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ANALYSIS

Can solar cooking save the forests?

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Abstract

Cooking with the sun has become a potentially viable substitute for fuelwood in food preparation in much of the developing world. Fuelwood scarcity is a growing problem that has thus far been poorly addressed. Solar cooking is one possible solution but its acceptance has been limited partially due to cultural barriers, relatively high start-up costs, and a lack of continued support subsequent to introduction. One possible source of some funding for solar cookers may be the Clean Development Mechanism (Article 12 of the Kyoto Protocols) aimed at reducing carbon emissions to curtail the impact of global warming. Using Haiti as an example, CDM funding is shown to be promising but only a partial solution. With CDM as a possible source of at least seed capital, more ambitious solar cooking programs are feasible but their success will be a function of addressing cultural barriers and providing support for adaptation well beyond the introductory stage.

Keywords: Clean development mechanism (CDM); Deforestation; Global warming; Solar cooking

1. Introduction

Today, approximately two billion people rely on fuelwood for cooking and/or heat (Lampinen, 1994). More than two-thirds of those living in developing countries depend on wood for fuel (Miller and Tangley, 1991). The majority of the two billion people who are fuelwood dependent live in the tropics, predominantly in rural areas. In Nepal, 96% of the population still depends on biomass energy for domestic purposes, 76% of this is provided by fuelwood and the population of over 22 million is growing by over 2% per year (World Resources Institute, 1994; Manandhar, 1997). Up to 70% of the population of south and southeast Asia still lives in rural areas in need of fuelwood while remaining dependent upon the integrity of nearby land, water, soils, and forests (Poffenberger and Stone, 1996). In addition to fuelwood, 350 million tons of crop residue and 400 million tons of dung are also burned annually. Had the animal wastes alone been used to fertilize the soil, 14 million additional tons of grain could have been grown and harvested—more than twice the level of all grain contributed

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to global food aid (Miller and Tangley, 1991). There are over 200 million indigenous people living in dwindling forested areas who are not engaged in the global economy at all. With this many people cooking and space heating with wood daily, the sustained impact on the surrounding forest can be enormous. While the examples given and to be discussed below are disparate and cut across many different ecosystems, what they do have in common is the possible use of solar cooking devices to reduce the impact of deforestation. Successfully introducing solar cooking is less certain. The Clean Development Mechanism (CDM) under Article 12 of the Kyoto agreement on global warming is one area from which assistance might be obtained to pay for the introduction of solar cooking devices as will be seen later in an example (UN Third Conference of the Parties, 1997).

Optimists have estimated that 36% of the developing world's use of fuelwood could be replaced by solar stoves. This would save 246 million metric tons of wood from the flames with a market value of as much as US$20 billion per year (Lampinen, 1994). In the most wildly optimistic scenario, the potential for solar stove sales could be as large as 200 million units, one unit per ten people of the two billion using fuelwood. At US$90 per cooker and a 10-year life, US$1.8 billion of solar cookers could be sold every year. It should be emphasized that even if such widespread use of solar cookers were to occur, deforestation from slash and burn agriculture, cattle ranching, mining, logging, and oil production would still have overwhelmingly negative consequences to the survival of the world's forests. The use of solar cookers would be of particular importance in more heavily populated regions and especially in the arid tropics.

Modern solar cooking had its debut in 1837 when John Herschel, on an expedition to the Cape of Good Hope, built a simple black box with a double glass cover and buried it in the sand to keep heat from escaping. Attaining a temperature of 116° C, this simple solar oven was used to successfully cook meat and vegetables. One hundred and fifty years later in 1987, Solar Cooking International (SCI) was founded with the ambitious goal of informing all of the more than two billion users of fuelwood about the benefits of solar cookers and converting at least 1% of them to at least partial reliance on the sun instead of complete dependence on the forest for their cooking needs by the year 2000. Such a conversion, they estimate, would save 2.9 million metric tons of fuelwood per year (Ethiopia Project, 1997). Substituting solar ovens for wood burning, while a modest cost to the developed world, may be prohibitively expensive for people in the developing world without some form of economic assistance. There are also cultural problems that have made diffusion of solar cooking technology a slow process.

2. Fuelwood

Fuelwood gathering and burning, occurring mainly in tropical dry forests and non-forest, wooded areas, accounts for the largest portion of wood use in developing countries (World Bank, 1991). In the late 1970s and 1980s planners and foresters assumed fuelwood could be grown on community woodlots and managed under common property tenure regimes making the use of fuelwood a perpetually renewable resource (World Bank, 1991). This optimistic outlook was never realized, typically because of communities' lack of incentives and poor organization. Pressure from foragers in the forests continued to increase as conveniently available wood became more difficult to find.

