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The Economics of Improved Charcoal Stoves in Kenya

by
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Abstract

Charcoal for cooking is a major expenditure for urban households in Kenya and improved stoves can reduce fuel costs by at least 25%. Although an improved stove is more expensive than a traditional stove, the payback period is short and an improved stove also lasts longer. The benefits to society of a program to encourage small-scale, informal sector production of charcoal stoves are large, even after accounting for the administrative costs. Such a program may also provide limited employment and income gains for producers. The environmental impacts may be significant because of the energy loss in converting wood to charcoal and the fact that charcoal is usually made from felling whole trees.

Introduction

Charcoal comprises almost two-thirds of the energy used by lower and middle income households (those with an annual income of K.S. 3,100-54,600 in 1980) in urban areas of Kenya. Relatively well-off households (those with an annual income exceeding K.S. 54,600) also use charcoal for one-third of their domestic energy.[1] Unlike wood, charcoal takes little storage space, is ready to use without chopping, and burns cleanly. Many rural households cannot afford marketed cooking fuels and may have access to wood or crop residuals for free, but urban households have to pay cash for wood.

In 1980, 637,000 tonnes (t) of charcoal provided 21.1 million Giga Joules (GJ) of end-use energy in Kenya. It took 5,306,000 t of wood to make this charcoal in traditional earth kilns. By comparison, 12,900,000 t of wood were burned directly as fuel. Over 49% of this charcoal was used in cooking by urban households and over 25% by rural households.[2]

Due to expected changes in population, household size, urbanization, and per capita incomes, charcoal consumption may increase by 6.7% per year between 1980 and 2000, in the absence of policy changes. Charcoal would then provide 76.2 million GJ of

end-use energy by the year 2000, the equivalent of 42% of Kenya's wood consumption. About 73% of this demand would be by urban households and 15% by rural households. The predicted mean annual increment of wood 2000 could meet only 35% of the annual consumption.[3] Part of the shortfall could be eliminated if households adopted more fuel-efficient charcoal stoves ("jikos").

About 17% of rural households and 83% of urban households in Kenya owned charcoal stoves in 1980.[4] This amounts to 490,900 rural and 577,400 urban households in mid-1985. Many Kenyan households use several kinds of stoves for different fuels, depending on the food cooked, season, and time of day. Perhaps 545,000 urban and 85,000 rural households use charcoal as their primary cooking fuel.[5] A household using charcoal as a primary fuel source for cooking and heating water in a traditional stove might consume 0.700-1.100 t of it per year. However, the average household that owns a jiko consumes 0.662 t per year in urban households and 0.405 t per year in rural areas.

Fuel costs per unit of heat often are just as high for charcoal as for kerosene, liquefied petroleum gas, or electricity (table 1). However, a charcoal stove is much cheaper than the stoves for these other fuels because those stoves have many imported components. In addition, the supply of charcoal is more reliable.

The price of charcoal varies by season, location, and volume of purchase. Retailers who specialize in charcoal buy it in sacks from wholesalers. Transportation costs vary with distance from the source of the charcoal. The official price of charcoal in various locations is set by the Ministry of Finance. The

Table 1

The Price of Common Cooking Fuels Per Unit of Effective Heat in July 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)	Capital Costs of Stove (K.S.)
Wood (kg)	16.0[b]	15-25[f]	0.00-0.50[h]	0.00-0.21[h]	0-70[c]
Charcoal (kg)	33.1[c]	20-35[f]	1.70-3.00	0.15-0.45	35-125[c]
Kerosene (l)	35.1-38.9[d]	45-50[g]	4.37-6.56	0.22-0.42[i]	145-390
LPG (kg)	45.2	55-60[g]	9.20	0.34-0.37[i]	1,250
Electricity (kwh)	3.6[e]	70-75[g]	1.00	0.37-0.40[i]	1,450

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

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

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

[d] Varies with the grade.

[e] Excluding losses in generation and transmission.

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

[g] In typical Kenyan stoves.

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

[i] 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

Sources: Reference 6.

schedule of prices has not changed since late 1982, but the price controls are not rigorously enforced.

Charcoal is scarcest in the rainy season when wood is harder to collect, the weather interferes with charcoal production in outdoor earth pits or mounds, and agricultural labor requirements are at their peak. During the dry season, charcoal makers produce more because many have a greater need for cash, and transportation and storage of charcoal are also easier. To circumvent the fact that the controlled prices do not allow for seasonal variation, sellers reduce the weight contained in the sacks and tins during the rainy season.

