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Review of Issues and Research Relating to Improved Cookstoves

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REVIEW OF ISSUES AND RESEARCH RELATING TO IMPROVED COOKSTOVES

by

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PREFACE

At the June 1986 meeting of the Executive Committee of the Board of Governors, the Science, Technology and Energy Policy Program (STEPP) was asked to put together a review of the issues and research on wood-fuelled cookstoves for consideration at the following Board meeting in October 1986. This paper was put together in response to that request by Hartmut Krugmann, with inputs and feedback from his colleagues in STEPP, the Forestry Program and other Centre units. It examines the rationale for cookstoves; reviews early attempts at stove design and promotion; gives an overview of current knowledge and programs; and provides some conclusions and recommendations for further research and Centre involvement. Further, in the Annexes, it reviews the Centre's activities in the field; provides some details about stove design principle, fuel efficiency and performance tests; and includes a bibliography.

The paper is not meant to be exhaustive. However, it includes the most recent general assessments and critical overviews of cookstove programs and research.

The paper drew heavily on recent general assessments and critical overviews of stove R&D and promotion. It also benefitted from other references and from information received in conversations with representatives from a variety of donor agencies and with international stove experts.

The author is grateful to the many individuals inside and outside IDRC who have contributed to this paper. Special thanks go to Dr. Amitav Rath (Social Sciences Division, IDRC) and Dr. Gautam Dudd (currently at the Universidad Nacional Autonoma de Mexico) for their careful reading and numerous valuable suggestions concerning earlier drafts.

INTRODUCTION

The promotion of improved cookstoves in developing countries dates back to the late 1940s. In India, a mud stove, called the Magan Chula, was introduced in 1947. After the country's independence, further efforts to promote improved stoves (so-called HERL stoves) were stimulated by the publication of the paper "Smokeless Kitchens for the Millions" (Raju, 1953). The major objectives were related to the benefits of health and convenience from the elimination of smoke. During the early sixties, Singer designed several new types of stoves in Indonesia, all of them equipped with chimneys (Singer, 1961). But none of these early programs appear to have substantial impact, and only a small number of stoves were actually built for use.

In the middle and late 1970s, however, the notions of "appropriate technology" and "small is beautiful" combined together with the international concern for deforestation and the perception of the adverse impact on the poor of rising energy prices in ushering in a wave of cookstove projects largely funded by international agencies (but not IDRC, which first remained sceptical of a number of these activities; see Table 1, for the sequence of IDRC support).

INITIAL COOKSTOVE PROGRAM RATIONALE

Wood and other forms of biomass remain the exclusive source of energy for the majority of people in the developing countries (Wood, 1985). In many developing countries, woodfuel accounts for more than two thirds of the energy consumption, over 70% of it being used for domestic cooking alone. This and two other observations combined together to provide the initial rationale for the focus of international activity on woodstoves. The first was the observation that traditional wood stoves converted inefficiently the primary energy available in wood into the useful energy used in cooking. Estimates of energy efficiency in traditional woodstoves were in the range of 5-10%, while for kerosene and LPG stoves, they range between 30 and 60%. The corollary to this observation was that, if the energy efficiency of woodstoves could be increased, the same amount of food could be cooked with smaller inputs of biomass. If that came to pass, it would reduce the total demand for biomass and thus the pressure on forests. It would also allow the poor people to spend less of their limited financial resources on purchases of cooking fuels. Finally, where the fuel is collected or gathered, it would reduce the time allotted for the task and thus give the poor, especially women and children, more time for other useful alternative activities. The fact that laboratory tests of alternative stoves seemed to show efficiencies of up to

30% led the proponents to the firm belief that an important solution was at hand which could have substantial impact, saving up to two thirds of the fuel consumed, and resulting in fuel savings as high as 70 to 80% of current practice. So a number of large dissemination programs were mounted.

The second observation which formed part of the initial rationale for woodstove activities was the increasing rate of deforestation. It was felt that this must result in woodfuel scarcity in many developing countries and regions. An estimated 10 to 15 million hectares (i.e., 1 to 2 percent) of existing forests are being lost annually through deforestation (World Bank, 1980 and 1983), with a corresponding decrease in the amounts of available fuelwood and an increase in price reflecting greater scarcity. There were two corollaries to this observation. One was that if wood supplies were declining, then more efficient woodstoves would be required, if only to maintain existing levels of cooking activity under conditions of steadily diminishing supplies. However, there was also a general belief that more efficient woodstoves would slow deforestation. This belief was considered to be valid without careful examination of the nature of the specific causes of deforestation.