Charcoal, made from wood heated in kilns, is used in many areas of the world instead of directly burning wood. Charcoaling begins to contribute to deforestation only after the distance between those who need fuelwood and supplies of it become so great that it is economically more viable to make and transport charcoal than fuelwood as has occurred in Tanzania (Hofstad, 1997). Charcoal demand is a function of charcoal price, the number of urban families, and average family income. As fuelwood supplies close to populated areas diminish to the point where the concentrations of wood fall below 20 m^3 per hectare, it is more economical to transform the remaining wood into charcoal on site. Transporting the resulting lighter charcoal to users is more cost effective and practical than the effort that would be required by users of fuelwood to gather the widely scattered fuel. At least in Tanzania when density falls to 5 m^3 or less, even charcoaling is inefficient and unprofitable.

Two of three developing countries are in the midst of a fuelwood shortage (Miller and Tangley, 1991). The FAO projects in the year 2000 as many as three billion people will have insufficient access to fuelwood to meet basic needs. Already this is the case in some areas. Contrary to findings in Tanzania, economically viable woodlot density required to make charcoaling profitable or even viable may be near zero in very impoverished countries. In Haiti even tree stumps and roots, the last remaining vegetation holding down the soil, are dug up to make charcoal. Every trace of a tree is removed to convert it to increasingly expensive charcoal, promulgating the ultimate 'scorched earth' policy (Worker, 1994). In some coastal areas, mangroves are cut below water line to feed the charcoal kilns, weakening the trees and eventually killing them. Without mangroves, estuaries can fall into rapid decline, spreading ecological devastation.

Declining fuelwood supplies mean more effort is needed to do the gathering. At Aisha Refugee Camp in Ethiopia, women who gather wood must plan on being away from home for two nights if they are fortunate enough to have access to a donkey. With the donkey they can gather enough fuel for 1 week's cooking requirements. Those without donkeys forage for fuel 8–12 h every other day, carrying their loads on their backs (Ethiopia Project, 1997). With many of the world's poor participating minimally in the market economy, purchasing fuelwood is atypical in most places, making price less of a direct issue. All that is relevant is travel and collection time, and even these may be heavily discounted. In poor regions with stagnating real wages, such as Northeast Thailand, the opportunity cost for family labor is low and constant which makes gathering wood from further distances less economically prohibitive (Panayotou and Sunsuwan, 1994). Price in such subsistence economies is not an issue, but shortages can have an impact in different ways. Reduction in fuelwood use to economize on scarce resources has resulted in the adaptation of new cooking methods. In parts of the African Sahel women light only ends of logs and branches and cook with them like spokes at the end of a wheel. In some areas, e.g., Bangladesh, the lack of fuelwood has reduced the number of meals that are cooked. There may also be a shift to less nutritious foods, as in Guatemala where fewer protein-rich beans are prepared (Agarwal, 1986).

2.1. Health and efficiency of using fuelwood

Incomplete combustion, heat loss from the stove when a stove is used, inadequate heat transfer from flame to pot, heat needed to arrive at a combustion level sufficient for cooking, and the persistence of a smoldering fire after cooking is finished are some of the inefficiencies of cooking with fuelwood. Even if a more efficient stove is used, such as the Jiko stove developed in Kenya, many households live so marginally that increases in efficiency of the stoves do not mean burning less wood, but rather cooking more food (Agarwal, 1986).

Smoke from burning fuelwood contains high levels of respirable particulates, carbon monoxide, nitrous oxide, benzene, formaldehyde, benzopyrene, and aromatics (Kammen and Kammen, 1992). Cooking often takes place indoors, leading to concentrations of hazardous fumes that can exceed smoke levels in industrialized cities. When cooking, many people close doors and plug windows. Some local Kenyan cooks believe it is unhealthy to allow any drafts when cooking. In extreme cases such enclosed cooking may be equivalent to smoking several packs of cigarettes per day. Young children in the care of their mothers are often excessively exposed. One-third of the 15 million annual deaths of children under the age of 5 years are attributable to respiratory ailments (Graham, 1990). A study in Nepal found a direct correlation between the number of hours a child spent near an indoor fire and the incidence of acute respiratory infections (Pandey et al., 1989).

