 4,227,000 | 2,579,000 | 6,806,000 |
| Present value of incremental costs to users | 12,993,000 | 17,787,000 | 30,780,000 |
| **Case I (most likely): Charcoal purchased in tins** | | | |
| Present value of gross benefits to users | 180,814,000 | 145,343,000 | 326,157,000 |
| Present value of net benefits | 163,594,000 | 124,977,000 | 288,571,000 |
| **Case II: Charcoal purchased in sacks** | | | |
| Present value of gross benefits to users | 108,489,000 | 87,206,000 | 195,695,000 |
| Present value of net benefits | 91,269,000 | 66,840,000 | 158,109,000 |

---

[1] Only includes the jikos produced by the enterprises set up by the projects. If demonstration effects lead to spontaneous establishment of additional enterprises or if the supported enterprises expand their capacity further, the present values of the gross and net benefits would be larger than those shown above. This analysis covers 11 years for the KREDP and 10 years for the ATI project). See Table 6 for the assumptions.

dings for an improved jiko than for a traditional jiko. A small amount of additional labor is required for making the liner, assembling the components, and fixing the insulation for an improved jiko. Any employment gains from the greater total labor input required to make an improved jiko are likely to be more than outweighed by the longer expected lifetime of this stove which reduces the number that have to be produced to replace worn-out ones.

Metal working is considered a low-status occupation in Kenya. Previously, many metal artisans were migrant workers, but most are now settled although they may only work in this occupation seasonally or irregularly. A workshop owner at Shauri Moyo makes a profit of about K.S. 10 per cladding so his total earnings depend on the number of workers he employs and the quantity and types of goods they produce. The number of artisans present in a given workshop varies considerably at different points in time, especially in Nairobi. Thus, it is difficult to estimate the net income of a workshop owner. Raw material and equipment costs are borne by the workshop owner and the workers are paid by piecework. Less commonly, groups of 3-5 metal artisans without employees share a shed.

Full-time metal artisans in Shauri Moyo work at least 6 days a week for 9 hours a day. Usually, an artisan receives K.S. 10 per bell-bottom cladding on K.S. 15-20 for an Umeme stove which takes more time to make. Metal workers rarely specialize in jiko production; they make a wide variety of products such as pots, skillets, washing basins, watering cans, and buckets. A metal artisan in Shauri Moyo typically earns K.S. 45-75 per day; apprentices are paid lower wages.

Given the estimated 1,068,200 households with jikos in Kenya and assuming that the average household buys a charcoal stove every 2 years (since many are not using these stoves for all of their cooking), the annual production of charcoal stoves (traditional and improved) exceeds 534,100. At a production rate of 6 metal claddings per day for 300 days per year, a metal artisan can make 1,800 claddings per year. Thus, about 300 artisans working full-time could meet the annual requirement for jikos. Since nearly all metal artisans diversify their product mix, it is safe to assume that a jiko maker would spend no more than one-third of his time making stoves. If so, slightly over 900 or so metal artisans are involved in making traditional jikos or claddings for improved jikos in Kenya. Even if the annual production rate were doubled by assuming that traditional jikos only last 1 year, just 1,800 artisans in the whole country would be involved in making charcoal stoves. Fewer artisans would be involved if the annual demand for charcoal stoves were lower, such as the 390,000 level assumed by Burne (1985a).

If labor receives K.S. 10 per traditional jiko or cladding, each of these metal artisans would earn K.S. 600 per month from making traditional jikos part-time. Because metal work for charcoal stove production is not a large source of employment, moving toward a more centralized production of stoves to reap economies of scale would not displace much labor and this labor easily could switch to fabrication of other metal products. However, decentralized production also reduces distribution and marketing problems and maintains competition in pricing.

Pottery making is also a low-status occupation in most of Kenya where women are the traditional potters. Women usually do this work part-time or seasonally as a supplementary source of cash income. However, among the Luhya tribe around Kakamega, pottery is made by the men and the occupation has a higher status. Typically, a pottery worker making ceramic liners in Kakamega on a piece rate would earn K.S. 30-50 per day. Burne (1985b) estimates that the production of 250,000 liners per year would require 200-300 full-time equivalent jobs in the ceramics industry. Given the potential competition, it is unlikely that most of these jobs would go to groups of poor, rural women working part-time or seasonally. An enterprise with well-trained experienced women or men working full-time and having good transport for clay and finished liners would have a definite advantage in maintaining quality and controlling costs.

## Health Effects

In decreasing order of significance, three main health issues surround cookstoves: indoor air pollution, fire and burn hazards, and occupational safety.

### Air Pollution

First, the use of wood-burning stoves inside a house subjects the cook and other members of the household to substantial amounts of smoke and other air pollutants. Hydrocarbons are produced by incomplete combustion. Particulates are a major component of smoke. Hydrocarbons and particulates can lead to lung diseases, such as emphysema, asthma, lung cancer, and eye irritation. Whether these chronic health effects are widespread or significant relative to malnutrition and unsafe drinking water remains to be demonstrated. Exposure to acute CO concentrations of 1% without proper ventilation can be quickly fatal and with little warning since the gas is odorless and nonirritating (Marwick 1985). Fortunately, ventilation is generally good in homes in LDCs because they are not tightly closed or insulated. The concentration of nitrogen oxides in wood smoke is not high due to the relatively low combustion temperatures. Sulfur dioxide is not a problem because wood has a low sulfur content, less than 0.20% (Ramsay 1985).

Human exposure levels to the above pollutants may be lower when cooking is done over open fires outside the house than with indoor woodstoves. Nevertheless, outdoor air pollution from household cooking can also be a serious problem, and wood fires have been banned in Dakar, Senegal for that reason (Evans 1985).

One recent study monitored pollutant concentrations under a hood raised or lowered over a small chula (South Asian mudstove). The emissions were measured at 9 kg of total suspended particulates (TSP) and 84 kg of carbon monoxide (CO) per tonne of wood burned. Corresponding figures for an outdoor three-stone fire were 7.7 kg and 63 kg (Butcher et al. 1984).

Another study relied on portable monitors worn by the cooks to better measure human exposures to pollutants generated by wood combustion. This study found that cooks were exposed to levels of TSP, CO, particulate benzopyrene (a), and formaldehyde comparable to or greater than those inhaled by heavy cigarette smokers (Smith 1984). About 50-75% of these particulates are of the very small sizes that usually become trapped within the lungs and therefore pose the greatest long-term health threat (Ramsay 1985).

Hydrocarbon and TSP emissions are likely to be much lower for combustion of charcoal than for wood although CO levels could be high for charcoal (Smith 1985). Limited testing has shown that the ceramic-lined jiko generates 20% less CO than the traditional jiko (Kinyanjui 1985). Thus, the substitution of charcoal stoves for woodstoves could have major beneficial health effects, but the substitution of improved charcoal stoves for traditional charcoal stoves would have only modest health effects.

**Fire Hazards**

Most households perceive that traditional and improved jikos are less of a fire hazard than open fires, but there is little difference between traditional and improved jikos in this regard. However, some nonusers of the Umeme perceive a possible problem with burns when stirring foods while cooking or when removing a cooking pot; this is less likely to be a problem with the Haraka stove. Kenyan women customarily hold the edge of the pot with their hands while stirring or lifting it out of the stove. Since heat is convected around the top of the Umeme, this could result in burns unless a thick piece of cloth is used as a potholder. However, actual users of the Umeme report that they do not have any problems with burns. The outer wall of the Umeme does not get too hot unlike the traditional jiko which may reach 700°C on the outer surface. The Haraka stove's outer wall will get hotter than the Umeme's outer wall. Since both the bell-bottom stove and the Umeme are heavier than the traditional jiko, they are less likely to tip over from the unusually strenuous cooking practices that Kenyans use in preparing ugali. There should be fewer burns from accidental spills with the Umeme than with the traditional or the bell-bottom jiko because the pot rests inside the Umeme; this is an important advantage when children play in the kitchen.

**Occupational Safety**

An improved stoves program may have some occupational safety effects. The recommended technique of folding and rivetting metal sheets for an improved jiko may result in fewer accidents than the traditional technique of metal cutting for jiko manufacture. People making either traditional or improved jikos may experience headaches and tinnitus from the noise. In addition, scrap metal drums used for jiko making often contain traces of pesticides or other hazardous chemicals. Sometimes, the drums are burned before re-use to remove some of the residual chemicals. These occupational exposure rates to hazardous chemicals have not been measured, but could be significant.

## Environmental Effects

It often is alleged that the demand for fuelwood and charcoal is responsible for a large share of the deforestation and forest degradation taking place in many tropical countries. Deforestation refers to the conversion of forests to other land uses. Forest degradation refers to declines in the productivity or species mix of trees. In most countries, fuelwood and charcoal use contribute mainly to forest degradation while deforestation is usully due to agricultural conflicts, commercial logging, or large-scale development projects (Hamilton and King 1983).

What are the environmental impacts of woodfuel harvesting? If woodfuel harvesting is carried out **at sustainable rates and is limited to lopping of twigs and branches without mechanized harvesting or extraction and road construction**, its environmental impacts should be minimal. The reduction in the tree canopy may decrease interception of water, increase throughfall, decrease evapotranspiration, and increase stream flows. There is little information on the effects on stream flow timing. Some nutrients would be exported from the ecosystem, but the quantity would not be significant. Erosion would not increase significantly unless woodfuel harvesting were combined with grazing or repeated skidding of wood by hand or by animals (Ibid.).

However, **excessive cutting of trees, in combination with animal grazing and repeated burnings**, may result in the conversion of forest land to grasslands or savanna. These grasses create a dense mat of shallow roots at the soil surface and have fire-resistant rhizomes. The environmental impacts of this conversion would be decreased interception and evapotranspiration, and increased water yield and groundwater infiltration if the soil has **not** been compacted in grazing or wood extraction. If the grass cover becomes depleted, there will be much more erosion from these lands than from mature forests. During the conversion process, stream sediment loads may increase substantially, but may stabilize later if the grass cover is maintained. Nutrient outflows are larger if the conversion is rapid. Once the grasses are established, the nutrient losses are mainly due to burning.

Most tropical grasslands are overgrazed and periodically burned. In some situations, the severity of local floods may increase due to higher and faster peak flows even though the stormflow volume might not increase. In large river basins, no significant change in flood risks is expected due to conversion of forest to grasslands because changes in the vegetative cover are dwarfed by other river basin variables (Ibid.). Approximately 80% of the wood cut in Kenya is used for fuel (Shakow, Seiderman, and O'Keefe 1982), but much of this wood comes from lopping of branches and twigs rather than felling of whole live trees. The environmental impacts of charcoal use may be larger than those of fuelwood use even if the same amount of wood is involved. Fuelwood often consists of twigs and fallen branches collected while whole trees including the roots are often removed for charcoal production. Moreover, fuelwood often is collected from scattered areas of brush whereas wood for charcoal often comes from trees on pasture land or areas with unclear land tenure.

Closed forests have a full canopy of tree tops that blocks most light from reaching the ground. Open forests are a mixture of scattered broadleaved savanna trees and grasslands. Kenya has a total land area of 56,925,000 hectare (ha) (Ramsay 1985). At the end of 1980, Kenya had 490,000 ha of productive closed forest (71% broadleaved and 29% coniferous); 615,000 ha of unproductive closed forest (55% broadleaved, 27% bamboo, and 18% coniferous); and 55,000 ha of fallow agricultural lands in former closed forest (73% broadleaved and 27% coniferous). Only 14% of the productive closed forest was intensively managed. In addition, there were 565,000 ha of productive open forests; 690,000 ha of unproductive open forests; 550,000 ha of fallow agricultural lands in former open forests; and 37,550,000 ha of shrublands (FAO/UNEP 1981). About 8,000 ha of productive closed forest and 11,000 ha of unproductive closed forest are being converted to other land uses each year in Kenya (FAO/UNEP 1981).

Table 11 lists the potential woodfuel resources in Kenya, regardless of their location. Woodfuel resources can come from any woody biomass, not just forestland. In fact, the bulk of the potentially available woody biomass in Kenya is on rangelands. Agricultural lands also contain more woody biomass than forests and plantations. However, much of this biomass is accessible for use as woodfuel.

Accessibility depends on the topography, distribution of the population, transportation infrastructure, land tenure arrangements, the availability and type of tools for extracting wood, and whether fuelwood is purchased, collected for free, or grown by households and cottage industries. Since the economically-accessible forest reserves in Kenya have largely been cut (FAO/UNEP 1981), most of the woodfuels come from high-potential agricultural land and fringe areas (Shakow, Seiderman, and O'Keefe 1982). Although plantations are situated to be economically accessible, over 90% of these plantations are for industrial pulpwood or sawtimber and 5% are for tannin (FAO/UNEP 1981).

Accessible woodfuel supplies in Kenya vary considerably by province, ecological zone, and land uses (Table 12). By 1980, wood stocks in four provinces already were being depleted (Central Nairobi, Nyanza, Rift Valley, and Western provinces). Two more provinces (Coast and Eastern provinces) are expected to

Table 11

Potential Wood Resources in Kenya, 1980
(From Trees and Woody Biomass)[a]

| | Eucalyptus and Wattle Plantations | Other Plantations | Commercial Natural Forest[b] | Noncommercial Natural Forest[c] | Agricultural Areas | Urban and Built Areas[d] | Tea, Coffee, and Coffee Shade Trees[d] | Range Areas[d] | Total |
|---|---|---|---|---|---|---|---|---|---|
| | **Current growing stock ($1000 m^3$)** | | | | | | | | |
| Exploitable | 4,919 | 41,771 | 60,756 | 79,272 | 103,271 | 253 | 1,000 | 984,000 | 1,275,242 |
| Protection Forest and National Parks | --- | --- | 7,102 | 10,162 | 15,023 | --- | --- | --- | 32,287 |
| **Total** | **4,919** | **41,771** | **67,858** | **89,434** | **118,294** | **253** | **1,000** | **984,000** | **1,307,529** |
| | **Estimated sustainable harvest of woodfuels ($1000 m^3$)** | | | | | | | | |
| Exploitable | 416 | 465 | 542 | 2,049 | 5,508 | 14 | 390 | 22,540 | 31,924 |
| Protection Forest and National Parks | --- | --- | 62 | 275 | 801 | --- | --- | --- | 1,138 |
| **Total** | **416** | **465** | **604** | **2,324** | **6,309** | **14** | **390** | **22,540** | **33,062** |

---

[a] Includes inaccessible resources.

