# Cookstoves for the Developing World

*Traditional wood, charcoal and coal stoves are used in hundreds of millions of homes. Their redesign can have a dramatic effect on energy usage, the environment and community health*

by Daniel M. Kammen

Half the world's population of nearly six billion people prepare their food and heat their homes with coal and the traditional biomass fuels of dung, crop residues, wood and charcoal. The procurement and consumption of these fuels define the character of everyday life in many developing countries.

In rural areas, women and children may spend several hours a day collecting wood for cooking or making charcoal, tasks that contribute to deforestation and soil erosion. Worse, the choking smoke from indoor wood fires causes respiratory disease—mainly pneumonia—which is the leading health hazard in developing nations and annually kills four to five million children worldwide.

Living in the city provides no refuge. The urban poor frequently spend a significant fraction of their income on the purchase of charcoal and wood. Combustion of biofuels contributes to the hazy pall that hangs over the cities of the developing world. Carbon dioxide, methane and other greenhouse gases from cooking fires may also foster global warming.

Since the energy crisis of the 1970s, international aid organizations have targeted the improvement of traditional cooking practices as a simple and affordable way to address the environmental, economic and energy issues posed by the home fire. Several hundred projects spread throughout dozens of countries have promoted the "improved" cookstove—a more efficient adaptation of the metal or clay implements on which many of the world's families cook their daily meals. These efforts range from national initiatives that have introduced more than 120 million stoves into homes in rural China to village training programs in East Africa in which small groups of women learn to build and maintain their own stoves.

Cookstove programs follow closely the model for technology development and adoption established by the late British economist E. F. Schumacher in his 1973 classic *Small Is Beautiful*. Schumacher made a compelling case for "appropriate technologies" that were affordable and could be produced and maintained locally. Unfortunately, the enthusiasm of many of Schumacher's early followers concealed a meager technical know-how or simple naïveté. Virtually every developing country can point to examples of dilapidated wind pumps or photovoltaic power systems that either did not work or could not be repaired with local materials.

Modernized woodstoves were often too bulky or saved fuel only when used under ideal conditions seldom found in the field. Cookstove training courses were sometimes offered only to men, even though women perform more than 90 percent of the cooking duties in most developing countries.

Over the past decade government programs, development assistance groups and community-based organizers have undertaken a thorough review of the requirements for successful dissemination of cookstove technology. A new generation of stove programs is now implementing these hard-won lessons. This effort encompasses everything from an examination of stove thermodynamics and materials science to market research and grass-roots educational campaigns.

### Cookstoves in Kenya

A case history that traces the progress of stove development from early misstep to ultimate acceptance can be found in East Africa. Almost one million households now cook with the

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**OPEN FIRE (*left*) used for cooking in millions of rural homes transfers heat to a pot poorly. As little as 10 percent of the heat goes to the cooking utensil; the rest is released to the environment.**

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**COOKSTOVE SMOKE is ubiquitous in Kenya, where wood, charcoal and other biomass fuels are used for cooking and heating. Particulates in smoke are a major contributor to respiratory disease, the leading cause of illness in developing nations.**

Kenya ceramic *Jiko.* The *Jiko*—the word means “stove” in Swahili—consists of a metal casing with a ceramic lining that helps to direct 25 to 40 percent of the heat from a fire to a cooking pot. The traditional metal stove that the ceramic *Jiko* replaces delivers only 10 to 20 percent of the heat generated to a pot, whereas an open cooking fire may yield efficiencies of as little as 10 percent.

The first improved stoves began to appear in the early 1980s and were designed by aid groups such as UNICEF and CARE-Kenya. The response from stove users was mixed at best. The designers, mainly natives of the U.S. and Europe, two havens of consumerism, had forgotten the first thing about marketing. Field testing was all too brief, sometimes with pathetic results. In one of the first models, the stove’s opening did not match the size of most pots.

Even more fundamental problems plagued some of the early prototypes. Designers acted as if it would be an elementary exercise to improve the efficiency of the common metal stove, a deceptively simple canlike enclosure into which charcoal or wood is fed and ignited. In fact, after much trial and error, it turned out that an extensive investigation of stove physics and engineering design was needed. This analysis revealed that the largest loss of heat from the fire, about 50 to 70 percent, occurs from radiation and conduction through the metal walls. Makers of some of the first stoves took measures to deliver more of the fire’s energy directly to the pot. They sometimes accomplished their job a little too well.

The design for one early improved *Jiko* model emerged after an aid group named the Kenya Renewable Energy Development Program sponsored a research trip to Thailand to inspect an improved stove—the Thai bucket. The resulting *Jiko* design had inward-sloping metal walls, like the Thai stove, as well as an insulating liner made of ceramic and a mica called vermiculite. The liner was cemented from the top to the bottom of the inner surface walls. It caused excessive amounts of heat to be retained inside the tapered vessel. Metal fatigue resulted from exposure to the trapped hot gases, which caused structural segments to crack.