Using solar stoves would not only eliminate or at least diminish the respiratory illnesses arising from exposure to smoke, they could also be used to defeat another scourge of the developing world, contaminated water. UNICEF estimates that five million children under the age of 5 years die as result of drinking contaminated water (Andreatta, 1994). Pasteurizing water over a wood fire when fuelwood is scarce is unlikely. Water pasteurization with a solar stove costs nothing once the stove is built or bought. Contrary to popular belief, it is not necessary to boil water to make it safe to drink. It only needs to be heated to 65°C for 6 minutes to accomplish pasteurization. Solar stoves can efficiently and usually quickly attain such temperatures.

Besides indoor pollution problems, burning fuelwood is a part of a significant contributor to global carbon emissions. Burning fuelwood, charcoal or crop residue, slash and burn agriculture, and deforestation accounts for 5–20% of all carbon emissions worldwide (Smith et al., 1993). Other greenhouse gases emitted by such combustion are also significant contributors to global warming. The global warming potential from non-carbon dioxide gas emissions due to wood and charcoal burning can rival that of its carbon dioxide emissions alone.

3. Deforestation

The World Bank (1991) has identified three crucial functions of forest ecosystems: timber production, carbon fixation, and protection of water resources. Carbon fixation is the natural mechanism for balancing greenhouse gas emissions. Demand for industrial roundwood—wood that will be used as raw material in production processes—and the demand for fuelwood and charcoal have been rising at a very similar pace since 1950 (see Fig. 1). In 1982, the millions of metric tons of fuelwood and charcoal used surpassed industrial roundwood usage with both products increasing at a parallel rate since that time. The industrial roundwood component of logging is the economically measurable component. World trade in forest products, nearly exclusively industrial roundwood, is US$114 billion per year with paper usage being the fastest growing component (Abramowitz, 1998).

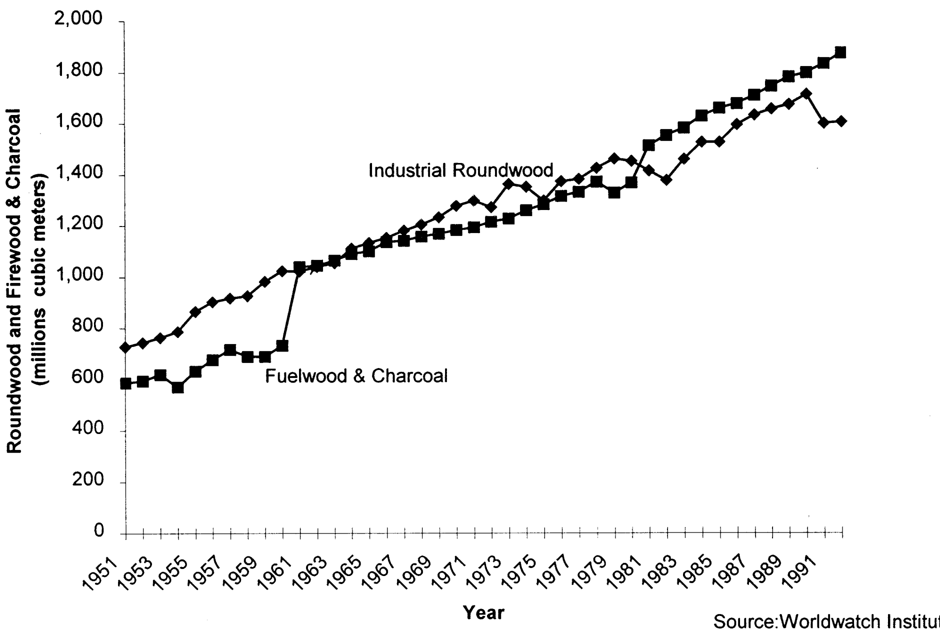

Fig. 1. Demand for industrial roundwood, and firewood and charcoal.

Table 1
Forest cover and deforestation[a]

Region	Forest cover 1990 (million hectares)	Annual deforestation 1981–90	
		Million hectares	Annual percentage forest loss
Asia and the Pacific	310.6	3.9	1.0
Latin America and Caribbean	918.1	7.4	0.8
Africa	527.6	4.1	0.7
Total	1756.3	15.4	0.8

[a] Source: World Resources Institute, FAO

Wood consumption and resulting deforestation have been spurred by falling prices. In constant dollars, industrial roundwood prices fell 14% from 1980 to 1992 (Worldwatch Database, 1996). Table 1 shows that deforestation at its current pace removes less than 1% of the world's forest per annum. Consumption of forest products, industrial roundwood and fuelwood combined, has been growing at 2.15% per year since 1950. Projecting this rate of usage forward, the world's forest cover will be completely gone by 2048. Extrapolating Asia and the Pacific's rate of deforestation would leave that region without remaining forest by as early as 2025.