[b] Commercial and noncommercial areas are not distinct, but have been allocated according to the percentage of commercial trees present.

[c] Includes bamboo, with or without trees, and scrub areas.

[d] $1.4 m^3 = 1$ tonne.

Source: Openshaw 1982c.

Table 12

Provincial and National Wood Supply and Demand, 1980
(Million Tonnes)

| Source of Demand | Central/ Nairobi | Coast | Eastern | North-Eastern | Nyanza | Rift Valley | Western | Total |
|---|---|---|---|---|---|---|---|---|
| Local Woodfuel Demand | 2.4 | 1.7 | 3.0 | 0.4 | 2.5 | 3.8 | 1.9 | 15.7 |
| Woodfuel Demand Other Regions[a] | - | - | 0.8 | 0.1 | - | 1.5 | 0.2 | 2.6 |
| **Subtotal Woodfuel Demand** | **2.4** | **1.7** | **3.8** | **0.5** | **2.5** | **5.3** | **2.2** | **18.3** |
| Feedstock Demand | 0.1 | - | - | - | - | 0.3 | - | 0.4 |
| **Total Demand** | **2.5** | **1.7** | **3.8** | **0.5** | **2.5** | **5.6** | **2.2** | **18.7** |
| Accesible Sources of Supply | | | | | | | | |
| Sustainable Supply | 1.2 | 1.7 | 3.8 | 0.5 | 0.4 | 5.1 | 0.3 | 13.0 |
| Supply from Stocks | 1.3 | - | - | - | 2.1 | 0.4 | 1.9 | 5.7 |
| **Total Supply** | **2.5** | **1.7** | **3.8** | **0.5** | **2.5** | **5.5** | **2.2** | **18.7** |

---------------------

[a] Woodfuel demand from other regions refers mainly to inter-province exports of charcoal.

Source: O'Keefe, Raskin, and Bernow 1984.

experience a net depletion of wood stocks in the early 1980s. Without increased conservation or production of wood, the cumulative stock depletion and supply shortfall would be sizeable by the year 2000 (Table 13). A supply shortfall means that there might be less cooking of foods and boiling of water, shorter cooking times, more use of nonwoody biomass, more careful use of charcoal and wood, and substitution of wood or fossil fuels. The increase in net stock depletion would slow after 1995 due to reduced accessibility of remaining stocks and, as a result, the shortfall then would grow faster. The total annual shortfall would increase from 5.4 million t in 1985 to 30.6 million t in the year 2000. At the same time, standing of wood would fall from 974 milllion t to 800 million t (O'Keefe, Raskin, and Bernow 1984).

Can improved charcoal stoves save a significant amount of wood? At the average charcoal consumption rate of urban households that use charcoal, assuming that 80% of the improved jikos produced through the first quarter of 1985 remain in use and result in a 25% fuel savings over traditional jikos, over 11,000 t of charcoal already are being saved each year as a result of the achievements to date. This amount is equivalent to about 92,700 t of wood if the charcoal is made in traditional kilns.

If 80% of the urban and rural households that used charcoal in 1985 adopt improved jikos that have a 25% fuel savings, 116,100 t of charcoal would be saved annually. With traditional charcoal conversion methods, this savings is equivalent to 967,000 t of wood per year. This savings would grow in future years. By the year 2000, the annual charcoal savings would be

Table 13

Summary of Regional Supply/Demand Relationships, 1980-2000

| | Central Nairobi | Coast | Eastern | North-Eastern | Nyanza | Rift Valley | Western |
|---|---|---|---|---|---|---|---|
| Onset of Supply Shortfall | 1988-90 | - | - | - | 1982-85 | 1997-2000 | 1982-85 |
| Onset of Net Stock Depletion | 1980 | 1983-85 | 1984-85 | - | 1980 | 1980 | 1980 |
| Shortfall as Percent of Demand[a] | | | | | | | |
| 1985 | - | - | - | - | 100 | - | 98 |
| 2000 | 92 | - | - | - | 100 | 92 | 98 |
| Net Stock Depletion as Percent of Wood Supply | | | | | | | |
| 1980 | 52 | - | - | - | 85 | 6 | 86 |
| 1985 | 76 | 18 | 13 | - | -[b] | 38 | -[b] |
| 2000 | -[b] | 89 | 80 | - | - | - | - |
| Cumulative Stock Depletion (%) | | | | | | | |
| 1985 | 16 | 1.3 | - | - | 51 | 2 | 36 |
| 2000 | 33 | 24 | 19 | - | 52 | 29 | 36 |
| Contribution to National Shortfall (%) | | | | | | | |
| 1985 | - | - | - | - | 56 | - | 44 |
| 2000 | 19 | - | - | - | 14 | 54 | 13 |
| Contribution to National Shortfall (million tonnes) | | | | | | | |
| 1985 | - | - | - | - | 3.0 | - | 2.4 |
| 2000 | 5.7 | - | - | - | 4.4 | 16.5 | 4.0 |

[a]In some provinces, the shortfall never reaches 100% since the demand for industrial/construction feedstocks is met from managed forest yields.

[b]Accessible stocks have been depleted by this time leaving none available to meet demand.

Source: O'Keefe, Raskin, and Bernow 1984.

419,300 t of charcoal, the equivalent of 3,492,600 t of wood. The Beijer Institute's projection of potential annual savings is even more optimistic -- 8.23 million t of wood in the year 2000 from adoption of improved jikos by 95% of urban charcoal-burning households and 100% of rural ones (O'Keefe, Raskin, and Bernow 1984).

The environmental effects of an improved jikos program depend on the types and locations of wood cut for charcoal, the importance of charcoal as a cooking fuel for jiko-owning households, and the extent to which fuelwood users switch to charcoal as a result of the program. These environmental effects could be significant at the local level, but might not reduce overall deforestation rates at the national level.

In 1980 there were 156,000 ha of woodlots and peri-urban plantations in Kenya yielding an average of 16.1 t of wood per ha and 166,700 ha of managed, productive forests yielding 4.9 t per ha (O'Keefe, Raskin and Bernow 1984; FAO/UNEP 1981). Assuming that both types of forest are the source for additional supplies of wood for charcoal making in proportion to their current total annual yields, an 80% adoption rate for improved stoves by households using charcoal in 1985 would eliminate the need to clearcut 45,300 ha of woodlots and peri-urban plantations as well as 47,800 ha of managed, productive forests each year. The annual savings in the year 2000 would be 163,600 ha of woodlots and 172,600 ha of managed forests.

A monetary value may be imputed for the wood savings in 1985. The current stumpage price for fuelwood from managed, natural forests is K.S. 19 per stacked cubic meter ($m^3$), but the price would have to be K.S. 55 per $m^3$ for fuelwood production on the Forest Department's peri-urban plantations to be economically viable, ignoring the opportunity cost of the land (Dewees 1985). It is possible that smallholders could produce fuelwood more economically than that. Smallholder production of tea has been quite successful in Kenya; however, the likelihood of substantial smallholder production of wood is low given the current incentives.

The analysis below assumes that the current stumpage price fully reflects the present value of production costs for fuelwood from managed, natural forests. In fact, this stumpage price is subsidized and might not even cover the Forest Department's costs of replanting (Maingi 1985); therefore, the benefits of charcoal conservation would be even greater than these estimates indicate. The higher projected price should reflect the production costs for fuelwood from peri-urban plantations.

The annual wood savings from adoption of improved jikos by 80% of households using charcoal in 1985 would be worth K.S. 96,195,000 per year (using the conversion factors of 1.4 solid cubic meters wood per tonne and 0.65 stacked cubic meters per solid cubic meters. Taking 2 years as the lifetime of an improved jiko at full use and discounting the annual savings at 15%, the present value of the **social benefits** is K.S. 179,842,000. To achieve this savings, over 854,600 households would have to purchase an improved jiko and would need to have the liner, grate, and insulation replaced twice during the 2-year period. The **social costs** of buying and repairing these jikos may be valued at the production costs including a modest profit (K.S. 70 for a new jiko and K.S. 30 each year to replace the liner and grate). The present value of the social costs amounts to K.S. 107,685,000, excluding administrative costs. Thus, the present value of net benefits of 80% adoption of improved jikos exceeds K.S. 72,157,000 for a two-year period. If the true costs of wood from government forests or growth in the number of households, urbanization, and income are considered, the future annual savings would be even greater.

The above calculation of the social value of the wood savings is a different way of estimating the benefits from the aggregate cash savings to households from reduced expenditures for charcoal. The latter estimate is larger because it includes transport costs, charcoal conversion costs, and profits to retailers. These two separate estimates cannot be added together because that would be double counting since charcoal prices include a component for acquisition of wood (although the social costs of the wood may be undervalued at the controlled prices). However, if a charcoal stoves program induces a large number of households to switch from wood or even LPG or kerosene to charcoal, it could increase the amount of wood cut by more than the amount saved because of the net energy loss in charcoal conversion.

## Alternative Technologies

Other ways to achieve a more favorable balance between woodfuels consumption and supply are to adopt more efficient charcoal kilns, household woodstoves, or institutional woodstoves; or to increase wood production. These options are not mutually-exclusive alternatives because they can be carried out in combination with each other and/or in conjunction with an improved charcoal stoves project.

**More Efficient Charcoal Kilns**

Improved charcoal production technologies can be used to meet a given level of demand for charcoal using much less wood. More efficient charcoal kilns and improved charcoal stoves are not mutually exclusive, but the total wood savings from adopting both options would be less than the sum of the separate savings if both were adopted alone. Nevertheless, it is unlikely that more efficient charcoal kilns will be adopted rapidly.

Nearly all of the charcoal used for household cooking in Kenya is made by small producers in simple earth pits or mounds near where the trees are felled. Charcoal often is produced sporadically when agricultural labor requirements are low or the producer needs extra cash. Usually, less than 5 $m^3$ of wood are carbonized in one cycle in a traditional kiln (Evans 1984). A production cycle takes about 1 week in a pit kiln (Baldwin 1985) and production is limited by the weather in the rainy season. About 12 t of charcoal can be made per year in a traditional kiln. Approximately 26 person-days of labor are required per 1 t of charcoal produced in a traditional kiln (O'Keefe, Raskin, and Bernow 1984).

There is a substantial loss of usable energy in converting wood to charcoal. The yield of charcoal in traditional kilns is 8-15% of the weight of the wood consumed (Evans 1984; O'Keefe, Raskin, and Bernow 1984). Nevertheless, the efficiency of a traditional kiln can be improved somewhat through minor modifications. A long path for hot gases or a reverse draft circulates the heat generated by carbonization to the rest of the charge. Tight packing of wood reduces the likelihood of cave-ins and decreases air channels that can increase incompleteness of combustion. The wood also should be dry. Larger pit kilns are more efficient than smaller ones, all other things being the same. The pit should be sheltered from the wind, and smoke leaks should be covered. A metal lining can help retain heat and improve the quality of charcoal by keeping out stones and soil. Chimneys also can be added (Hyman 1983a; Karch and Boutette 1983).

Alternative methods of charcoal conversion include metal drum kilns, portable steel kilns, beehive kilns, cement kilns, and retorts. Metal drum kilns are simple adaptations of 1 or 2 used oil drums and can yield 22-27% of the wood by weight. A single drum kiln can produce 2,100-2,600 kg of charcoal per year and a double drum kiln has twice this capacity. These kilns should last at least 2 years and there can be 3 or more production cycles per week (Medrano 1976; Baldwin 1985).

Portable steel kilns such as the Mark V design can be 20-50% more efficient than traditional kilns. Their capacity is 50 t of charcoal per year and they require 4 person-days of labor per 1 t produced. Portable steel kilns can last 3 years. Thin steel is prone to getting distorted while heavy steel is too expensive. Furthermore, repairs are difficult for these kilns because welding often is necessary. A shortage of trucks can limit the actual portability of these kilns in rural areas (Earl and Earl 1975; O'Keefe, Raskin, and Bernow 1984). Two designs of portable steel kilns have been tried in Kenya by private industries without much success: the CUSAB kiln and the Mark V kiln (Kionga-

Kamau 1983).

Kilns may be made of adobe or bricks in rectangular or beehive shapes. These kilns are relatively efficient because they are well-insulated. However, they are not portable and a lot of labor is required for their construction. A brick kiln o the Missouri design can produce 300 t of charcoal per year, usin only 1 person-day of labor per 1 t produced. Brick kilns can last 7 years, but adobe kilns have a shorter lifetime because they are susceptible to cracking (O'Keefe, Raskin, and Bernow 1984). Brick kilns are easier to repair than steel kilns. Thes kilns can be charged up 3 times in a week (Baldwin 1985). At present, 24,000 t of charcoal in Kenya are produced each year by the East African Tanning and Extracting Co. at Eldoret in 12 mud plastered kilns made of unfired bricks. These kilns yield 25-32 by weight (Kamweti 1983). The Eldoret kilns are the only brick charcoal kilns currently in commercial use in Kenya. The agro-forestry center at Jamhuri also has some masonry kilns used for experimentation and training and plans are underway to build these kilns at the Mtwapa, Bukura, and Kitui agroforestry center

Cement kilns are durable and relatively efficient. Yet, cement kilns are not portable and are expensive. Furthermore, cement may not be available in some rural areas.