A sack contains about 30 kg of charcoal and another 2-3 kg of charcoal fines, twigs, and sometimes stones which are deliberately added. When purchased by the sack, charcoal costs consumers an average of K.S. 1.7-2.0 per kg in Nairobi and K.S. 1.2 per kg in other areas.

Many households cannot afford to buy a sack at a time and face the possibility that stored quantities of charcoal would be stolen. Consequently, most households buy charcoal in small tins ("debes"). Although sold by volume, these units usually weigh between 1 and 4 kilograms. No effective controls exist on the retail price of charcoal in tins. By the tin, charcoal costs an average of K.S. 3 per kg in Nairobi and K.S. 2 per kg in other areas. A charcoal vendor would earn about K.S. 35 in Nairobi or K.S. 25 outside of Nairobi for each sack broken up into debes.

An average user of a traditional jiko in Nairobi spends K.S. 166 per month for this fuel. Since a laborer in Nairobi might earn K.S. 700-800 per month, charcoal purchases account for 21-24%

of the cash income of a household with one wage-earner. The average charcoal user in other urban areas spends K.S. 110 per month because charcoal prices are lower. The average rural charcoal user consumes a smaller quantity of charcoal and also pays a lower price, spending K.S. 68 per month. However, charcoal purchases could amount to an even larger share of household income outside of Nairobi where wages are much lower.

Types of Charcoal Stoves

Practically all of the jikos in use in Kenya before 1980 were of the traditional design. The traditional jiko was introduced into Kenya in the early 1900s by Indian railroad laborers. This stove is made entirely of scrap metal and is assembled by local tinsmiths in the informal sector. 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 two handles. Since it is uninsulated, this stove radiates heat to the air as well as the pot. The most common size for this stove is 28 centimeters (cm) in diameter and 28 cm in height and weighs 3 kg.

An improved stove was developed under the Kenya Renewable Energy Development Project (KREDP). This project was funded by U.S. AID and implemented by Energy/Development International and the Ministry of Energy and Regional Development. About 84,000 improved jikos were disseminated through March 31, 1985 as a result of this project, mostly in and around Nairobi. The administrative costs of this project were K.S. 3,652,000, or K.S. 43 per stove. This project was successful because of the strategies it

followed for technology adaptation and a decentralized, market-based approach to production and distribution.[7]

The KREDP jiko combines features of the traditional jiko and Thai liner stoves. These stoves have three other components: 1) a fired 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 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.

The liner stove designs evolved a great deal during the project. The current design has a bell-bottom shape with the liner extending halfway down the stove to the "waist." The ceramic grate is now part of the liner. These changes increased the durability of the stove while decreasing its cost and weight.

A follow-up project that builds on the achievements of the KREDP began in mid-1985. Appropriate Technology International is providing a grant of K.S. 4,065,550 to the Kenya Energy Nongovernmental Organizations Association (KENGO) to accelerate the production and dissemination of the KREDP jiko design outside of Nairobi. This 3-year project is providing training, technical assistance, and loans covering 75% of the capital costs of establishing production of the improved stoves in up to 20 existing, jiko production units throughout the country. These informal sector production units are expected to supply 10% of the annual demand for charcoal stoves. In addition, support is being provided for public education, a marketing program, and a quality control certification

process.

UNICEF's Technology Support Section in Nairobi developed a different charcoal stove design, the Umeme, in 1981. The Umeme is an all-metal, double-walled 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. The insulating layer may be filled with ash, soil, or just air. A major difference between the Umeme and the traditional or bell-bottom stoves is that an average-sized pot sits inside the Umeme rather than resting on top of the stove. Approximately 4,000 Umeme stoves have been produced to date in Kenya. The Haraka stove, a less expensive version of the Umeme with a single wall, has recently been developed.[8] If 80% of the bell-bottom and Umeme stoves produced in Kenya through mid-1985 remain in use, about 6% of charcoal-using households have a fuel-efficient jiko.

The Cost, Expected Lifetime, and Efficiency of the Jikos

The traditional jiko retails for K.S. 35-45, depending on its size and location. When first introduced, the bell-bottom stove wholesaled at K.S. 85-125 and retailed at K.S. 125-250. Producers and distributors were able to charge high prices for the bell-bottom stove because the quantity produced was much lower than the demand. These prices provided good incentives for existing producers to expand their output and to encourage entry of new

producers. As the novelty of the stove began to wear off and output expanded, competition forced producers and vendors to lower their profit margins.