Accessibility is the most important factor determining how long it will take to meet a family's fuelwood needs, and accessibility may be largely due to logging activity, particularly road building that opens up previously inaccessible forest to foraging. Road building is the linkage between logging for industrial roundwood with many end uses and the increase in the use of fuelwood and charcoal with the end use of cooking and heating. Government and foreign aid donors build roads to reduce transport costs at the expense of making the exploitation of virgin woodland possible (Hofstad, 1997). Tropical and subtropical deforestation is occurring at a rate of 10 million ha per year (Poffenberger and Stone, 1996).

Logging is an initiating factor in encouraging settlement and eventual complete deforestation. The nature of logging concessions granted by developing countries plays a role in methods used by companies exploiting forest resources. The typical short-term logging concessions granted motivate clear-cutting. Longer-term concessions would motivate different logging behavior, possibly stewardship and reforestation. The insecurity of short-term concessions is related to the potential for excessive and destructive logging. Long-term concessions would essentially entail awarding of private property rights, an extremely rare concession in tropical forestry (Panayotou and Sunsuwan, 1994). Private property rights, including the right to sell although end-use could still be circumscribed, would motivate owners to better manage resources that are only currently held for only the short-term gains.

Once accessibility to the forest is established, population density becomes the major factor in determining the rate at which deforestation will proceed. The study of Palo (1994) of 60 countries, found total population density was more strongly correlated with the extent of forest cover than rural population density ($r = 0.97$). Interestingly, population growth had zero correlation with forest cover. Population pressure in conjunction with unequal land tenure and poverty are seen as critical exacerbating factors in deforestation. Economic development and deforestation may have a curvilinear relationship. In the poorest countries, small increments in wealth lead to more roads and more deforestation. In richer countries, added income may mean migration to cities and a decline in deforestation (Rudel and Roper, 1997).

Under effective forest access controls, logged forest lands will regenerate rapidly and heterogeneously—an alternative which costs 1–5% of the cost of the commercial alternative of establishing typical monoculture tree plantations to generate forest cover. Dealing with a major cause of deforestation, the shifting cultivator employing slash and burn agriculture in the wake of commercial logging, means tackling the much larger problems of population growth, inequitable distribution of farmland, inadequate rural infrastructure, and the lack of attention by governments to subsistence agriculture. Controlling logging by establishing forest plantations on deforested land or curtailing access by force are remedial solutions to these much larger problems.

4. Global warming and the Clean Development Mechanism (CDM)

Concomitant to the inroads of development and fuelwood use taking their toll on the world's forests is the threat of global warming. A Dutch study estimates that 24% of the world's parks and protected areas will undergo major vegetation changes by 2050 (O'Meara, 1997). The feedback effect from the shrinkage or even elimination of forests as a major carbon sink will further exacerbate the accumulation of carbon dioxide in the atmosphere. Kammen (1992) estimates the cost of sequestering an additional ton of carbon by using a solar oven and therefore avoiding the burning of fuelwood is US$20–30. This assumes the cost of the program is US$100 over a 10-year period and wood consumption is reduced by an optimistic 50%. The cost of reforestation in the United States is US$25–40 per ton of carbon sequestered. Of course, reforestation could be considerably less expensive in other areas of the world, but it does present an argument for spending money on a proven technology, solar ovens, to reduce CO_2 accumulation in the atmosphere (Kammen, 1992).

The Clean Development Mechanism (CDM) is the Kyoto Protocol update of Joint Implementation. Previously, under JI, developing countries with projects that reduce carbon dioxide emissions or increase carbon sequestration could implement them jointly with parties in other countries (Harvey and Bush, 1997). Under Article 12, CDM allows for similar trades between developed and developing countries. Introducing solar ovens is one way to reduce the burning of biomass and it could be done through CDM. An interested corporation, possibly a utility seeking to build a new power plant in a developed country, would seek to offset the increase in carbon emissions that would ensue by purchasing and dispensing solar ovens in a developing country. In order for this transaction to be economically and environmentally viable, the solar ovens would have to reduce the burning of biomass to the extent that it could justify their purchase, the cost of their introduction and subsequent technical support to make the introduction a success.

A typical pre-Kyoto price paid for sequestering a ton of carbon was US$2.20 per metric ton as in the case of New England Electric's payment for sequestration in Malaysia (Pearce, 1995). Prices were as high as US$5 per metric ton or higher as in the case of PacifiCorp considering a Salt Lake City urban tree project that would have entailed prices of US$15–30 per metric ton of carbon sequestered.