Retorts have an external fuel source and therefore do not consume part of the wood charge as fuel. The charcoal yield of a retort is about 32% by weight (Baldwin 1985). Retorts also allow capture of some byproduct gases and chemicals for subsequent use and 3 production cycles can be done in a week. Yet, retorts are much more expensive and complex to build and operate than other types of kilns.

In general, since more efficient charcoal kilns are capital-intensive and large-scale, they mainly are appropriate for semi-industrial or industrial production. Compared to a traditional kiln, the capital costs for a single drum kiln are 15 times higher, a portable steel kiln is 20 times higher, a brick kiln is 140 times higher, and a retort is 1,000 times higher. As a result, the gross revenues per dollar of capital cost and labor cost are highest for traditional kilns (Openshaw 1982; Baldwin 1985). Due to the high initial capital costs, adoption of more efficient kilns could lead to both higher consumer prices for charcoal and centralized production controlled by the urban middle class. At present in Kenya, charcoal usually is made sporadically in small quantities by a large number of people. Most of these producers are illegal and difficult to locate and charcoal-making is an occasional, but significant major source of cash income for the rural poor. Centralized production would displace this labor and probably would require a large, steady source of wood from forests or plantations whereas dispersed small-scale producers can rely on branches and twigs from scattered trees or scrub.

If 10% of Kenya's charcoal demand in the year 1990 were produced through improved kilns, 0.45 million t of wood could be saved per year. This amount is less than one-eleventh of the savings that could be obtained if improved jikos were adopted by 95% of urban households and 100% of rural households. Using improved kilns to meet 50% of the charcoal demand in the year 2000 could conserve one quarter of the amount of wood saved by improved jikos (O'Keefe, Raskin, and Bernow 1984). Yet, achieving that level of adoption may be difficult because charcoal produced in improved kilns might not be economically competitive as a household cooking fuel.

**More Efficient Household Woodstoves**

The energy content of wood varies a great deal with the species and moisture content, but 16.0 GJ per t is a representative figure for hardwood at 15% moisture content. Since an average tonne of charcoal has an energy content of 33.1 GJ (O'Keefe, Raskin, and Bernow 1984), charcoal has 107% more energy per unit weight than wood. Suppose that 12% is the average yield in converting wood to charcoal. Accounting for the energy loss in conversion, 1 t of charcoal produces 25% of the gross energy of 1 t of wood.

However, charcoal stoves also extract energy more efficiently than wood stoves because charcoal 1) has a higher combustion temperature, 2) has a lower volatiles content which allows the combustion chamber to be smaller so the pot can be closer to the fire, and 3) tends to insulate the pot from radiant and convective heat losses since charcoal burns from the bottom and center up instead of from the top down. An open wood fire has an end-use efficiency of about 15% (Baldwin 1985), compared to 30% for an improved charcoal jiko. Taking all of these factors into account, 1 t of charcoal burned in an improved jiko provides about 50% of the net usable energy of 1 t of wood burned in an open fire.

Thus, a sizable amount of wood could be saved if households that cooked with charcoal burned wood in an efficient woodstove instead. However, for the reasons mentioned earlier, urban households using charcoal are unlikely to switch to wood unless the relative prices and availability of these two fuels change a great deal to outweigh the extra inconvenience.

Thus, the potential for wood conservation through more efficient woodstoves mainly rests on convincing rural households to use them effectively as a replacement for open fires or inefficient traditional woodstoves. Yet, of the more than 100 major woodstove projects in LDCs that have been started, only about 10 have thrived for more than 2 years. Of the 100,000 or so improved woodstoves distributed under these projects, 10-20% of those stoves are not being used at all and another 20-30% only are being used intermittently (Manibog 1984).

One reason for this low rate of success is that it is difficult to convince people to buy a fuel-conserving stove when they do not pay cash for the fuel. Most fuelwood users in Kenya collect it for free; an exception is an area north of Nairobi where people purchase fuelwood. In many places where fuelwood is purchased, its price is still much lower than that of other fuels despite increasing wood scarcity. Therefore, in this country, most wood users lack the financial incentive to buy improved stoves that charcoal users have to buy improved jikos. Since cash is scarcer for these households than labor time, most would rather use either a three-stone fire which does not cost them any money or a low-cost traditional woodstove. Nationally, about 89% of women collect fuelwood regularly, while only 5% of men do (Kenyan Ministry of Economic Planning and Development, 1981). In

Kenya, men cntrol decisions on household items, and they may place a low weight on timesavings by their wives.

Scrap metal availability may be a problem for the decentralized production of metal woodstoves. Although replacing a traditional jiko with a bell-bottom stove saves metal because of the longer cladding life for the improved jiko, the replacement of a three-stove fire with a metal woodstove increases the demand for scrap metal. Production of metal woodstoves in urban and peri-urban areas may reduce the availability problem.

Other reasons why woodstove projects in many countries have done poorly are technical problems with the stove designs, incompatibility with cultural preferences, and inadequate dissemination strategies. To date, most of the efforts have been devoted to massive, multiple-port, mudstoves built by users (e.g. Lorena stoves). For short periods of cooking, massive stoves are inefficient because too much unusable heat is stored within the bulk of the stove. In addition, massive stoves often have a poorly-controlled and excessively-large air draft. With multiple-port woodstoves, too little heat is transferred to the second or third ports for them to be useful for cooking (Ouedraogo, Yameogo, and Baldwin 1983).

Adoption and continued use of improved woodstoves by households has been a major problem because the promoted designs often did not meet local preferences for portability, convenience, and perceived safety (Foley and Moss 1983). Characteristics other than fuel efficiency (e.g. smokelessness and appearance) may matter most to woodstove users. Where nights are cool, for example at higher elevations, the "waste" heat radiated from "inefficient" stoves is desired for space heating. Furthermore, the durability of mudstoves tends to be poor so their useful life is short. Many woodstove designs do not accept the wide variety of types and sizes of fuels available seasonally in rural areas (O'Keefe 1982).

Since accurate construction of woodstoves according to the design specifications is critical, especially if there is a chimney and flue system, the actual efficiency of a user-built stove may even be less than that of a traditional stove (Baldwin 1984). Potential efficiency gains also depend a great deal on correct methods of stove use and maintenance (Foley and Moss 1983). The self-help strategy of training individuals to build stoves for their own households can be an expensive and slow way to disseminate the technology (Ellis 1983).

A considerable amount of work has been done in Kenya on improved woodstoves, but the results have not been impressive to date. In 1982, UNICEF provided a training course on construction of woodstoves for NGOs in Kenya. Most of the early efforts in Kenya involved massive, multiple-port mudstoves with or without chimneys and, in some cases, with sheet metal heating plates. Subsequent to the UNICEF course, the Diocese of Maseno South, Action-Aid, Utooni Development Group, Karai Water Tank Improved Stove Group, and other groups implemented woodstoves projects. In some projects, people were trained to build their own stoves while other projects relied on trained specialists to produce stoves for households. Even though these projects included large subsidies for producers and/or users, they only resulted in dissemination of a few hundred woodstoves (Fowler et al. 1983;

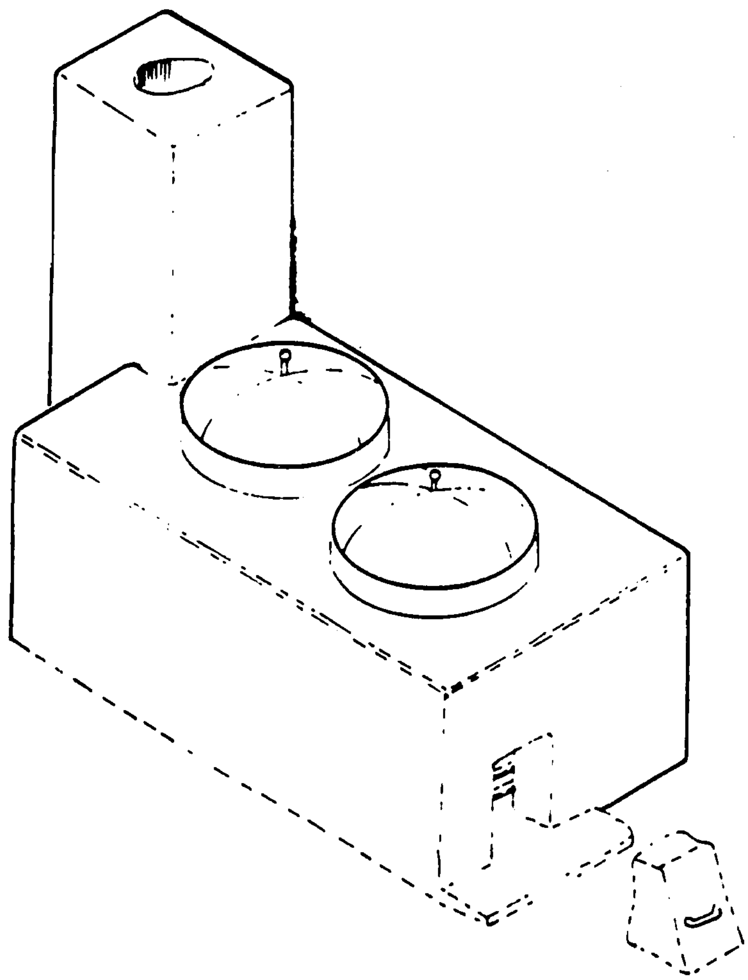
Kamweti 1983).

The Bellerive Foundation has emphasized variations of two design concepts for artisan-built household woodstoves: the Pogbi stove and the Polish stove. The Pogbi (or Ruthigiti) has a massive clay body, a metal heating plate with openings for two pots, and a large chimney made of clay segments which are sometimes extended with sheet metal pipes (Figure 7). Molds are used to shape the pot holes and chimney. The Pogbi stove is too expensive for most fuelwood-using households as its unsubsidized production cost was cost K.S. 200 in 1982. It requires the use of specially designed pots that are not currently commercially available. Proper use of this stove requires households to clean the ash chambers daily, close the stove doors, chop wood into small pieces, avoid adding too large a fuel charge, and sweep the chimney regularly. Unfortunately, few of the households who have received this stove use it properly.

The Polish stove is an all-metal brazier with double walls welded to a round base, a conical firebox that fits inside the double walls and also serves as a flue, a ring-shaped pot shield at the top, a tray for control of air entry, and a tall chimney (Figure 8). This stove requires the use of a large, specially designed pot which fits down into the stove. The Polish stove is also complicated to make. The fuel efficiency of the Polish stove is relatively high, but it is inconvenient to use because it should be lit outside and then brought inside after the wood has been converted to glowing embers. Although it is portable, this stove is relatively heavy. Besides wood, this stove can burn wood waste and charcoal fines. Total costs for this stove

Figure 7

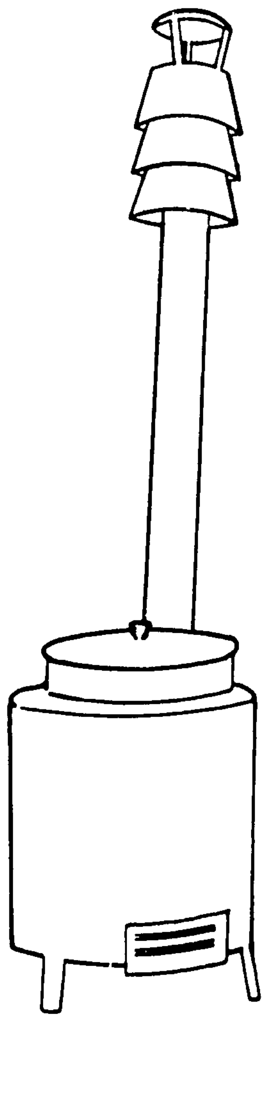
The Pogbi Stove



Source: Micuta 1985.

Figure 8

The Polish Stove



Source: Micuta 1985.

and the pot are estimated at K.S. 600 in 1985. The small proportion of rural households who could afford this stove probably would prefer to cook with kerosene or LPG. A modification of the design may have some potential for institutional users.

The Bellerive Foundation also encourages the use of insulating hay boxes to allow food to continue cooking after removal from the fire. Hayboxes are an appropriate technology because they are simple and low-cost, but cooks have to be educated to take the extra effort to use them.

The Bellerive Foundation has not been effective in disseminating its household stoves due to the cost and complexity of use of the stoves and its failure to consider sociocultural factors. To reduce the cost of this stove to the users, the Bellerive Foundation urges a "radical cut in prices of imported metal sheets" through large subsidies. Since massive subsidization is not likely, this is not a practical approach to designing household woodstoves. The authoritarian, "missionary attitude" of Micuta has created antagonism among local women in the areas where he has worked. The production and dissemination strategy of the Bellerive Foundation is dependent on large subsidies and has had little impact. A University of Nairobi professor reported that many of the Bellerive household stoves distributed in Ruiru are in disuse and some have bird's nests in their chimneys.

The Rafiki is a nonportable, woodstove designed by UNICEF (Figure 9). It is a modification of the Karai stove designed by Micuta. The base is made of sand and clay shaped in a mold with inserts for the single pot hole and the brick chimney. The stove is made in pieces and fitted together with wet clay joining the

Figure 9

The Rafiki Sto'

Source: UNICEF Technology Support Section n.d. b.

parts. The primary design objective of the Rafiki and Karai stoves was smokelessness as the fuel efficiency began to deteriorate after a year. The Rafiki is built by artisans using wooden and metal molds. Training courses for artisans have been held at the Family Life Training Centers and a few hundred have been built. The materials for a Rafiki stove cost about K.S. 80; but labor costs, overhead, and profit must be added to that (Claassen 1985). UNICEF field tested 25 Rafiki Stoves in Machakos District.