One of the first and internationally more influential of these efforts started in Guatemala, as part of the reconstruction work in rural areas after the 1976 earthquake. It relied upon the promotion of a heavy mud and sand stove called the Lorena, (from the Spanish words lodo, clay or mud, and arena, sand). It is a massive fixed stove, with typically three pot-holes, a metal damper to control air flow, a chimney to remove smoke and a built-in container for heating water with waste heat. The Lorena stove appears to have attained a measure of success, despite some shortcomings (Foley, 1983; Caceres, 1983; Estrada, 1983). It became popular with stove programs and inspired programs of similar stoves in a number of other countries. Among these efforts, the "Ban ak Souf" program (Denève-Steverlynck, 1982; L. Diop, 1983) and the "Louga" stove in Senegal (using sand and clay as materials) and the "Nouna" (GATE, 1980) and "Kaya" stoves in Burkina Faso (using fired bricks/cement and concrete/stone/sand/clay, respectively) are well-known and frequently cited. Some 5,000 stoves had been built in Senegal and Burkina Faso by 1983 (Foley, 1983). All of the Lorena-type stoves are high-mass models, owner- or custom-built and targetted at the poor rural population (Manibog, 1983; Foley, 1983).

Worldwide, some 100 stove projects and programs (and a similar number of programs where stoves are important components) had been initiated by 1983 according to the Food and Agriculture Organization (Joseph, 1983). Virtually all international donor agencies have been involved in one or more of them with the principal objective of achieving woodfuel savings in order to alleviate the pressures on forest biomass and to improve the energy supplies of the affected population. To this end, large numbers of improved stoves were to be disseminated in order to make a dent on national woodfuel consumption and to help stem deforestation.

After years of promotional effort, it became clear that large-scale diffusion of the early woodstove improvements was not occuring as expected. By 1983, around 100,000 stoves had been distributed worldwide (much fewer than today), of which 20-30 percent were used only intermittently and other 10-20 percent not at all (Manibog, 1984). Even where stoves had been used, woodfuel savings either had not taken place, were hard to verify or not directly attributable to the stoves.

WEAKNESSES OF EARLY WOODSTOVE PROGRAMS AND CURRENT KNOWLEDGE

Why did the early improved-cookstove programs do so badly? As one observer put it: "The first generation of stoves and stove programs failed to deliver because they did the wrong thing, in the wrong place, in the wrong way, for the wrong reasons and with the wrong people" (Floor, 1985). This was also the major reason for the limited involvement of IDRC in the early stove programs. A variety of factors and assumptions appear to have contributed to this generally perceived stove malaise. They include the following.

Advantages of Traditional Cooking Methods

Traditional cooking devices, in particular the universally used open or three-stone fires, were assumed too quickly to be both grossly inefficient and unpleasant to use. The truth, however, is that in practice they are not as inefficient as was assumed. Though thermodynamically efficiency is not high, statements that open fires have efficiencies of around 5 to 10 percent are guesses and technically misleading. Fuel consumption of open fires can be reduced in a variety of ways and higher fuel economies are found to occur in real life wherever people recognize fuel to be scarce. More careful fuel feeding and fire tending, sheltering the fire against draught and placing the fuel on a grate if available, using the fire for shorter periods - all of these measures can contribute to higher fuel economy than the limited types of laboratory tests used. Tests show that efficiencies of up to 20 percent for three-stone fires and traditional stoves (Wood, 1985) are possible. In several field tests, traditional cooking devices were found to be no less efficient and sometimes even more economical in actual fuel use than the "improved" stoves introduced (Foley, 1983). Of course, in areas where they are used for cooking and space heating, fuel efficiency of traditional fires even approaches 100 percent. Finally, open-fire stoves have further special advantages: they are versatile, easy and cheap to build and provide heat and light while in operation; they can be positioned to provide a stable support for different shapes and sizes of pots and thus permit prolonged stirring of paste-like foods where required; and the heat output (or heat absorbed by the pot) can be controlled relatively easily and varied over some range by adding or withdrawing fuel (fuel sticks) and by raising or lowering the pot through a repositioning of the stones.