4.1. CDM and Haiti: an example

Haiti, with a population of just over seven million and dwindling fuelwood resources, is a country possibly ready for a massive introduction of solar ovens. Smaller projects have been instituted in scattered villages to date and even larger bakery-sized ovens have been considered and installed. If 10% of the approximately 900 000 households in Haiti could be targeted as acceptable candidates for solar oven use, that would mean the introduction of 90 000 solar ovens. Assuming that cloudy days and inconvenience of use might reduce utilization to 60% of cooking time, there would still be a sizeable reduction in the burning of charcoal and fuelwood.

Total household fuelwood use in Haiti is just under 3.3 million m^3 per year (Haiti, 1994). Assuming 20 m^3 per wooded hectare translates total domestic fuelwood use into the burning of 165 000 ha per year by all households. Each Haitian household would therefore use 0.1825 ha of woodlot per year. Reducing that amount by 60% would result in saving 0.1095 ha of wooded area per year for carbon sequestration. In the simplest case where we leave out regrowth of wood harvested for burning—not an unusual assumption in a country where deforested land is rapidly becoming desert—over a 10-year period approximately 1 ha of woodlot could be considered as available for carbon sequestration per household using solar cooking.

How much carbon a hectare of depleted soil in Haiti can sequester or store in the form of plant matter is crucial in determining just the economic viability of CDM. At an optimistic six tons per acre, an estimate for a fast growing forest, the value of sequestered hectare would be US$12–30 (Trexler, 1995). To reach that level of growth, more funds would need to be expended on fertilizer. An inexpensive stove costing US$20–30 could be distributed, but it would be necessary to provide support services to ensure its use, which would entail ancillary costs. Emissions from the manufacturing of the stove would also need to be considered in a complete calculation. In the aggregate, 90 000 households sequestering US$30 worth of carbon could attract a US$2.7 million carbon sequestration investment from an interested party in the developed world. The scale of the project might make it feasible, although stoves in this price range are less likely to last 10 years, thereby further reducing the amount of sequestration. Additional costs for land preparation and support services would add hundreds of thousand of dollars to the project; however, financing some of it through CDM does appear to be a feasible alternative. Money saved on charcoal purchases, as much as US$20 per month in Haiti, could provide considerable further impetus to jump starting a CDM program. If Haitian families could borrow on their future savings, there would be sufficient capital to finance a more sophisticated solar oven and effective training programs.

5. Solar Cooking

Solar Cooking International claims solar cooking has been or is being introduced in 69 countries (1995). At the end of 1993, the largest number of stoves in use were in India (340 000) and China (140 000), largely due to government promotion and subsidization efforts (Kontinnen, 1995). Solar cooking has been part of India's National Program since 1982. In India, 85% of predominately solar box cookers were distributed in just six states with government subsidies reducing costs by one-third.

Two types of solar cookers are in general use: those that use the sun directly with parabolic reflectors that reflect heat onto the cookpot, and indirect solar cookers—insulated boxes (Hankins, 1987). On a larger scale, institutional type solar cookers use flat plate collectors to trap and transfer heat to kitchens. The solar box type cooker is probably the most effective design for households because of convenience, ease of handling and efficiency when compared to basket and reflector models (Devadas, 1992). The box of a solar box oven may be made of many different types of materials ranging from cardboard to plastic. The simplest and yet effective Kerr/Cole design constructed of cardboard, glass, and aluminum foil can attain temperatures of 105°C even on partially sunny days in an hour in tropical regions (Rodgers, 1994).

With cardboard difficult to find in some areas of the world and also susceptible to damage from moisture, corrugated plastic—polypropylene profile or flute-board—which is unaffected by water, steam, termites, or ultraviolet rays—is proving to be a more desirable material. Its availability in different colors can also enhance the aesthetic aspect of solar ovens. The plastic's insulation value is equivalent to 2.5 cm of rock wool. Pre-cut and creased plastic sheets including a serviceable reflector may cost less than US$10 per stove. The reflector consists of aluminized paper glued to the cover. Two transparent plastic sheets may be used in lieu of tempered glass for glazing. An inner tray of aluminum and 5.0 cm of rock wool between the outer shell and inner tray provide insulation (Magney, 1992).