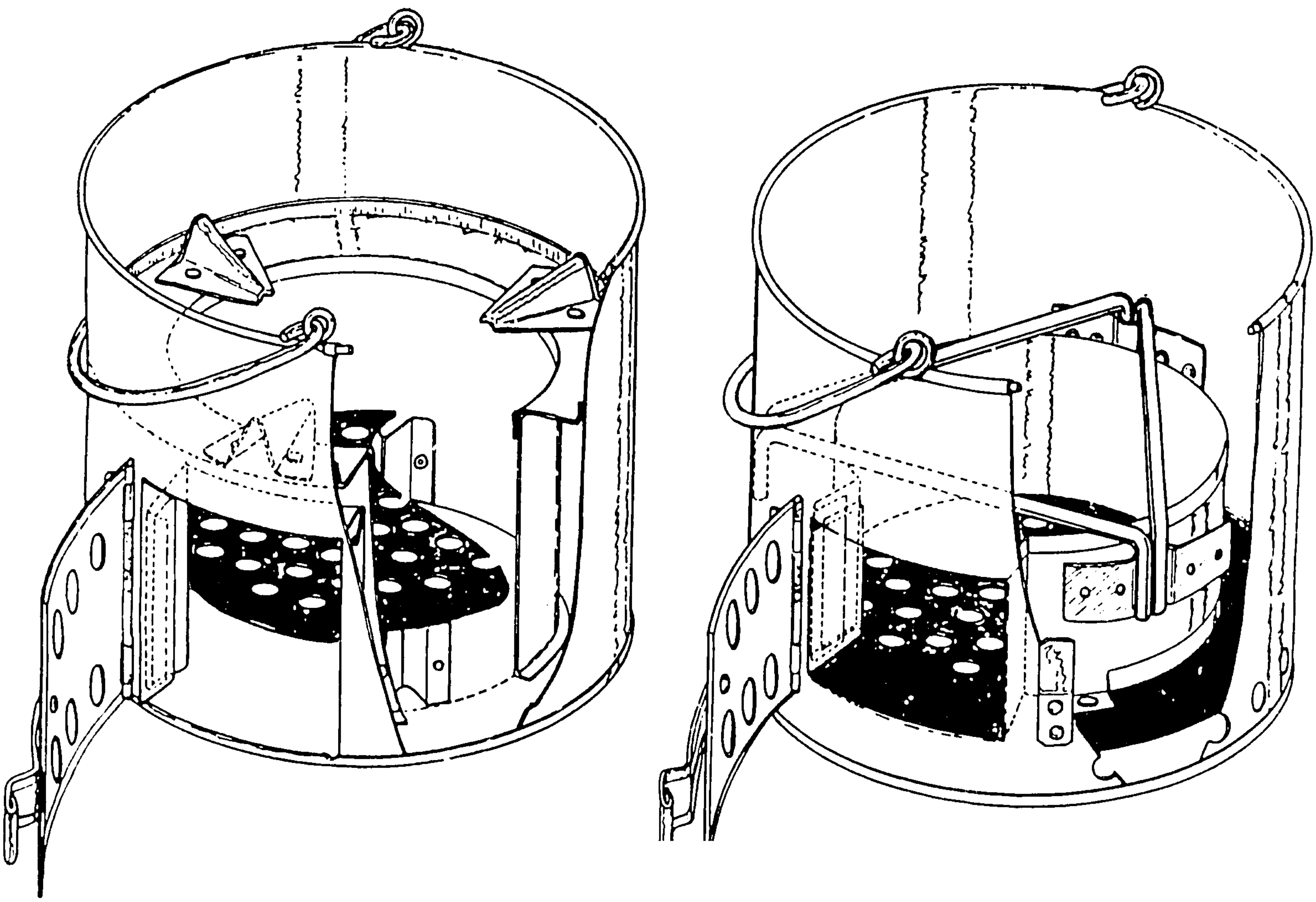
The BRET woodstoves are based on a similar concept to the UNICEF charcoal stoves. Both models of BRET stoves are all-metal, cylindrical bucket type stoves. Model "B" has a double wall like (Figure 10). A small field test of the BRET stoves found an average fuel savings of 22% compared to an open fire (Ashworth 1984). These stoves have shown some potential in an AID project in Botswana, but have not been disseminated in Kenya.

GTZ and Maendeleo ya Wanawake have done work on 3 different kinds of woodstoves; only the third type is portable. Approximately 50 of each of these stoves have been built and provided to households for free. This program has had an annual budget of about K.S. 528,000.

GTZ's type A stove is basically a massive, enclosed three-stone fire with one cooking port (Figure 11). It is made of dried sand and clay and is constructed around a single pot size leaving 1 cm between the stove walls and pot. Three clay inserts form the pot support. Smaller pots can be used but the efficiency of heat transfer is reduced. Three bricks are placed over the firedoor. It may or may not have a thick insulating layer of cement/vermiculite on the inside of the firebox. Without insula-

Figure 10

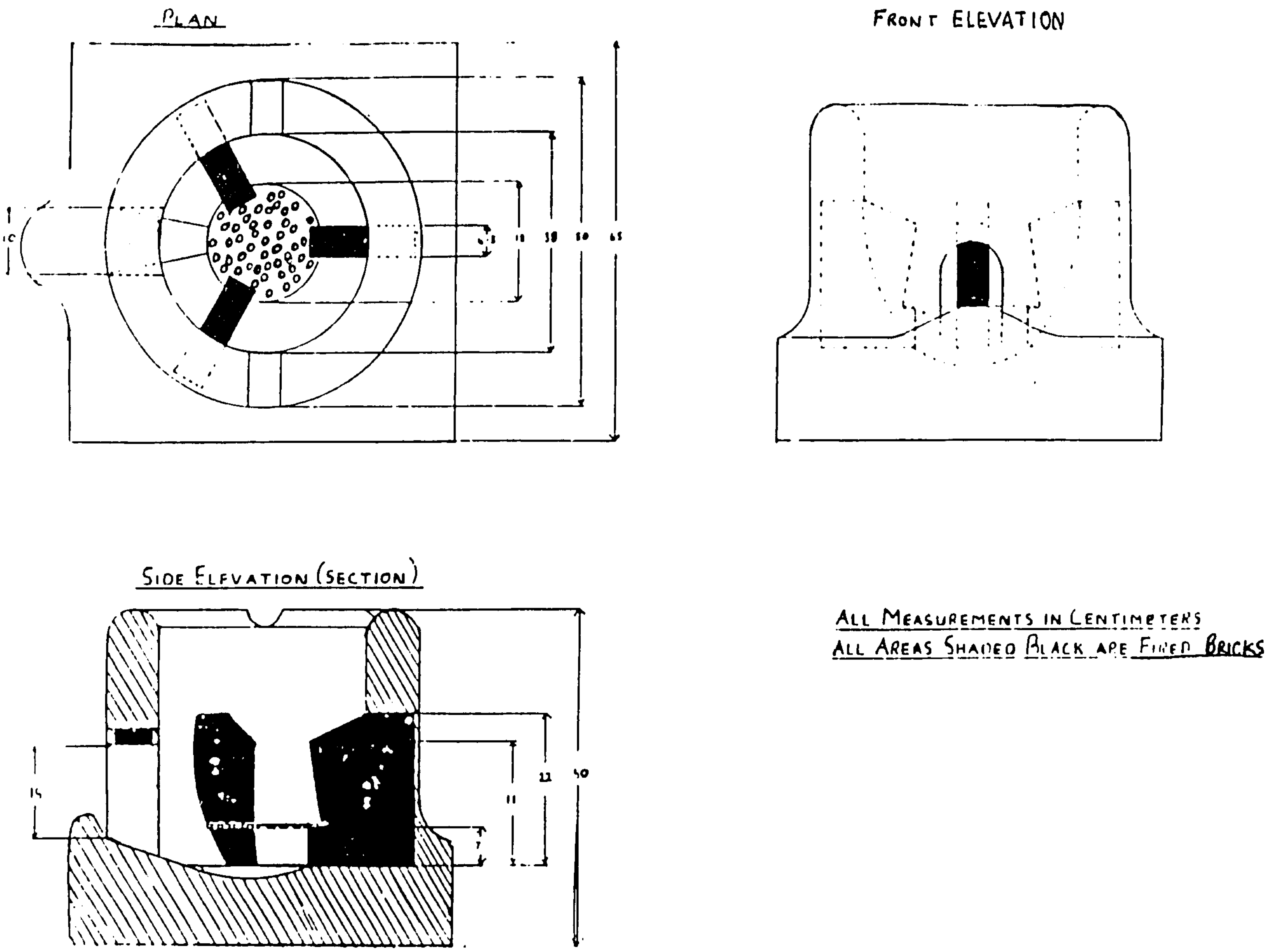
The BRET Stove



Source: Brunet and Ashworth 1984.

Figure 11

The GTZ Type A Stove




Source: Krosigk 1985b.

tion, the performance of the stove is poorer at low power. The type A stove has no grate and can burn wood or agricultural residuals. Materials for this stove cost K.S. 30 and labor is considered "free" because households are expected to build their own stoves.

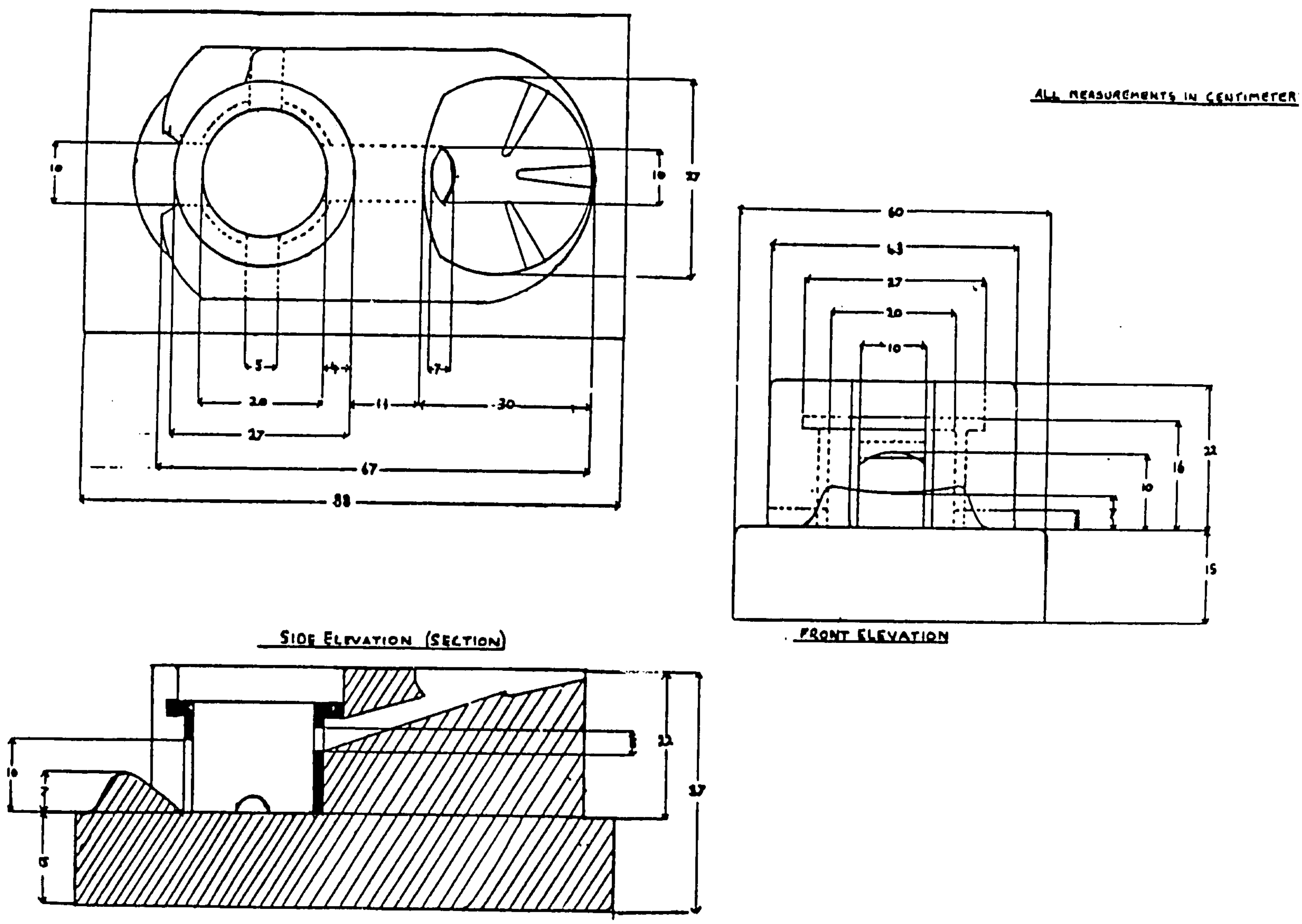
When new, the type A stove has a $PHU_2$ of 34% if insulated and 26 to 29% if uninsulated. It takes 47% longer to boil 2.0 l of water in this stove compared to a three-stone stove. A controlled cooking test showed a fuel savings of 24 to 46% when this stove was used instead of an unshielded open fire. The type A stove is also more difficult to light and extinguish than an open fire (Krosigk 1985b). It is not portable.

GTZ's type B stove consists of sand and clay plastered around a fired, ceramic insert with two cooking ports (Figure 12). This stove has a brim for keeping the pot still during stirring. The first port is intended for foods that require long cooking times; the second port only can be used for simmering. If the second port is covered and wet wood is used, this stove produces a lot of smoke and the fire does not burn well. This stove also is user-built and the materials for it cost K.S. 30.

With the type B stove, it takes 96% longer to boil 2.0 l of water than with an open fire (Ibid.). This stove may increase the kitchen temperature by 1-2°C compared to 4-5°C for a 3-stone stove (Krosigk 1985a). When the type B stove is built with a chimney, the draft is adversely affected if the second port is left uncovered. Using both ports, the $PHU_2$ of a new type B stove is 26 to 28% without a chimney and 28-30% with a chimney. Without a chimney and using the second port to preheat water, the

Figure 12

The GTZ Type B Stove




Source: Krosigk 1985b.