In mid-1985, the factory price of the 28 cm bell-bottom stove in Nairobi was K.S. 60-85 in Nairobi and K.S. 125 in western Kenya. Retailers as well as individual consumers can purchase stoves directly at the factory price. The retail price at other sales outlets ranges from K.S. 90-125 in Nairobi and up to K.S. 145 in western Kenya.

As the market for bell-bottom stoves becomes saturated, a factory price of K.S. 50-65 and a retail price of K.S. 55-75 are expected. Factory prices are most likely to drop if the metal claddings and liners are made in integrated production units that produce at least 50-100 jikos per day. Some additional cost savings could be achieved through more systematic marketing.

The Umeme stove wholesaled at K.S. 70 and retailed at K.S. 85 at the workshops in Nairobi in early 1985. The retail price at other outlets in Nairobi was K.S. 97-125. The production costs for the Umeme were K.S. 60, including K.S. 20 for labor. The Haraka is about K.S. 15 cheaper to produce than the Umeme.[9] Since UNICEF arranges for direct purchases of metal from large companies, the Umeme artisans are able to buy metal at 40% less than the prevailing price charged by middlemen. Such assistance can be helpful in accelerating producer and consumer acceptance, but the production costs of the Umeme will be higher when UNICEF eventually withdraws its support. If these artisans had to rely on informal sector sources of metal, the Umeme might wholesale for K.S. 95 and retail for K.S. 120.

The expected lifetime of a charcoal stove at actual use is

about double that at full use because most households cook with other fuels in addition to charcoal. At full use, a traditional jiko lasts about 1 year, but its metal grate may need replacement after 3 months at a cost of K.S. 10.

Since improved jikos have been in use for a relatively short time, little data exists on their durability. If carefully handled, the metal cladding on a bell-bottom stove should last 2-3 years or more at full use because the liner and insulation keep heat away from the metal. The ceramic liner/grate for this stove may need replacement after 8-12 months and the insulating material after 6-12 months.[10] This should cost K.S. 30 in Nairobi and K.S. 40 in other areas. At present, the availability of replacement liners is limited outside of Nairobi, but this will change with the establishment of production units throughout the country.

The Umeme stove body can last 3-4 years or more at full use. 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; it costs K.S. 15-20.[11]

Lab PHU_2 tests measured the percent of the heating value of charcoal utilized in boiling and evaporating 2.0 liters (l) for 60 minutes (min): 20-22% for the traditional jiko, 29-32% for the bell-bottom stove, 33-36% for the Umeme stove, and 28-31% for the Haraka stove.[12] Thus, the bell-bottom stove results in a 34% fuel savings over the traditional jiko in lab tests. However, charcoal stoves are sometimes used for space heating as well. Stoves that radiate a lot of heat appear to be inefficient in

PHU_2 tests even though the energy used for space heating is not wasted.

As PHU_2 increases, the time it takes to boil water generally decreases although this relationship is not uniform. The bell-bottom stove is easier to light than the traditional jiko which, in turn, is easier to light than the Umeme. The total time required in lab tests for lighting the stove and boiling of 2 l of water was 28-32 min for the traditional jiko, 20 min for the bell-bottom stove, and 22 min for the Umeme.[13]

To achieve the full efficiency gains, improved jikos require more careful use than is customary. Although liner stoves can provide high heat, they are optimized for slow cooking. Users can reduce the 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 bell-bottom stove. While the charcoal is burning, average-sized pots must be placed inside the Umeme. Larger pots may be placed on top of the stove, but that reduces the fuel efficiency 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.

Controlled cooking tests and field tests can provide more meaningful information than lab tests on how much fuel is saved in actual cooking of foods. The difference between the various tests depends on how complex a stove is to use. The traditional jiko has a fuel efficiency of about 18% in controlled cooking tests.[14] Controlled cooking tests for the bell-bottom stove are being carried

out as part of the ATI project. A field test has already been conducted. Controlled cooking tests have not been done for the Umeme stove.

Inputs for Production of Improved Jikos

Traditional jikos are made by small-scale metal artisans in the informal sector ("fundis"). Fundis also make the metal claddings for bell-bottom jikos, purchase the ceramic liners, assemble the jikos and add the insulation, and sell them to households directly or through middlemen. A few larger-scale enterprises have dominated production of the ceramic liners because it is more exacting than cladding production. Nevertheless, small-scale potters are capable of making the liners if given proper training.