In Afghanistan, most solar stove sales or distribution has taken place in Kabul which at times has been without electricity for as long as 2 years. In this crisis situation where alternatives to cooking with fossil fuels or electricity are extremely limited, solar stove demand has been greater than supply. Many Afghanis, in the midst of the disruption of civil war, have been willing to accept change and have quickly learned how to use the ovens. One supply trip sold 780 ovens in a 5-day period to people already on a waiting list (Continuing War, 1996). Overflow demand was so great that people wanting ovens broke down the compound gate. In 1995, 7 weeks of work with families in a refugee camp led to the installation of 5700 ovens with accompanying follow-up training.

Afghanistan has been an exception in the attempts of many NGOs to convince people to use solar ovens. Diffusion of innovation is a difficult and not always successful undertaking. For example, a 2-year campaign in a Peruvian village succeeded in convincing only 11 of 200 families to boil their water to avoid illness (Rogers, 1983). For Peruvians, heating water was associated with treatment for illness, not disease prevention. Communicating innovation is considerably more complex than simply announcing a new way of doing things. In order to be widely adapted, it is necessary but not sufficient for innovation to be beneficial. The major characteristics of successful innovation include a sufficient degree of relative advantage over what the innovation is superseding; compatibility with existing values, past experiences and needs of prospective adapters; the innovation must be understood, which means simplifying its communication; people must be able to try it out without risk. Rogers (1983) outlines five steps in the diffusion process: knowledge, persuasion, decision, implementation and confirmation.

Change agents perceived as or actually different from those who are presented with innovation can inhibit its adaptation. The US Peace Corps and SCI used change agents from outside local communities who were from different socioeconomic classes and did not hold the same norms as prospective innovation adapters (Grundy and Grundy, 1996). Diffusion can succeed much better if a local person can be trained who will then plug into various cliques facilitating ‘bridge ties’.

Ex post surveys and examinations seeking to determine why solar oven use has not become popular may turn up results that include:

- lack of information
- lack of confidence
- comparatively high cost (US$25–30)
- impossible to make breakfast
- limited time of day it can be used
- it takes longer
- it can’t fry meals
- there are fuel subsidies but no subsidies for solar ovens
- unexpected changes in weather disrupt cooking
- high interest rates making borrowing difficult
- insufficient space or too shaded or children play where oven would need to be put
- both husband and wife work
- no strong motivation to change current way of cooking
- manufacturers unknown (Nandwani, 1992).

In a survey of households in Belize and Honduras, consisting of 314 interviews and 554 mailed questionnaires, results were mixed. Individual households tended to begin solar cooking intermittently over a 2–3-year period gradually increasing use as confidence increased. Forty-two percent used solar cookers most sunny days, 32% used the cookers several times per month, but 25% used them only rarely (Blum, 1992). Promoters agreed that successful introduction required the extensive involvement of women, ability to adapt to local conditions, and ongoing resources available to explain how to use the solar cookers (Blum, 1992). Another survey tried to pinpoint why adaptation had been successful in a program that used oven-building workshops. It found that contributing factors included adaptation of solar cooker designs to local conditions, predetermination of essential accessories, preliminary assessment of likely success, the structure of the oven-building workshops, and follow-up programs for those who built solar ovens (Lankford, 1992). Key to the process is the assurance that the stove fits user needs as closely as possible and the generation of a high degree of personal interest by the user in order to open up informal communication channels that lead to a greater possibility of diffusion (Agarwal, 1986).

A survey of 155 users of solar box cookers in Zimbabwe found that 51% of users believed that the cost of building a solar box cooker prevented others from adopting them. Twenty-one percent felt the lack of assistance and follow-up discouraged diffusion. Nineteen percent cited the difficulties in obtaining materials (Rodgers, 1994). Namibians liked the taste of solar cooked meat, but did not care for solar cooked millet-porridge which is a mainstay of their diet (Kontinnen, 1995). Frying any foods is virtually impossible and making chappatis (unleavened bread) is difficult at best. Dietary changes that must be made to conform to shortcoming of solar cookers are a decidedly negative factor in adaptation and, as such, violate central tenets of Rogers' major characteristics of successful diffusion.

Convenience is also crucial in the introduction of a new cooking method. During prime cooking hours, women are often engaged in agricultural work away from the home, making solar cooking difficult. Food safety concerns are also very real inhibiting factors. Food outside the home may be meddled with by people, birds or livestock (Devadas, 1992). In Nepal, where solar cookers could successfully be used 6 months of the year, barriers to acceptance can range from fear of the 'evil eye' cast on food cooking outdoors, to unwillingness to change cooking and eating habits (Manandhar, 1997). Houses built on hillsides may also lack open, sunny spaces to locate a solar cooker.