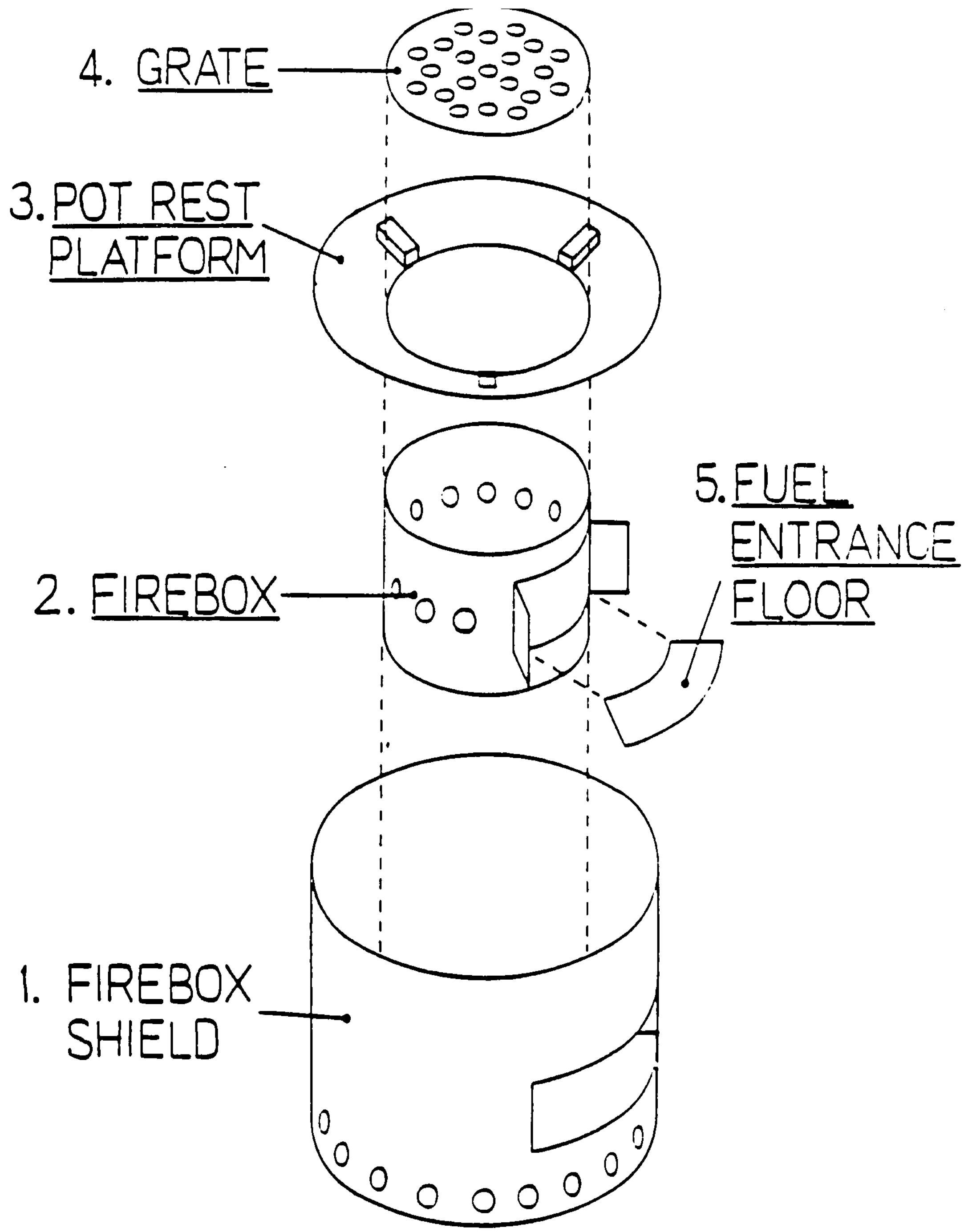
wood savings in a controlled cooking test was 23 to 51% compared to an open fire (Krosigk 1985b). Accuracy in the dimensions of this stove is critical and this is a problem for a user-built stove like this one unless a complete set of templates and molds is loaned to each household interested in building one.

The third type of stove supported by GTZ in Kenya is an all-metal, portable stove designed by ITDG. About 2,000 of these stoves have been disseminated in Gambia. The pot sits inside this stove and only certain-sized pots can be used (Figure 13). This stove has a $PHU_2$ of 26 to 28%, but it takes [illegible]% longer to boil water (ITDG 1984, 1985; Krosigk 1985b). Woodchips and briquetted crop residuals also can be burned in this stove. One problem with this stove is that the metal gets very hot so the stove poses a burn danger to children unless installed in an elevated position out of their reach. However, the stove is quite stable even during vigorous stirring of foods and it greatly reduces smoke emissions. GTZ has commissioned one informal sector metal artisan in Shauri Moyo to build the Gambian stove at a wholesale price of K.S. 70 (Krosigk 1985c). The estimated production costs for this stove in mid-1981 were K.S. 41, excluding overhead and profit (Burne 1985c). The artisan has these stoves on display and will sell them to individuals, but no individuals have ordered any to date.

Maendeleo ya Wanawake has hired 2 trainers in each of 5 districts (Lamu, Meru, Kiambu, Murang'a, and Kisii) to teach women's groups how to build the first two types of stoves and to use the third type. This field testing began in 1983 and was completed in 1985. In the next phase, Maendeleo ya Wanawake

Figure 13

The Gambian Stove




Source: ITDG 1984.

hopes to distribute 5,000 stoves of types A and B.

The Kuni Mbili stove is the wood-burning equivalent of the bell-bottom charcoal stove and can be built by the same artisans (Figure 14). "Kuni Mbili" means two sticks of firewood. The Kuni Mbili consists of a ceramic liner fixed inside a traditional, metal charcoal stove casing with cement/vermiculite insulation. This stove is portable and users do not have to do a lot of extra wood chopping because large pieces of wood may be left sticking out of the firebox. After this stove has been lit, only small pieces of wood need to be added due to the high firebox temperature. Anoth[illegible] ossible benefit of this stove is a reduction of smoke due to higher combustion temperatures.

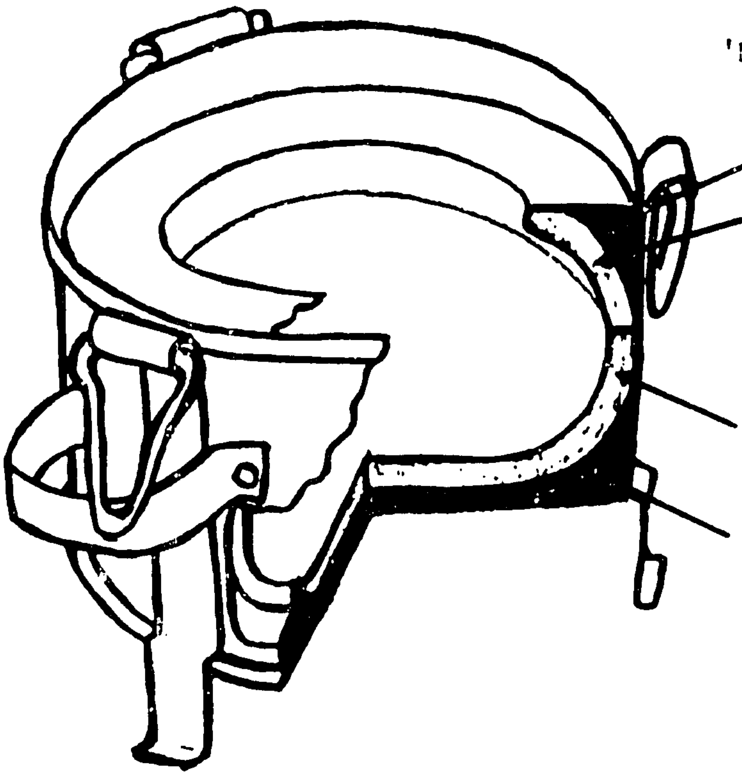
The early Kuni Mbili was optimized more for simmering than for high power. With the assistance of Stephen Joseph, this stove has undergone further design work to improve its energy efficiency. For example, more grate holes were added, the ash box was made larger, and the top opening was widened. A pot shield could decrease this stove's fuel consumption further, but it would require use of only certain sizes of pots.

The Kuni Mbili could be produced by the same informal sector artisans that make bell-bottom charcoal stoves. This strategy requires training of far fewer people and is likely to result in better-quality stoves than the user-built approach. Yet, it remains to be seen whether an effective demand for any improved woodstove now exists in Kenya. The estimated production cost for the Kuni Mbili is K.S. 50, excluding overhead and profit. Its ex-factory price would probably be around K.S.70 (Burne 1985c).

CARE-Kenya subsidized the production of the early version of

Figure 14

The Kuni Mbili Stove




Source: Prepared by Hugh Allen 1985.

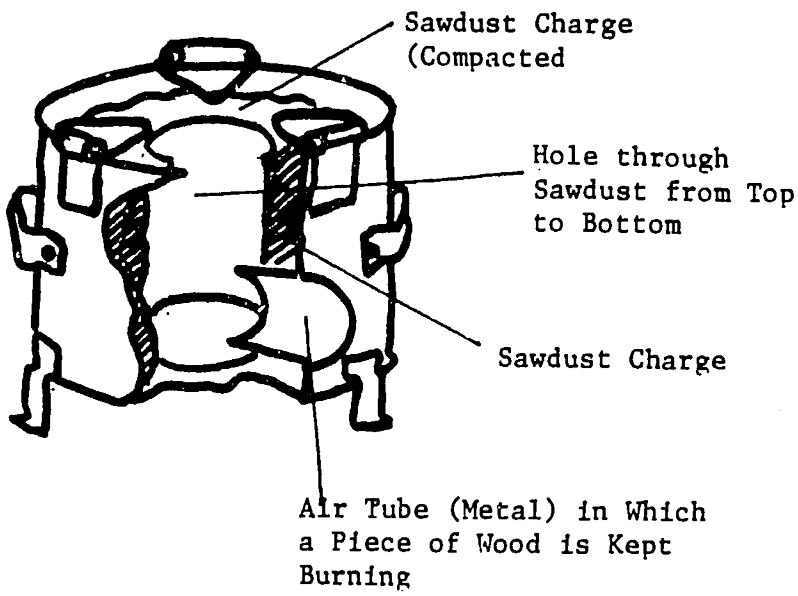
the Kuni Mbili at Siaya in western Kenya, but did not distribute its inventory of those stoves because substantial design modifications were made to increase its fuel efficiency. Contingent on satisfactory controlled cooking tests done on an improved Kuni Mbili, ATI will provide K.S. 140,000 for a field test of 200 of the new version of this stove in 1985 in rural locations within 50 miles of Nairobi.

Informal sector artisans are producing a sawdust stove on a commercial basis (Figure 15). This all-metal stove has an ex-factory retail price is K.S. 40-60, depending on the size. Sawdust is densely packed into the stove. Next, a stick of wood is inserted and then removed to leave an opening. The stove is then ready to be lit with a piece of newspaper (in some cases, soaked with kerosene) and a match. Too much kerosene-soaked paper can choke the airway in the stove. Most households dislike using sawdust because it is difficult to light and keep burning and because it produces a lot of sparks and flying ashes. To pack sawdust, it must be partially damp and, as a result, it does not burn well. Users often have to keep feeding in thin sticks of firewood to maintain a sawdust fire. Once the sawdust has burned half-way through, the stove's performance is better because the fuel is hotter and the effective firebox area is larger.

Sawdust has limited availability, but households in some areas can obtain it for free or at low cost from local wood product factories or carpentry shops. Major forest product industries that yield sawdust as a byproduct are located in Kiambu, Nakuru, Nairobi, Ruiru, and Thika. In some places, timber dealers pay truck drivers to dispose of sawdust and sawdust sellers

Figure 15

The Sawdust Stove




Source: Prepared by Hugh Allen 1985.

pay the truck drivers to dump it on their land.

Simple, unfired, clay pot shields for an open fire could improve the efficiency by keeping out wind. They would cost only K.S. 5-10. Ceramic wind baffles are more durable and would still be much cheaper than special woodstoves. Pot shields and baffles can be compatible with existing cooking practices. A simple, portable, all-ceramic woodstove might be preferred by households who want to cook indoors.

Because of the energy loss in converting wood to charcoal, a household that cooks with charcoal has a larger effect on the total amount of wood cut than does a household that cooks with wood. As a result, the dissemination of a certain number of improved charcoal stoves to existing charcoal users would save much more wood than dissemination of the same number of improved woodstoves to wood users. If 40% of rural fuelwood users and 20% of urban fuelwood users adopt improved woodstoves and if these stoves can save one-third of the amount of wood used by traditional stoves, 3.7 million tonnes of wood could be saved annually by the year 2000 (O'Keefe, Raskin, and Bernow 1984).

**Improved Institutional Stoves**

Market prospects for improved woodstoves may be better for institutional and commercial users than for households. At present, most institutional fuelwood users cook food and boil water for tea and other purposes on open fires or simple brick stoves. Since schools, hospitals, restaurants, hotels, and food-processing enterprises generally buy fuelwood rather than collecting it for free, they have a greater financial incentive to conserve wood than households, and institutions usually have the cash to buy an improved woodstove. It is also easier to target institutions than households because there are fewer of them.

Administrators of institutions have incentives for economizing on fuel costs (although hired cooks might not and this could lead to some conflicts if improved stoves are less convenient to use). Institutional stoves often operate all day-long. An institution serving cooked food and hot water to 300 people per day might consume 50 to 70 t of fuelwood per month using an open fire. Reliability of supply and cost of this fuelwood are often problems, and alternative fuels are much more expensive.