An initial round of field tests did not provide enough feedback to stop this first-generation improved *Jiko* from reaching the

**METAL STOVE (*left*), a traditional cooking implement, directs only 10 to 20 percent of the heat to a pot. From 50 to 70 percent of the heat is lost through the stove’s metal sides, and another 10 to 30 percent escapes as carbon dioxide, carbon monoxide, methane and other flue gases.**

**KENYA CERAMIC *JIKO* (*left*) increases stove efficiency by addition of a ceramic insulating liner (the brown element), which enables 25 to 40 percent of the heat to be delivered to the pot. From 20 to 40 percent of the heat is absorbed by the stove walls or else escapes to the environment. In addition, 10 to 30 percent gets lost as flue gases, such as carbon dioxide.**

market, where it received an equivocal response from purchasers. Various governmental and international aid groups, however, continued to work with a loose consortium of craftspeople, called *Jua Kali,* or "Hot Sun," to try to rectify the problems.

Better stove designs gradually came about during the mid-1980s. At that time, a number of academics began to publish serious analyses of optimal stove combustion temperatures and of the insulating properties of the ceramic liner materials. One of the most notable contributions to enhanced design came through the responses of several women's organizations that had formed around such issues as community health and protection of the environment. These groups were part of a feminist movement spreading throughout the developing world. In Kenya, it was women who suggested recasting the metal bucket design, with its unstable narrow base, into an hourglass shape.

That alteration prevented the new stove from tipping over, a constant danger when food was vigorously stirred in the Thai-influenced, bucketlike implement. It also meant that the insulating liner need extend only from the upper lip to its narrowest circumference at the stove's middle—and the tapered shape let the liner rest stably cemented to the upper metal walls without falling into the stove's bottom cavity. Because the liner covered only half the stove's interior, it did not cause the overheating and consequent cracking that had plagued the early versions.

These design changes, along with extensive training programs established by aid groups and women's organizations, caused dramatic gains in acceptance for the more efficient stoves. Schools, churches and businesses were among the first owners and helped to spark the interest of individual buyers. Today hundreds of *Jua Kali* manufacturers provide stoves to some 20,000 purchasers every month.

### Benefits of the *Jiko*

The ceramic *Jiko* has had a considerable impact on household finances. Typical savings of 1,300 pounds of fuel a year frees up about $65 per household—up to a fifth of the annual income for urban dwellers. Women have benefited in that they control a disproportionately small share of family income yet are the primary purchasers of fuel. The Kenya ceramic *Jiko* has improved their lot in important ways. Many have invested the savings from reduced fuel purchases in small businesses or school fees for their children.

Currently more than half of all urban households in Kenya own the ceramic *Jiko,* and purchasers range from the poor to the affluent. The concentration of demand in urban areas points up another difficulty with the early stove programs, which commonly targeted users in the countryside. Programs outside the cities, where more than 70 percent of the Kenyan population lives, seemed justified because they met the needs of the poorest segment of society. But the $2 to $5 stove price proved too high for many households that had the option of collecting their own firewood and cooking over open fires. For city dwellers, who sought ways to cut their unavoidable fuel costs, more efficient stoves held a greater allure.

Establishing an infrastructure for stove production has begun to benefit the masses who live outside the city. Village residents have little ability to pay for a ceramic *Jiko* that may cost up to $5. But they may be willing to spend something less than that amount, some observers reasoned. After all, there are undeniable benefits for an implement that will diminish the drudgery of collecting wood for hours on end and that will reduce the acrid smoke in cooking huts. The smoke can cause exposure to particulates at 20 times the level that the World Health Organization considers a serious health risk.

Success of the ceramic *Jiko* in Nairobi and Mombasa did not go unnoticed by many of the women's groups that had organized in rural areas. An alliance developed between leading government and aid organizations in Nairobi and women's groups, most notably *Maendeleo ya Wanawake* (literally "Women's Development"). From these efforts has come a simplified and affordable variant of the ceramic *Jiko.*

The *Maendeleo* stove borrows the insulating element from the ceramic *Jiko* without the metal outer covering. The ceramic liner is set down in the middle of the open fireplace; it is then reinforced with mud and stones. A pot placed atop the stove heats almost as quickly as one on a Kenya ceramic *Jiko.* Indoor smoke is reduced considerably through more efficient combustion. Further, a *Maendeleo* stove is usually placed near a wall of the hut so that smoke can climb along the wall and exit more easily.

The *Maendeleo* stove costs as little as 80 cents; more than 100,000 of them have been disseminated so far. This rural success story helped to spawn a third-generation cookstove, the *Kuni Mbili* ("two-stick") stove, which has a larger firebox to accommodate wood instead of the charcoal typically used in urban settings.

The Kenyan program has been emulated in a number of other African countries, where the improved stoves continue to gain popularity. Variants of the Kenya ceramic *Jiko* have made their way to Tanzania, which has more than 54,000 stoves; Sudan, which has 28,000; Uganda, which has 25,000; and Zambia and Burundi, each having from 5,000 to 10,000.