Efforts to promote solar cooking are hampered by lack of infrastructure. Initial cost of the cookers, while often apparently low, may yet be a considerable barrier to subsistence farmers only peripherally engaged in the market economy. Solar cooking has to be understood as only a partial solution to cooking needs and, as such, integrating it into cooking routines with existing devices and kitchen management is crucial to acceptance.

6. Cultural and gender dilemmas

Introducing a new way of food preparation that entails a new approach to cooking itself can be culturally disruptive in ways that are not readily apparent, such as the inability to bake bread at night in a solar oven. Among the radical changes required is that meals would need to be planned well in advance and preparation begun hours earlier (Rodgers, 1994). Solar ovens, because of the need for advanced planning, limit the ability to cook food quickly when unexpected guests drop by. Prospective users of solar ovens as well as their promoters fail to explain and/or understand that the solar oven is not necessarily a complete replacement but rather an addition to the kitchen. For some, cooking in more than one way may be as difficult to comprehend as using the solar oven itself.

If the use of solar ovens were to become widespread, that use would interrupt established work patterns of women and children by reducing the many hours spent foraging for fuelwood. One local chief in Lesotho wondered what women and children would do with the additional time they would have on their hands, hinting that it could only lead to mischief or meddling (Grundy and Grundy, 1996). Another villager, sensing opportunity, suggested they could do other work with the freed up time, making the cooker a valuable asset.

Ironically, it may sometimes be those more attuned and accepting of the culture of the developed world who are less likely to embrace change they do not view as sufficiently modern. More traditional Ladakhis in India are more likely to adapt cookers to use for preparing dahl and beans and other foods requiring more cooking time as well as for heating water. Younger and more fashionable Ladakhis eschew solar cookers as not quite appropriate for late 20th-century lifestyles they see on media heavily influenced by the developed world (Solar Box Cookers in Ladakh, 1996). In Botswana, a local man asked if the solar cookers eagerly promoted by a European in his village were used extensively in Europe. When he was told they were not, he said he would not be interested in them until Europeans used them (Pulfer, 1992).

Women in rural communities or even many urban settings in the developing world typically have neither access to credit nor their own disposable income to purchase innovative products such as solar ovens. In many societies, women may rarely have access to information on the existence of new products. Rural women are infrequently educated or provided with the opportunity to engage in decision-making (Agarwal, 1986). One strategy to counteract the lack of adaptation and to involve women might be to use simple, locally built cookers. Local women could be trained to promote the solar stoves they build. Women could also be engaged in the basic research of cooking various types of local foods and subsequently disseminate information to prospective users (Manandhar, 1997).

Gender issues surround the introduction of new technology. While women do all or most of the cooking, it is men who are often seen as the decision-makers when it comes to the adaptation of new technology. The few Zimbabwean men who participated in workshops building solar cookers later forbid their wives to use them, leaving the cookers to remain idle curiosities. More often, men do not concern themselves with the women's work of cooking and foraging for fuelwood. One villager in Zimbabwe summed up the male view of cooking succinctly: “When there is not enough wood available to cook a meal, I will marry another woman who can find wood further away as my first wife cooks” (Rodgers, 1994).

Innovative improvements in wood burning stoves or the introduction of solar stoves would not be as attractive to men who make decisions but do not do the cooking. Purchasing improved food preparation technology would also lack the same social ‘prestige’ benefits, as do other goods, such as radios, televisions, etc. New cooking technology is also in conflict with what is seen as important traditions. In some areas of Africa, the three-stone stove is considered a symbol of a united family even though it is occasionally modified with the addition of a fourth stone. An obvious shortcoming of solar cookers is their inability to heat the house or hut in the early morning. For this and other reasons discussed, the solar oven has a long way to go to attain the threshold of a novel and yet acceptable innovation, as has the television and other modern technology. The cooking fire as social hub is unlikely to be replaced by solar stoves any time soon (Rodgers, 1994).

Cultural issues even extend to being accustomed to the smoke generated by cooking fires. The smoke is also seen as a way to control insects. To the Maasai of eastern Kenya, smoke is an ingredient of rural homes. It is believed to repel mosquitoes. Scientific findings contradict these assumptions. A recent Gambian study demonstrated no relationship between smoke exposure and the prevalence of malaria symptoms among 649 children up to the age of 9 years. It could be that particulates and not the smoke itself repel mosquitoes. Those particulates, however, are also harmful to human respiration. Dissemination of mosquito nets would be a better alternative (Kammen, 1994).