In 1984, Kenya had at least 11,996 primary schools with 4,323,000 students and 2,230 secondary schools with 490,000 students. Approximately one-quarter of the primary schools serve 1 cooked meal per day, and one-quarter of the secondary schools are boarding institutions that serve 2 or more cooked meals per day (Pryor 1985). These figures imply that more than 1.3 million hot meals are served in primary and secondary schools while they are in session. The fuel costs for cooking are passed along to students in their fees or meal costs.

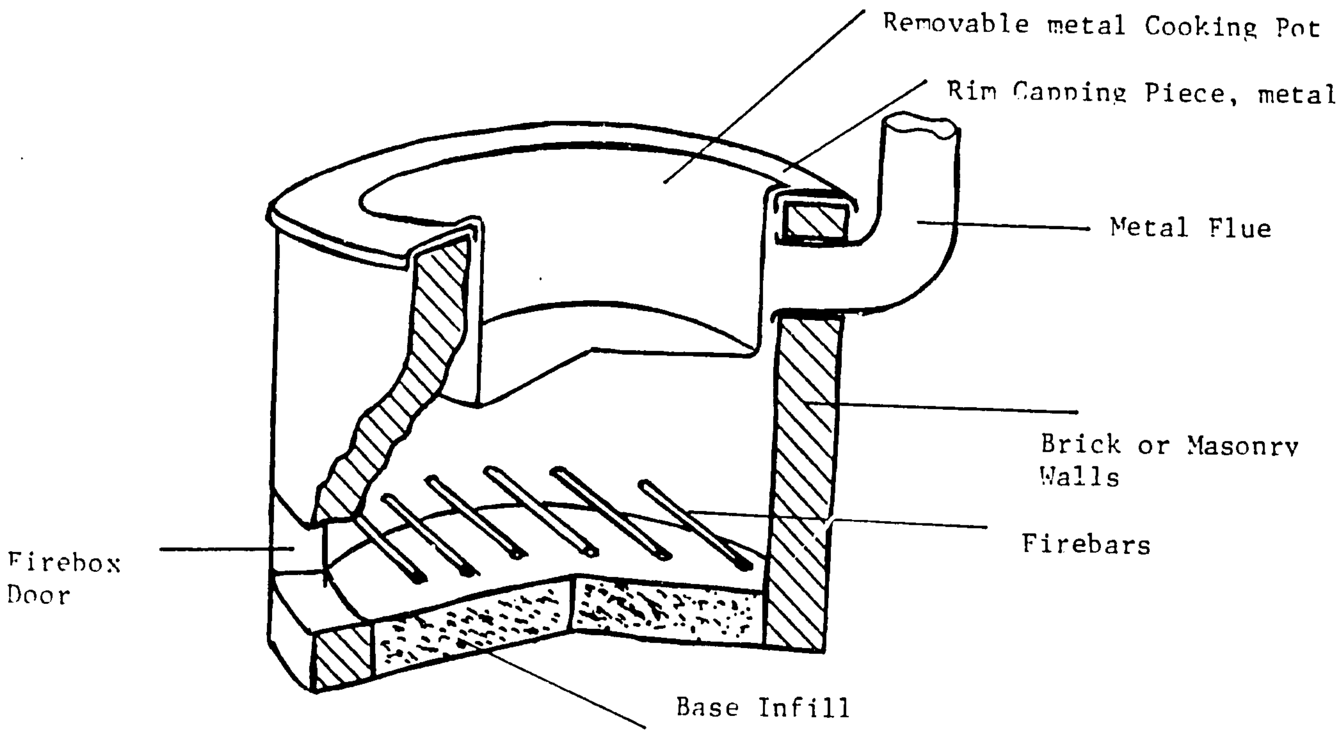
In 1980, schools and hospitals (categorized under "commercial users") consumed 1.6 million GJ of fuelwood and 0.4 million GJ of charcoal. Their consumption is projected to increase to 3.4 million GJ and 0.8 million GJ, respectively, in the year 2000 (O'Keefe, Raskin, and Bernow 1984). These estimates are based on a 112% increase in the number of people served by the schools and hospitals between 1980 and 2000, but may be too high because they do not allow for economies of scale in cooking. Restaurants and food (categorized under "informal urban industries") consumed 0.2 million GJ of wood and 0.4 million GJ of charcoal in 1980. Their comsumption is projected to increase to 0.8 million GJ of wood and 1.8 million GJ of charcoal in the year 2000 (Ibid.).

Emil Haas of the Bellerive Foundation has designed a promising institutional stove. This stove is built on-site and has a circular outer casing made of mud bricks or masonry. An optional galvanized iron cladding around the masonry may be added to improve the appearance although it has little effect on the efficiency. The stove has a firebar array at the bottom front and a flue at the top in the back. A metal pot sized to fit below a circular metal top plate sits inside the casing (Figure 16). This design forces heat to pass around the pot walls before leaving the stove through the flue, doubling the surface area of effective heat transfer. Heat losses from radiation and convection are relatively low with this stove. However, the efficiency would be reduced if large pieces of wood are left sticking out of the open door of this stove. The stove can be custom-built around a certain size of pots, but most commonly, the stoves are designed to hold 50 l or 200 l pots (Allen 1985).

The production costs for the Bellerive institutional stove are K.S. 4,000-9,000 depending on the materials used and pot size. Most institutions would need 3 or 4 large stoves. Georges Protzen has taught contractors how to build this stove. Most of these stoves have been installed in institutions at cost or at a subsidized price. If these stoves were built by a commercially-viable contractor, the sales price probably would range from K.S. 6,000-13,000. There would be an additional cost for

Figure 16

The Bellerive Institutional Stove




Source: Prepared by Hugh Allen

new pots if the stove is not custom designed around the pots already owned by the institution (Pryor 1985).

**Increased Wood Production**

Increased wood production can take many forms: agroforestry, replanting of forests, periurban plantations, managed nearby forests, managed remote forests, or industrial plantations. Unfortunately, the potential of increased wood production is limited for reasons of land competition and cost.

Some of the charcoal used in Kenya comes from natural forest stands managed by the Forest Department, but hardly any is from other managed stands or plantations (Ng'ang'a 1983). Most of the woodfuels are taken from high-potential agricultural land and fringe areas. The pressure to farm these lands will increase due to population growth. Even with a 50% increase in the productivity of farmland, the cultivated area would have to rise from 2.3 million ha in 1980 to 3.66 million ha in the year 2000 to reach food self-sufficiency in Kenya. Also, rangelands constitute 87% of the land area in Kenya and these lands yield much lower amounts of wood per unit of capital and labor invested than agricultural lands. In addition, the built environment in urban and rural areas is expected to jump from 405,000 ha in 1980 to 805,000 ha in the year 2000 (O'Keefe, Raskin, and Bernow 1984). Thus, the available lands for forestry are likely to be of marginal quality or located in remote areas. Furthermore, two-thirds of the total land area is arid or very arid with an annual rainfall of less than 500 millimeters. Although tree nursery techniques for arid lands exist, they are not widely known in

Kenya (Burley 1982).

Intensive management of natural forests or the establishment and maintenance of plantations requires sizable investments of capital and labor. As a result, charcoal makers probably would have to pay a higher price for wood, and consumer prices for charcoal would increase in turn. Goals for increased wood production assume that forestry operations will be sufficiently profitable to provide the necessary incentives to producers. This assumption is tenuous when much of the wood burned as fuel is collected for free by rural users. Charcoal users already are accustomed to paying cash for cooking fuels, but many wood users cannot afford to buy their cooking fuels. Studies in a number of countries show the difficulty of encouraging small farmers to grow fuelwood (Noronha 1981; Hyman 1983b and 1984; Spears 1984).

The Beijer Institute estimated the potential land allocation and yields for increased wood production in the year 2000, and set goals for a hypothetical policy case (Table 14). Table 15 disaggregates these goals by province which is important because the availability of land for increased wood production is not uniform, and also because per hectare yields, production costs, and transportation costs to markets vary with location. If these policy case goals can be met, 18.1 million t of wood could be produced per year. This amount is 50% higher than the amount of wood that could be saved through improved jikos. Increased wood production projects and improved jiko projects can be implemented at the same time. In fact, since improved jikos can show immediate results, stove projects may help bridge the gap during the long maturation period for wood production projects. Neverthe-

Table 14

Maximum Potential for Increased Wood Production in the Year 2000 and Goals for a Hypothetical Policy Case

| | Potential Area (1,000 ha) | Potential Total Yield (million tonnes/year) | Area Assumed in Policy Case (1,000 ha) | Yield Assumed in Policy Case (million tonnes/year) |
|---|---|---|---|---|
| Agroforestry | 1,500 | 11.1 | 871 | 7.1 |
| Replanted high potential forest | 400 | 8.6 | 281 | 5.0 |
| Peri-urban plantations | 200 | 4.2 | 165 | 3.7 |
| Managed nearby forests | 300 | 1.8 | 260 | 0.8 |
| Managed remote forests | 200 | 1.2 | 180 | 0.9 |
| Industrial plantations | 15 | 1.1 | 39 | 0.6 |
| **TOTAL** | **2,650** | **28.0** | **1,796** | **18.1** |

Source: O'Keefe, Raskin, and Bernow 1984.

Table 15

Location of Increased Wood Production Goals by Province Under a Hypothetical Policy Case for the Year 2000 (1,000 ha)

| | **Agroforestry** | **Replanted Forest** | **Peri-urban Plantations** | **Managed Nearby Forest** | **Managed Remote Forest** | **Industrial Plantations** |
|---|---|---|---|---|---|---|
| Central/Nairobi | 101 | 100 | 105 | 70 | 5 | 15 |
| Coast | 65 | 15 | 5 | 15 | 5 | - |
| Eastern | 95 | 15 | 10 | 15 | 5 | 4 |
| Northeastern | - | - | 5 | - | - | - |
| Nyanza | 250 | 1 | 15 | - | - | - |
| Rift Valley | 210 | 130 | 15 | 128 | 165 | 15 |
| Western | 150 | 20 | 10 | 32 | - | 5 |
| **TOTAL** | **871** | **281** | **165** | **260** | **180** | **39** |

Source: O'Keefe, Raskin, and Bernow 1984.

less, in addition to increases in stumpage price, government policies relating to land tenure, the harvesting of forest products on public and private lands, and taxation may need to be changed before smallholder fuelwood production projects can be successful.

## Replication Potential

The Kenyan experience with the dissemination of improved charcoal stoves has considerable applicability for the replication of similar projects elsewhere. As a direct result of the KREDP, some activities have spread autonomously to neighboring Tanzania. In early 1984, a medium-scale pottery firm in Arusha (Sheriff Dewji), manufactured 350 bell-bottom stoves after seeing an example brought to Tanzania by a GTZ employee. However, the Dewji stoves were of poor quality. They had liners made of an unsuitable clay mix that did not contain cow dung or sufficient sand and hence were prone to cracking after less than a month's use. In addition, they lacked cement/vermiculite insulation. Furthermore, the stoves were heavy (8 kg) because the liners spanned the entire height of the stove, rather than just the upper half. This stove also used a metal grate separate from the liner. A metal grate is likely to burn out quickly, but can be replaced easily. Dewji eventually decided that production of these stoves was best left to the informal sector and then showed a small-scale artisan how to construct them.

Several of the key people involved in the dissemination of liner stoves in Kenya are providing assistance to AID-assisted programs in other countries such as the Sudan, Somalia, and

Rwanda although different designs are being promoted in accordance with local preferences and materials. The U.N. High Commission on Refugees is ordering from Kenya over 60,000 bell-bottom stoves for refugees in Sudan and more orders are likely. If gradually done, this order could increase the commercial viability of Kenya jiko production units and could have positive demonstration effects in Kenya. It is also possible that sudden, temporary large orders could lead to a "boom and bust" situation that eventually bankrupts many producers. UNICEF has disseminated 2,000 Umeme stoves in Rwanda in a year and a half. As of early 1985, GTZ-Tanzania had disseminated over 600 Umeme stoves in Dodoma, and, more recently, over 150 in Arusha (Roeske 1985; Schneiders and Mkallatta 1985). The limiting factor has been availability of metal drums to build these stoves. Sudan's Department of Community Development has also introduced a modified Umeme stove. The Haraka stove is being produced in Somalia and Zambia.

The replication potential for improved charcoal stoves is large because charcoal use is widespread in urban households and traditional stoves are relatively inefficient in many African countries. Furthermore, the resources needed to carry out an improved charcoal stoves program are relatively modest provided that indigenous metal working and pottery industries exist.

## Lessons From This Experience

Some broader lessons about the factors affecting the design, adoption, and use of appropriate technologies in general can be gleaned from the Kenyan jikos experience. These lessons concern the relationship between technology choice and delivery systems as they interact with social, economic, institutional, and policy factors.

In this case, the choice of the technology was not based solely on laboratory experiments or engineering principles. Instead, the design work accepted the traditional (established) technology as a starting point which helped ensure widespread acceptance by households. Like the traditional stove, the improved stove is easily portable. Users were not expected to make any major changes in the way they used the stove. A totally different design would have been unfamiliar to the users and there would have been a greater likelihood that it would not have met their perceived needs. Yet, the fact that there was a readily-observable difference between the traditional and improved stoves (e.g. the new bell-bottom shape) was important so that consumers can recognize the difference between the improved and traditional technologies easily. Since "the best can be the enemy of the good", emphasis was placed on getting a satisfactory design into production rather than concentrating efforts on modifying designs to optimize all factors.