In addition to labor, the main inputs for bell-bottom stoves are clay, scrap metal, and insulating material. 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 through trial and error. If the ingredients are not mixed well, the liners are more likely to crack.[15]

After the clay/sand mixture is prepared, ash (or silica, soapstone powder, mica, or crushed fired clay) and water are added to improve the structure of the mix before it is shaped. Few existing manufacturers are using tooling and wooden or metal molds to ensure consistency of the shape and size of the liners, despite the low cost of doing so, approximately K.S. 100 per liner maker.[16] The liners are then left to dry for 1 day before the grate holes are punched out of the liner floor. If there are too few grate holes, the stove will be

difficult to light, but if there are too many, the charcoal will burn too fast. Uneven drying or handling the liners too soon can cause cracking.[17] After drying, the liners must be fired. About two-thirds of the establishments making liners use a traditional kiln for firing, but these are the smallest producers. Thus, the bulk of production is fired in a masonry kiln which results in more even quality.[18]

There is little specialization of skills in a small pottery firm under the traditional Kenyan apprenticeship system. 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 who prepares the clay and makes liners could produce 60-70 in a day. Drying and firing take a small amount of additional labor.

The cladding can be fabricated from the circular top and bottom sections of scrap metal drums which have little use otherwise. Middlemen obtain the drums from oil companies and chemical manufacturers and resell them at high mark-ups. Since there have been some problems with the cost and unreliability of metal drums, most metal artisans in Nairobi are now using thinner scrap, galvanized iron sheets. In Mombasa where metal prices are cheaper, consumers prefer to buy jikos made of heavier scrap metal.

In addition to the drums or metal sheets, round metal bars are needed for the pot rests and flat iron bars are used for the hinges and handles. The firebox door, legs, and pot rests/handles are attached to the jiko body by riveting.

An experienced metal artisan can produce 5-7 claddings for bell-bottom stoves or traditional jikos in a day. The metal working techniques are similar for both types of stoves and only simple hand

tools are needed. However, there is more folding and rivetting for the bell-bottom stove and a metal grate is needed for the traditional jiko.

The layer of insulation should be 1 cm thick. A 1:3 mixture of cement and vermiculite appears to be best as the insulation. At present, vermiculite is not routinely available in most of the country without the assistance of KENGO and CARE-Kenya. Diatomite is a good substitute for vermiculite. Less effective substitutes include a 1.5:4 mixture of cement and white ash or a 1:2 mixture of cement and carbonized coconut husks. The insulation should be cured for 2-3 weeks before use to prevent cracking. 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.

After all of the components have been prepared, it takes 5-10 min to put the jiko together. Sometimes, the outside of improved jikos are painted for greater aesthetic appeal. Average unit production costs for the most common size of bell-bottom stove (excluding profit) range from K.S. 44-56, depending on the capacity of the enterprise and the production rate (table 2). About 52-66% of total costs is for materials and 14-18% is for labor.

The Umeme stove is more expensive to make than the traditional jiko because it requires 4 times the amount of metal and 5 times the amount of labor.[19] Although thin metal can be used for the stove walls, heavier-gauge metal is required for the inner grate, pot rests, and upper grate.[20] The construction of the Umeme must be done more carefully. For example, the number and location of rivets and air

Table 2
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	1.1
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

Table 2 (continued)

	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

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[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: Ref 10; Allen, op cit, Ref 11.

inlets in the Umeme is especially critical to the stove's efficiency. However, the Umeme only requires one type of artisan which avoids the quality control problems that are common with the ceramic liners. Most Kenyan metal artisans can copy metal products accurately even without using templates. One artisan can usually make 4 Umeme stoves in a day. The Haraka stove requires less metal and labor than the Umeme.

Financial and Economic Analysis

Table 3 lists the assumptions behind an ex post financial and economic analysis of the jikos component of the KREDP and an ex ante analysis of the follow-up ATI project aimed at expanding production to the take-off stage. Although laboratory tests show that a 34% fuel savings is feasible, only a 25% savings is assumed because households often do not use or maintain stoves properly. Basing the analysis on average charcoal consumption rates of households that own jikos also results in a conservative estimate of benefits because it is likely that the heaviest charcoal users will be the first to buy improved stoves.