### Chinese and Indian Programs

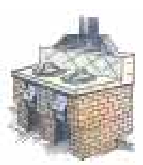
Higher efficiency cookstoves have been adopted throughout the developing world. China has by far the world's most extensive program, with more than 120 million stoves in place—seven out of 10 rural households own

**METAL COOKSTOVE:** Traditional cookstove, produced by local artisans, has a metal skin that lets heat escape easily. Efficiency: 10 to 20 percent. Cost: $0.25 to $10. Number disseminated: hundreds of millions.

**KENYA CERAMIC *JIKO:*** This metal stove with a ceramic liner has achieved great popularity both within Kenya and in neighboring countries. Efficiency: 25 to 40 percent. Cost: $2 to $5. Number disseminated: nearly one million.

***MAENDELEO:*** This ceramic insulating liner can serve as an inexpensive stove when placed in an open fireplace and reinforced with mud and stones. Efficiency: 15 to 35 percent. Cost: $0.80 to $1.20. Number disseminated: more than 100,000.

***KUNI MBILI:*** A variation on the ceramic *Jiko,* this stove has a large firebox to hold wood sticks instead of charcoal, making it more suited for rural cooking. Efficiency: 25 to 40 percent. Cost: $2 to $5. Number disseminated: more than 20,000.



**CHINESE IMPROVED COOKSTOVE:** Brick and mortar stoves with chimneys are used to burn wood, straw, rice husks and coal. Efficiency: 20 to 40 percent. Cost: $8 to $9. Number disseminated: more than 120 million.

**INDIAN *CHULA:*** Efficient clay fireplaces, called *Chulas,* have been installed in rural homes in India. Efficiency: 10 to 40 percent. Cost: $8 to $10. Number disseminated: more than eight million.

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these units. The longtime isolation of that huge country has, until recently, made it less influential than Kenya as a model for other developing countries.

The Chinese stoves, which burn wood, crop residues and coal, consist of a brick and mortar construction with a chimney that fits in the central living area of a home. An insulating material, such as ash and mortar, is packed around the circular cast-iron opening, which holds a wok.

Even the centralized Chinese government recognized that a successful stove program could not be mandated from Beijing and must meet local people's needs. Besides conducting stove research, the government confined itself to clearing away bureaucratic hurdles, giving local energy offices the responsibility for technical training and setting standards for manufacturing production. Most important, people made their own decisions to buy the stoves: no direct subsidies were supplied to purchasers by the government.

In contrast, a program in India, in which the government subsidized 50 percent of the cost of the eight million stoves distributed, resulted in half the stoves lying unused. The government ignored important regional differences in cooking habits. Respondents to follow-up inquiries often complained that the stove did not really save energy or get rid of smoke. Fortunately, reforms by the government and the launching of new research programs during the past five years have begun to correct these problems.

The lessons of improved stove programs can serve as the basis for a more radical shift away from traditional cooking technologies—fuel use can be eliminated by harnessing the energy of the sun. The solar oven, an idea reported a century ago in *Scientific American,* is essentially a greenhouse for cooking food. It consists of an insulated box made of wood, metal, plastic or cardboard whose open top is covered with one or two plates of glass.

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**SOLAR OVEN, shown in Kenya, cooks food in a glass-covered box where pots are placed.**

### Trapping Sunlight

Solar oven designs are as varied as cookstoves, but a "box cooker," as it is known, typically incorporates walls with a reflective coating, such as aluminum sheet or foil, and a metal floor plate to absorb sunlight. The energy is then reradiated within the box as infrared heat, which does not escape because it is blocked by the glass. Pots on the bottom metal plate can heat several liters of water or food to more than 300 degrees in under an hour.

The ovens are mostly used for crock-pot-style cooking. They allow for slow simmering, baking and roasting in covered pots. On a sunny day, rice, stews, chicken or bean dishes will be fully cooked in two to five hours.

Solar-box ovens will never compete with the microwave oven in speed of preparation, and they must be supplemented with a wood cookstove for a rainy day. But they require no fuel except the sun's rays—and they emit no health-damaging smoke. By using the technology, some households in Africa, Latin America and elsewhere have reduced their cooking-fuel expenditures by 50 percent.

As with the early stove programs, acceptance rates are still modest: only 20 to 40 percent of the Kenyan families who adopted some 2,500 solar ovens early on continue to use them. The cost of the stoves—$20 to $40 apiece—remains too high for many households. Yet the *Jua Kali* artisans who have mastered mass production of the ceramic *Jiko* might also be able to make large numbers of solar ovens, which could halve the price. The cost of the ceramic *Jiko* dropped markedly, from $12 to as little as $2, once the stoves were mass-produced. In many places, a manufacturing base has begun to emerge that could bring costs down. Women's groups, artisans and several large-scale commercial industries in more than 100 countries are making solar ovens in a diverse range of styles. (Besides Kenya, China and India each have more than 100,000 in use.)

Cookstove projects boast a record of accomplishment that may serve as a model for the development of an array of renewable-energy projects, such as wind-energy systems and photovoltaic electrical generators. The halting first steps of the appropriate technology movement are now being translated into solid research and a more pragmatic execution. These programs may become a realization of Schumacher's vision: for one out of every two people worldwide, modifications in their means of cooking offer enormous promise for improvements in health and economic well-being.

## The Author

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## Further Reading

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