In fact, the traditional technology itself had been introduced from another LDC earlier. From this base, improvements in the technology were made after examining the experience in other LDCs. The sharing of experience across countries can reduce time-consuming and expensive duplication of efforts in designing technologies as long as it is recognized that the appropriateness of a technology will vary with local conditions. In some cases, developed countries may be using technologies that are appropriate and transferable, but frequently these technologies are too complex and expensive for LDCs, require materials and skills that are unavailable, or are socioculturally unacceptable. The appropriateness of a design may even vary within a country. It is often best to emphasize use of resources and skills that are readily available locally so that production and training costs can be kept down, bottlenecks in input supply can be minimized, and parts can be repaired or replaced easily.

The KREDP was timely because it built on the earlier activities of a large number of people, both locals and expatriates. The project also avoided the common pitfalls of inflexibly pushing a single design set in advance of implementation, or spending a lot of time and money trying to change people's cultural preferences for stoves. After laboratory tests narrowed the range of alternative technologies, field tests were conducted to obtain feedback from potential users. Following the field tests, further sorting out of the technologies was left to the natural selection process of consumer purchases.

Many stove projects elsewhere have not taken off because the private sector was not given a role in the design or implementation of the projects. The informal sector lacks the capacity for R & D or testing of a new technology, but has the ability to adapt rapidly to introduced designs if they are appropriate. Reliance on existing informal sector artisans avoids the expense of having to establish a whole new infrastructure and completely train inexperienced and less committed workers. Although artisans do not have incentives to train anyone other than their own apprentices, a moderate amount of project resources can substantially increase the specific skills of a significant number of experienced artisans. Since one-time, short-term training is often inadequate, follow-up sessions that include observation of the trainees' work are essential.

Decentralized training and other support can be provided to artisans effectively through nongovernmental organizations where these groups have the necessary knowledge, resources, and management ability. These prerequisites are most likely to be met if the activities of various NGOs are well-coordinated and there is a tradition of self-help in the project area.

The informal sector is capable of producing simple consumer goods in large numbers and at a relatively low cost. Furthermore, this can be done in a way that encourages the maintenance of a competitive and self-sustaining industry in the long run. Generally, informal sector artisans have a low overhead and can spread the risks of labor-intensive production of a new product across the large number of other products that they make. The induced expansion of small industries can be an important part of local economic development.

The experience in many woodstoves projects with user-built stoves (e.g. the Lorena) shows many problems with the quality control and durability of such stoves. The efficiency of user-built stoves as actually constructed can be inferior to open fires. In addition, administrative costs often are very high for user-built stove programs because a large number of people must be trained and they may have no experience in stove construction.

In contrast, the Kenyan experience demonstrates the advantages of artisan-built stoves. Nevertheless, maintaining quality control can be a problem with the decentralized approach of having many small-scale artisans producing of a new technology. Eventually, competition will drive low-quality producers out of the market or force them to improve their products. In the short-run, however, some consumers could become dissatisfied with the technology as a result of the inferior performance and poor durability of the imitations. To reduce this problem, consumers need to be educated about what to look for in a design and in the fabrication of the good. An educational program can include demonstrations at exhibitions, markets, churches, schools, and other community organizations; extension to households; radio and newspaper publicity campaigns; simple pamphlets that can be retained for future reference; and quality control stamps on the products.

Introducing a new technology to households is a gradual process that should begin with thorough field testing to obtain consumer feedback on design features. When a product serves an intermediate function such as increasing the efficiency of energy use, households are more likely to buy the product if the reduced energy consumption saves them money. As a rule of thumb, savings should be at least 20% for an innovation to have a potential for widespread adoption. Charcoal stoves are mostly used by households who pay cash for cooking fuels and can save more than 30% of their charcoal expenditures switching to improved stoves. By initially focusing on urban markets which are more geographically compact and contain a larger proportion of households that purchase fuels, distribution may be facilitated and the demonstration effects may spread faster.

An existing distribution system of small-scale merchants and larger shops often is convenient for informal sector artisans as well as consumers. Private sector distribution of charcoal stoves may be more cost-effective than government distribution of woodstoves through forest departments or agricultural extension services. Nevertheless, the small-scale, informal sector often needs some active support from public agencies, the media, and/or NGOs in promotion and demonstration of a new technology.

Government policies affecting the prices of wood and charcoal can contribute to deforestation and forest resource degradation and may have slowed the progress of this project. Although the price controls on charcoal are not well-enforced, they do have some effect on retail prices and hence reduce the incentives to conserve charcoal. If the purpose of price controls is to moderate the burden on consumers, the availability of an inexpensive improved stove that can produce a 25% fuel savings could allow a 25% increase in charcoal prices. Charcoal exportation currently is illegal in Kenya, but some charcoal has been exported to Somalia and the Middle East. Since exports bring higher prices than domestically-consumed charcoal and the law is difficult to enforce, some illicit exports of charcoal are likely to continue.

The Kenyan jikos experience shows that in some cases there is no need for extensive producer or consumer subsidies to disseminate a new technology once it has been developed, tested, and demonstrated. Producer subsidies include direct cash payments, provision of in-kind goods below cost, or special tax benefits.

Producer subsidies tend to lead to inefficient production by firms and if restricted to a few firms may stifle competition and further innovation. Providing financing at a commercial interest rate is not a subsidy, and may be important in stimulating production, especially in the initial stages. Consumer subsidies include price rebates, price controls, and special tax benefits. Where the benefits can be internalized by consumers and a technology is affordable, consumer subsidies are unnecessary. In fact, consumer subsidies might slow the project's replication in other locations if consumers defer purchasing the stoves while waiting for a subsidy program to be expanded. Price controls on the products of a new technology can interfere with production goals or can aggravate quality control problems. Thus, it may be best to leave price determinations to the market while encouraging further competition that eventually will reduce prices.

In conclusion, publicly financed research and product development is often necessary, but the findings must be linked to private sector production and marketed to satisfy consumer preferences. These activities need to be sustained over an initial gestation period. A wide variety of technologies and approaches may deserve support initially while leaving selection of the most appropriate ones to the marketplace.

## References


Allen, Hugh (Appropriate Technology International). 1985. Personal communication.

Anonymous. 1983. "Kengo Initiates Improved Jiko Project," Kengo News (August): 1.

Ashworth, John. 1984. Financial and Social Benefit/Cost Analysis of Renewable Energy Technologies in Botswana. Burlington, Vt.: Associates in Rural Development, Prepared for U.S. AID.

Baldwin, Sam. 1983. Technical Notes for the Senegalese Ban Ak Suuf (Improved Stove) Program. Arlington, Va.: VITA, December (draft).

Baldwin, Sam. 1984. "New Directions in Woodstove Development," VITA News (January): 3-13, 20-23.

Baldwin, Samuel. 1985. Engineering Heat Transfer, Rural Energy Technologies, and Development. Arlington, Va.: VITA.

Barnes, Caroline, C. Anthony Pryor, and Jim Seyler. 1984. Kenya Renewable Energy Development Project: (615-0205) REDSO Recommendations. Nairobi: U.S. AID.

Brokensha, David and Bernard Riley. 1978. "Forest, Fences and Fuel in a Marginal Area of Kenya," In Proceedings of USAID Africa Bureau Firewood Workshop. Washington, D.C.: U.S. AID.

Brunet, Eric and John Ashworth. 1984. BRET Metal Stove Production Guide for "B" and "Delta 3" Stoves. Burlington, Vt.: Associates in Rural Development, Prepared for U.S. AID.

Burley, Jeffrey. 1982. Obstacles to Tree Planting in Arid and Semi-arid Lands: Comparative Case Studies from India and Kenya. Tokyo: United Nations University.

Burne, Simon. 1985a. Charcoal Stove Developments in Kenya: The Present and the Future. Rugby, England: Intermediate Technology Development Group.

Burne, Simon (ITDG). 1985b. Personal communication.

Burne, Simon. 1985c. Seeing the Wood Through the Trees: Woodstoves in Kenya. Rugby, England: Intermediate Technology Development Group.

Butcher, S. et al. 1984. "Emission Factors and Efficiencies for Small-Scale Open Biomass Combustion: Toward Standard Measurement Techniques," Paper Presented at the American Chemical Society Annual Meeting. Philadelphia, Pa.

Central Bureau of Statistics. 1984. _Economic Survey, 1984_. Nairobi: Kenyan Ministry of Finance and Planning.

Ceselski, Elizabeth, Joy Dunkerley, and William Ramsay. 1979. _Household Energy and the Poor in the Third World_. Washington, D.C.: Resources for the Future, Research Paper No. R-15.

Chege, Gerald. 1985a. _Kitui Agroforestry/Energy Centre Cookstoves Section: Field Report_. Nairobi: E/DI.

Chege, Gerald (KENGO). 1985b. Personal communication.

Childers, Laurie. 1983a. _Establishment of Ceramic Jiko Liner Production, Ilesi Pottery, Kakamega, Kenya_. Nairobi: Energy/Development International.

Childers, Laurie. 1983b. _Training for Improved Stove Construction and Program Design_. Eugene, Oreg.: Approvecho Institute, Prepared for UNICEF.

Claassen, Frans (UNICEF). 1985. Personal communication.

"Country Energy Papers: Kenya," In _Proceedings of Workshop on Energy, Forestry and Environment_, vol. 3, Washington, D.C.: U.S. AID Africa Bureau.

Dewees, Peter. 1985. _Kenya Peri-urban Fuelwood Plantation Feasibility Study_, Nairobi: Institute for Development Studies, University of Nairobi.

Earl, Derek and A. Earl. 1975. _Charcoal Making For Small-Scale Enterprises: An Illustrated Training Manual_. Geneva: International Labour Office.

Ellis, Gene. 1983. "Peace Corps Stove Projects Evaluated," _Cookstove News_ 3, No. 4 (December): 8-10.

Energy/Development International. _Kenya Renewable Energy Development Project, Quarterly Progress Reports_. Nairobi: E/DI.

Evans, Ianto. 1984. "Kenya's Improved Jiko -- A Success Story with Commercial Charcoal Cookstoves," _Cookstove News_ 4, No. 1 (February): 4-9.

FAO/UNEP. 1981. _Forest Resources of Tropical Africa_. _Part III: Country Briefs_. Rome: FAO.

Foley, Gerald and Patricia Moss. 1983. _Improved Cooking Stoves in Developing Countries_. London: International Institute for Environment and Development.

Fowler, Alan et al. 1983. Report on the Woodstove Dissemination Activities of Four Grassroots Nongovernmental Development Organizations in Kenya. Nairobi: Consultants for Management of Development Programmes.

Gonza, Samuel. 1984. "Sawdust King Proves His Point," Development and Cooperation No. 5 (September/October): 33.

Gould, Helen and Stephen Joseph. 1978. Designing Stoves for Third World Countries. London: Intermediate Technology Development Group.

Hakkila, P. and M. Aijala. 1981. Fact-Finding Mission Report on Fuelwood/Charcoal Plantations in Kenya. Helsinki, Finland: Ministry of Foreign Affairs of Finland.

Hamilton, Lawrence and Peter King. 1983. Tropical Forested Watersheds: Hydrologic and Soils Response to Major Uses or Conversions. Boulder, Colo.: Westview Press.

Hassrick, Philip. 1982. "Umeme: A Charcoal Stove from Kenya," Appropriate Technology 9, No. 1 (June): 6-7.

Hassrick, Philip (UNICEF). 1985. Personal communication.

Hyman, Eric. 1983a. "Analysis of the Woodfuels Market: A Survey of Fuelwood Sellers and Charcoal Makers in the Province of Ilocos Makers in the Province of Ilocos Norte, Philippines," Biomass 3: 167-197.

Hyman, Eric. 1983b. "Loan Financing of Smallholder Treefarming in the Provinces of Ilocos Norte and Ilocos Sur, The Philippines," Agroforestry Systems 1: 225-243.

Hyman, Eric. 1984. "Providing Public Lands for Smallholder Agroforestry in the Province of Ilocos Norte, Philippines," 18: 177-190.

Intermediate Technology Development Group. 1984. Noflie II -- A Portable Wood/Briquette Stove. London: ITDG.

Intermediate Technology Development Group. 1985. Stoves. Rugby, England: ITDG.

International Development Research Center. 1983. Proceedings of the Regional Workshop on Wood Energy in East Africa. Ottawa: IDRC.

Joseph, Stephen. 1984. Advisory Visit to the Stoves Project of MOERD/KENGO, Kenya. London: ITDG.

Joseph, Stephen and Philip Hassrick. 1984. Burning Issues: Implementing Pilot Stove Programmes: A Guide for Eastern Africa. London: ITDG.

Joseph, Stephen; Beatrice Khamati; and Maxwell Kinyanjui. 1984. Kenyan Woodstoves: Standard For Boiling Water and Cooking Tests. London: ITDG.

Joseph, Stephen, Raphael Kapiyo, and Maxwell Kinyanjui. 1983. A Kenyan Standard for Charcoal Stove Performance. Nairobi: ITDG/Kenyatta University College.

Joseph, Stephen, Yvonne Shanahan, and Pete ng. 1982a. The Comparative Performance of Kenyan Ch Stoves. London: ITDG, Stoves Project Technical Paper N.

Kabagambe, D. 1976. The Role of the Charcoal ustry In The Kenyan Economy. Nairobi: Institute for Development Studies, University of Nairobi, Paper No. 271.

Kamweti, David. 1983. Review of Cookstoves and Charcoal Production in Kenya. Nairobi: African Development and Economic Consultants Ltd.

Kantai, Esther and Philip Koech. 1982. The Findings of the Feasibility Study on Types of Jikos Used and Charcoal Consumption Patterns in Kibera, Nairobi. Nairobi: Appropriate Technology Advisory Committee.

Karch, G. Edward and Michael Boutette. 1983. Charcoal: Small-Scale Production and Use. Eschborn: German Appropriate Technology Exchange.

Kash, Don et al. 1975. Energy Alternatives: A Comparative Analysis. Norman, Okla.: University of Oklahoma, Science and Public Policy Program, Prepared for U.S. Council on Environmental Quality et al.