A household in Nairobi can purchase an improved jiko directly from the producers. In other urban areas, allowance is made for the profits of middlemen. With careful use, the replacement and repair costs should be lower than those assumed. Since it is assumed that a household discards a serviceable traditional jiko when it buys its first improved jiko to reap the fuel savings, the whole cost of the new jiko is counted rather than the incremental cost over the price of a traditional jiko.

The net present value (NPV) to a household adopting an improved jiko for 2 years ranges from K.S. 257 to K.S. 884 if

Table 3

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 Areas
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 Areas
47,061	20,169

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

	Nairobi	Other Urban Areas
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.

charcoal is purchased in tins, or K.S. 109 to 518 if charcoal is purchased in sacks (table 4). The variation is due to differences in the price and quantity of charcoal consumed in Nairobi, other urban areas, and rural areas.

When aggregated over a large number of households, the total NPV is substantial (table 5). It amounts to K.S. 288,571,000 in the most likely case--where charcoal is purchased in tins. The NPV would be 45% lower if charcoal were purchased in sacks. It would be 45% higher if the fuel savings were 35% and charcoal were purchased in tins. It would be 55% lower, but still large, if the fuel savings were only 15%. If charcoal were purchased in tins, the NPV would be large even if the market penetration rate under the ATI project were half the expected level.

Other Social Effects

The employment and income distribution effects of the traditional and improved technologies are comparable because of the reliance on the informal sector for production of both types of stoves. It takes slightly less time to fabricate the metal claddings 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 adding the insulation for an improved jiko. However, the employment gains may be outweighed by the fact that the improved stove does not have to be replaced as often.

Metal working is a low-status occupation in Kenya. Many metal artisans used to be migrant workers, but most are now settled although some only do this work seasonally or irregularly. The income of a workshop owner depends on the number of workers employed and the

Table 4

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

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

Table 5

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
Net present value	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
Net present value	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 net present values would be larger than those shown above. This analysis covers 11 years for the KREDP and 10 years for the ATI project.

quantity and types of other goods produced. The number of workers varies considerably, especially in Nairobi. Raw material and equipment costs are borne by the workshop owner. A workshop owner makes a profit of K.S. 10 per cladding. Less commonly, groups of 3-5 independent metal artisans without employees share a shed.

Full-time metal artisans in Nairobi work at least 6 days a week for 9 hours a day. They are paid by piecework, receiving K.S. 10 for a bell-bottom cladding or K.S. 15-20 for an Umeme stove. Metal workers also make a wide variety of other products such as pots, skillets, washing basins, watering cans, and buckets. A metal artisan in Nairobi can earn K.S. 45-75 per day, but apprentices are paid less.

If the 1,068,200 households with jikos in Kenya buy a charcoal stove every 2 years, about 534,000 charcoal stoves are produced each year. At a production rate of 6 traditional jikos or claddings for improved jikos per day for 300 days per year, a metal artisan can make 1,800 stoves in a year. Thus, about 300 artisans working full-time could meet the annual requirement for jikos. Since most metal workers only spend one-third of their time making stoves, about 900 artisans are involved in this activity. Each of these workers would earn about K.S. 600 per month from making 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 reduces problems of distribution and marketing and maintains competition in pricing.

Pottery making is also a low-status occupation in most of Kenya where women are the traditional potters and this work is done part-time or seasonally for supplementary income. Pottery making has a higher status among the Luhya tribe in western Kenya where it is a full-time occupation for men. Production of 250,000 liners per year might result in 200-300 additional full-time jobs for potters.[21] These liner makers could earn K.S. 30-50 per day.

Environmental Effects

Significant local environmental effects may result from woodfuels consumption.[22] The environmental benefits 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.

If 80% of the Kenyan households that used charcoal in 1985 adopt improved jikos, 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. By the year 2000, an 80% adoption rate for improved charcoal stoves would save 3,492,600 t of wood per year. This savings would grow in subsequent years.

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.[23] Assuming that both types of forest are the source for additional supplies of wood for charcoal making in proportion to their current annual yields, an 80% adoption rate for improved stoves 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. In the year 2000, the annual savings would be 163,000 ha of woodlots and 172,600 ha of managed forests.

The environmental impacts of saving a tonne of wood intended for charcoal production may be larger than the impacts of saving the same quantity of wood burned directly as fuel. Fuelwood often consists of twigs and fallen branches while whole trees are often felled 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. However, if a charcoal stoves program induces a large number of households to substitute charcoal for wood, LPG, or kerosene, it could increase the amount of wood cut by more than the amount saved because of the net energy loss in charcoal conversion.

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