7. Economic Pressure to Change

In some areas of the world political situations have created demand for solar stoves that might not otherwise exist. Residents of Kabul have been eager to use solar stoves as exemplified by the riot-like conditions that exist when they occasionally become available. Out of necessity, refugees living in camps are more than willing to alter what is left of their customary lives to use solar ovens. For these desperate families the three stone stove may be an impossibility due to an almost complete lack of fuel. In a 1983 survey of Afghan refugees in Pakistan the average time families spent collecting fuelwood had reached 99 h per month (Allen, 1992).

Haitians are rapidly approaching an impasse as serious as that in Afghanistan without having had an open civil war. Poverty, overpopulation and generations of corrupt government have virtually eliminated forests. In Haiti, charcoal costs can range as high as 30–40% of family income and as a source of fuel its life expectancy is rapidly diminishing. Fuelwood expenditures as high as 25% of income is also a significant portion for urban Zimbabweans who cannot forage for fuel (Rodgers, 1994). Landless Hindus in Bangladesh often buy fuelwood instead of food during monsoon season (Agarwal, 1986).

In other areas of the world where there are no forests, fuel is scarce. Animal dung has been traditionally burned, but this too may be in short supply. The bleak landscape of northwest China and Tibet and the Andean highlands do not offer many options for fuel other than strong sunlight. In response, the Chinese government has instituted a program that subsidizes the cost of solar stoves in such areas (Xiping, 1992).

Where economies are relatively prosperous, solar cooking is still a curiosity. In Costa Rica, a country that is now considered to be well along in development, solar stove programs introduced in less prosperous rural areas have led to minimal diffusion. Researchers have quantified potential Costa Rican savings based on the degree to which solar stoves could be used during a typical year. The comparative list of potential annual savings includes 210 l of propane, or 203 l of gasoline, or 648 kg of fuelwood, or 1160 kWh of electricity (Nandwani, 1992). With electricity rates of US$0.04 per kWh, a subsidized rate, the less than US$50 annual savings is insufficient motivation in a country with a per capita income of well over US$2000 per year (World Resources Institute, 1994). Similar to Costa Rica's low-cost government-subsidized electricity, the Indian government chooses to do more to encourage the sale of gas stoves than it does in its solar stove construction and subsidization program (Solar Cooker Review, 1997).

Those with increasingly limited access to fuelwood typically live in areas where the sun can provide energy directly. Solar stoves are the most effective small-scale way to harness that energy. Unfortunately, it appears that only in instances of dire necessity are they being adopted. Wood-collecting households that are not impacted by fuelwood price changes, even though scarcity might prevail, are often not affected by fuelwood pricing policies of central governments (Amacher et al., 1996). Foragers will continue foraging, cutting ever wider swathes in remaining forests. Commercial logging is certainly a much more economically powerful factor in deforestation and the slash and burn agriculturist is close behind in eliminating many hectares of native growth in rainforests. In devastatingly deforested areas, such as Haiti, it is the inexorable wood gatherer or charcoal maker's persistent winnowing of remaining forest to serve the needs of an ever-increasing population who supplies the coup de grace to many remaining forests of the developing world.

8. Is solar cooking viable?

Simply marketing solar cookers on the basis of benefits, such as providing increased leisure time or additional agricultural labor, elimination of health problems arising from constant exposure to smoke or burned toddlers, stemming the loss of income spent on fuel, curtailment of deforestation and concomitant erosion, reducing infectious parasites by offering a cost effective way to pasteurize water, and the curtailment of air pollution (in general) from smoky fires has not been effective enough to result in widespread diffusion of use (Rodgers, 1994). Cultural and gender barriers have been stronger than these benefits and/or programs introducing solar ovens have not addressed all issues of resistance to adaptation sufficiently.

Societies shattered under stress, close to or having run out of fuelwood, e.g. Afghanistan, seem to be the most open to solar cooking as an alternative. Even then, inroads must be carefully made by conscientious NGOs working as virtual proselytizers of a new and yet ancient technology in order to assure that technology will in fact be diffused.

CDM to curb greenhouse gas emissions may provide a new source of funding to begin larger scale attempts to bring solar cooking to the developing world, but simply providing the solar ovens will not be sufficient. Even the economics of financing the introduction of solar cooking solely through CDM are inadequate or barely adequate, as was shown in a Haitian example. Nevertheless, there is sufficient possibility to at least partially fund solar cooking projects. Where fuelwood or charcoal is a priced commodity, as in Haiti, the viability of solar cooking would be well supported by the savings on charcoal that would ensue providing another potential source of making a larger scale program viable. What is necessary for successful implementation is a well considered program with community involvement.

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