KENGO. 1983. Planning Session on Woodfuel Conservation: Summary Report. Nairobi: Kenya Energy Nongovernmental Organizations Association.

KENGO. 1984. Report on the Field Test of the Kenyan Ceramic Jiko. Nairobi: Kenyan Energy Nongovernmental Organizations Association.

Kenyan Ministry of Economic Planning and Development. 1981. The Integrated Rural Surveys: 1976-1979. Nairobi: Government of Kenya.

Kernan, Henry, Peter Little, and Ianto Evans. 1984. Kenya Renewable Energy Evaluation. Binghamton, N.Y.: Institute for Development Anthropology, Prepared for U.S. AID.

Khamati, Beatrice (KENGO). 1985. Personal communication.

Kimani, Muiruri. 1985. "Consumer's Guide to the Kenyan Ceramic Jiko," KENGO News 1, No. 3 (April): 18-19.

Kinyanjui, Maxwell. 1982. _The Thai Claystove Industry_. Nairobi: Energy/Development International, Prepared for Ministry of Energy and Regional Development.

Kinyanjui, Maxwell. 1984. _The Kenya Charcoal Stoves Program: Interim Report_. Nairobi: Energy/Development International.

Kinyanjui, Maxwell (KENGO). 1985. Personal communication.

Kinyanjui, Maxwell and Laurie Childers. 1983. _How to Make the Kenyan Ceramic Jiko_. Nairobi: Energy/Development International.

Kinyanjui, Maxwell and Arsen Mbonye. 1982. _Informal Survey of Cook-stove Industry: A Case Study of Shauri Moyo, Nairobi_. Nairobi: Energy/Development International.

Kinyanjui, Maxwell and Susan Minae. 1982. _Extension/Training Programs in Renewable Energy Technologies: An Implementation Strategy_. Nairobi: Energy/Development International.

Kionga-Kamau, Stephen. 1983. "Charcoal Production in Kenya," In IDRC 1983.

Krosigk, Hilda. 1985a. _Evaluation of Field Tests in Kisii and Lamu District_. Nairobi: GTZ/Maendeleo ya Wanawake, Technical Report 3.

Krosigk, Hilda. 1985b. _Evaluation of Laboratory Tests on Four Permanent and Two Portable Cookstoves_. Nairobi: GTZ/Maendeleo ya Wanawake, Technical Report 2.

Krosigk, Hilda (GTZ). 1985. Personal communication.

Lippert, John. 1983. _Cooking with Kerosene: Calorific Content, Types of Kerosene Cookers in Common Use in LDCs, Combustion Processes and Testing Procedures_. Arlington, Va.: VITA.

Manibog, Fernando. 1982. _An Interim Assessment of Improved Woodstoves Components of Improved Woodstoves Components in Bank Fuelwood/Forestry and Rural Development Projects_. Washington, D.C.: World Bank.

Manibog, Fernando. 1984. "Improved Cooking Stoves in Developing Countries: Problems and Opportunities," _Annual Review of Energy_ 9: 199-227.

Maingi, D. (Kenyan Forestry Department). 1985. Personal communication.

Marwick, Stuart (Woodburning Stove Group, Eindhoven). 1985. Personal Communication.

Mbeche, Oyuko. 1980. "Energy Use in Kenya," Paper Presented at the Workshop on Energy Assessment Methodologies. Washington, D.C.: U.S. National Academy of Sciences.

McGranahan, G., S. Chubb, R. Nathans, and O. Mbeche. 1979. Patterns of Urban Household Energy Use in Developing Countries: The Case of Nairobi. Stony Brook, N.Y.: State University of New York, Institute for Energy Research.

Medrano, E. 1976. "Design Fabrication, and Operation of Drum Kilns for Charcoaling Coconut Shells," Natural Science Development Board Technology Journal 1: 26-35.

Micuta, Waclaw. 1985. Modern Stoves for All. London: ITDG.

Newman, David (Kenyatta University College). 1985. Personal communication.

Ng'ang'a, F. 1983. "Appropriate Technology for Wood Charcoal Productionin Kenya," In IDRC 1983.

Noronha, Raymond. 1981. "Why Is It So Difficult to Grow Fuelwood?" Unasylva 33, No. 131: 4-12.

O'Keefe, Phil, Paul Raskin, and Steve Bernow. 1984. Energy and Development in Kenya: Opportunities and Constraints. Stockholm: Beijer Institute for Energy and Human Ecology.

O'Keefe, Philip. 1982. "Case Study: Kenya," In Proceedings of Workshop on Energy, Forestry, and Environment, vol. 2. Washington, D.C.: U.S. AID Africa Bureau.

O'Keefe, Philip, Dan Weiner, and Ben Wisner. 1981. "A Cautionary Story of Forestry Planning in Kenya," In Proceedings of a Seminar on Agroforestry, edited by L. Buck. Nairobi: ICRAF.

Ongai, Francis (Miaki Jikos). 1985. Personal communication.

Openshaw, Keith. 1979. A Comparison of Metal and Clay Charcoal Cooking Stoves. Morogoro, Tanzania: University of Dar-es-Salaam, Division of Forestry.

Openshaw, Keith. 1980. Rural Energy Consumption with Particular Reference to the Machakos District of Kenya. Morogoro, Tanzania: University of Dar-es-Salaam, Division of Forestry.

Openshaw, Keith. 1982a. "Charcoal Stoves, Charcoal Conversion and Biomass," In Proceedings of a Workshop on Energy Forestry and Environment, vol. 2. Washington, D.C.: U.S. AID Africa Bureau.

Openshaw, Keith. 1982b. Costs and Benefits of Proposed Tree Planting Programme for Satisfying Kenya's Wood Energy Requirements. Nairobi: Beijer Institute for Energy and Human Ecology.

Openshaw, Keith. 1982c. Inventory of Biomass in Kenya: A Conditionally Renewable Energy. Nairobi: Beijer Institute for Energy and Human Ecology.

Openshaw, Keith (Energy Initiative for Africa). 1985. Personal Communication.

Opole, Monica. 1983. Informal Survey of Production and Sales of Improved Stoves in Kenya. Nairobi: University of Nairobi, Prepared for E/DI.

Opole, Monica. 1985. Review of Programme Cookstove Field Activities. Nairobi: University of Nairobi, Prepared for E/DI.

Ouedraogo, Issoufou, Georges Yameogo, and Sam Baldwin. 1983. Lab Tests of Fired Clay and Metal One-Pot Chimneyless Stoves, Arlington, Va.: VITA.

Prasad, Krishna. 1980. Some Performance Tests on Open Fires and the Family Cooker. Eindhoven, The Netherlands: T.H.E. Eindhoven.

Pryor, C. Anthony. 1985. Institutional Stoves--Project Feasibility Assessment. Nairobi: U.S. AID.

Ramsay, William. 1985. Bioenergy and Economic Development: Planning for Biomass Energy Programs in the Third World, Boulder, Colo.: Westview Press.

Roeske, Karin (GTZ: Arusha, Tanzania). 1985. Personal communication.

Sambali, J. and Heinz Schneiders. 1984. Projects on the Development and Production of Improved Charcoal Stoves in Tanzania -- A Survey and Laboratory Test Results. Dodoma, Tanzania: GTZ Dodoma Rural Energy Project.

Schneiders, Heinz (GTZ: Dodoma, Tanzania). 1985b. Personal communication.

Schneiders, Heinz and K. Mkallatta. 1985a. The Dodoma Stove After Eighteen Months -- Results of the Long-Term Investigation Into the Utilization and Savings of an Improved Charcoal Stove. Dodoma Rural Energy Project.

Schneiders, Heinz. 1984. "Jiko la Dodoma -- The UTAFITI Field Test of An Improved Charcoal Stove," GATE No. 2: 13-19.

Shakow, Don, Cara Seiderman, and Philip O'Keefe. 1982. "Kenya's Lesson in Conservation," Soft Energy Notes (January/ February): 173-174.

Shirey, Eric. 1984a. "Kenyan Jiko Construction Guide," Cookstove News 4, No. 2: 20-21.

Smith, Kirk (East-West Center, Resource Systems Institute). 1985. Personal communication.

Smith, Kirk. 1984. "Air Pollutant Emissions, Concentrations, and Exposures from Biomass Combustion: The Cigarette Analogy," Paper Presented at the American Chemical Society Annual Meeting. Philadelphia, Pa.

Smith, Kirk, Michael Apte, and Madan Shrestha. 1984. "Carbon Monoxide and Particulates from Cooking Stoves: Results from a Simulated Village Kitchen," Paper Presented at the Third International Conference on Indoor Air Quality and Climate. Stockholm, Sweden.

Spears, John. 1983. Tropical Reforestation: An Achievable Goal?" Washington, D.C.: World Bank.

Stewart, Bill. 1984. Preliminary Testing of a Cast Iron Stove From the Rajamanthri Iron Works, Andra Pradesh, India. Reading: ITDG.

Tillman, David. 1978. Wood as an Energy Resource. New York: Academic Press.

UNICEF Technology Support Section. n.d. a. The HARAKA Charcoal Stove. Nairobi: UNICEF.

UNICEF Technology Support Section. n.d. b. The RAFIKI Wood Stove. Nairobi: UNICEF.

UNICEF Technology Support Section. n.d. c. The UMEME Jiko. Nairobi: UNICEF.

U.S. Federal Energy Administration. 1977. Energy Interrelationships. Springfield, Va.: National Technical Information Service, Report PB-269 034.

Vollers, Maryanne. 1984. People and Technology: A Kenyan Experiment in Community Participation. Nairobi: UNICEF.

Volunteers in Technical Assistance. 1982. Testing the Efficiency of Wood-Burning Stoves: Provisional International Standards. Mt. Rainer, Md.: VITA.

Western, D. and J. Ssemakula. 1980. "The Present and Future Patterns of Consumption and Production of Wood Energy in Kenya," In Energy and Environment in East Africa: Proceedings of an International Workshop. Nairobi: UNEP.

Wood, Timothy. 1982. "Improved Woodstoves in the Sahel: A Critical Assessment," In Proceedings of Workshop on Energy Forestry and Environment, vol. 2. Washington, D.C.: U.S. AID Africa Bureau.

Yameogo, Georges, Paul Bussman, Philippe Simonis, and Sam Baldwin. 1983. Comparison of Improved Stoves: Lab Controlled Cooking and Family Compound Tests. Arlington, Va.: VITA.

Young, Peter. 1983. Stoves Project: Report of a Visit to Kenya, 14th June-14th July 1983. Reading Intermediate Technology Development Group.

Young, Peter (ITDG). 1985. Personal communication.

## Acknowledgements

### List of People/Places Contacted (in chronological order):

Sam Baldwin - Princeton University
Gene Ellis - University of Denver
Sandy Hale - Energy/Development International (E/DI)
Maxwell Kinyanjui - KENGO
Achoka Aworry - KENGO
Beatrice Khamati - KENGO
Peter Young - ITDG
Yvonne Shanahan - ITDG
Simon Burne - ITDG
Amare Getahun - E/DI
Bill Macklin - E/DI
Cyrus Ndegwa - MOE
G.N. Gathaara - MOE
Francis Njoroge - MOE
Gerald Chege - KENGO (formerly, E/DI)
Tony Pryor - AID REDSO
Mike Bess - AID Energy Initiatives for Africa
Keith Openshaw - AID Energy Initiatives for Africa
Monica Opole - University of Nairobi
Waclaw Micuta - Bellerive Foundation
Peter Dewees - University of Nairobi, Institute of Development Studies
Richard Greene - AID
Diana Rocheleau - ICRAF
Francis Ongai - Riruta Workshop
Njuguna Mwangi - Treasury
Dr. Chakrabati - Treasury
Berry Van Gelder - Beijer Institute
Charles Gitundu - CARE
Mr. Ayieko - CARE
Remko Vonk - CARE
Julius Pollo - CARE
Charles Musa - Ilesi Workshop
Laurie Childers - UNICEF
John Selker - UNICEF
Nyalenda Workshop - KENGO
Kibuye informal informal sector artisans - Kisumu
Sega Village Polytechnic
Siaya Workshop - CARE-Kenya
Mike Jones - E/DI
D.R. Maingi - Forest Department
David Newman - Kenyatta University College
Ianto Evans - Aprovecho
Kibera Workshop - ATAC
Shauri Moyo informal sector artisans - Nairobi
Rafael Omundi - Clayworks, Inc.
Githurai Workshop
Ruiru Workshop

Thika Workshop
Kenya Grain Growers Union Store - Nairobi
Hilda Krosigk - GTZ
Juliet Makokha - Maendeleo ya Wanawake
Frans Claassen - UNICEF
Philip Hassrick - UNICEF
Likoni Road Workshop - Nairobi
Selected households/establishments using bell-bottom and UMEME Stoves
Jamhuri Agroforestry Centre
Stuart Marwick - Woodburning Stove Group, Eindhoven
(formerly, Environment Liason Centre)
Ron Ayling - IDRC
Richard Kimani - Jerri International

**Special thanks are owed to the following reviewers:**

Hugh Allen (Appropriate Technology International)
Sam Baldwin (Princeton University)
Simon Burne (ITDG)
Gerald Chege (KENGO)
Ton de Wilde (Appropriate Technology International)
Ianto Evans (Aprovecho Institute)
Thomas Fricke (Experiment in International Living)
Amare Getahun (E/DI)
Sandy Hale (E/DI)
Philip Hassrick (UNICEF)
Keith Openshaw (Energy Initiatives for Africa)
Stuart Marwick (Woodburning Stove Group, Eindhoven)
Francis Njoroge (Kenyan Ministry of Energy and Regional Development)
C. Anthony Pryor (U.S. AID REDSO)
Bill Stewart (University of California at Berkeley,
Department of Forestry)