Neglect of Role and Perception of Stove User

In many of the earlier stove programs, little or no time was taken or effort made to examine the stove user and his/her needs or preferences. As a consequence, designs were produced largely without the feedback of the user and naturally did not satisfy certain valued functions of traditional stoves, or take into account the habits of cooks. Generally, the assumption was made that raising fuel efficiency was the only concern of stove users (it was often the only concern of the stove programs), which as we now know is often not the case, especially in rural subsistence areas. Also, there was a complete lack of definition of the target groups and dissemination programs and training courses often focussed on men, although women are the principal stove users and in rural areas also mainly responsible for fuelwood collection.

Stove Design and Testing

The early improved cookstoves were often designed by development workers with a great deal of zeal and enthusiasm but little technical background. Under the banner of "appropriate technology", new designs were quickly labelled "improved stoves" and construction manuals prepared, without prior serious scientific research. The design of the cook-stoves with the required characteristics is not easy. It requires an understanding of heat and mass transfer, combustion and material properties, a judgement of the needs and capabilities of the intended users, as well as a sensitivity for the opportunities and constraints for manufacturing and dissemination (Baldwin, 1986).

One deficiency of most early improved cookstoves (up until the early 1980s) was that they were bulky heavyweight models. Many were made of sand and clay mixtures (e.g. Lorena stove in Guatemala, see para 5) and had more than one pot opening and a chimney. Such stoves generally (with few exceptions) have a poor fuel performance - they may or may not save fuel relative to traditional stoves or open fires (Geller, 1983b; Yameogo, 1983). This low fuel efficiency can be attributed first to the large mass which absorbs considerable amounts of heat while warming up. This represents a significant heat loss unless the "waste" heat has some use (e.g. for the heating of the surrounding space or for drying). Further, the presence of a chimney and flue can cause problems of air flow control, if the stove is not properly designed, constructed and used. Finally, the heat transfer to the pot can be poor unless a damper is included, placed and used correctly (see Annex B).

Heavy sand-clay stoves can deteriorate quickly, dissolving in rain or developing cracks due to the heat. Thus, fuel efficiency (and other features such as smoke removal where there are chimneys) deteriorate quickly and the stove needs to be repaired or replaced soon if quality performance is to be restored. Finally, high-mass stoves are constructed on-site, often by their owners. While this can have the advantage of low cost, it complicates quality control and certain stove dimensions are critical to good fuel performance (see Annex B). It is difficult for unskilled and unsupervised persons to maintain these dimensions when constructing stoves.

Disparity between Laboratory and Field Tests

Many of the early stove projects claimed large fuel savings but few laboratory and almost no field tests of fuel consumption were carried out to substantiate the claims. Testing procedures tended to have sampling errors, faulty analysis and inconsistencies. There was also a lack of detailed follow-up and inadequate data of baseline fuel consumption patterns against which energy-saving achievements could be measured. In some cases, measurements of fuel savings were done right after the installation of the stoves, ignoring stove deterioration and declining performance over time. In other cases, laboratory performance was assumed to hold for the field, without any attention to the changes in the field relative to the lab. As a result, some data for the earlier stove programs suggested significant savings of fuel, while in others it was discovered that there were no savings or even fuel consumption increased (Foley, 1983).

In the last few years better criteria and more rigorous methods have been developed and applied systematically to the design, testing, production and dissemination of cookstoves. Application of scientific methods and analysis, at the theoretical and experimental level, has led to several key principles for stove design (Baldwin, 1985 and 1986). These concern the careful match between stove and pot (in some designs), the choice of stove materials and the maintenance of good combustion through the use of a grate and the control of the air supply. With regard to materials, one conclusion is that insulated light-weight stoves (e.g., metal stoves with ceramic liners, double wall construction, or use of insulating materials such as fiberglass or vermiculite) are desirable for minimizing heat losses and are superior to heavy mud stoves in terms of heat transfer to the pot and durability. Critical stove dimensions have been identified which must be maintained within a few millimeters according to specification if stove performance is not to suffer significantly. These include the stove wall-to-pot distance (in some designs) and the pot-to-grate distance. (More details on stove design principles and critical dimensions are found in Annex B).

The preparation of provisional stove testing standards in December 1982, recently updated in 1985, represented a major step forward in the development of improved cookstoves (VITA, 1982). Three different tests are proposed: The Water Boiling Test, the Controlled Cooking Test and the Kitchen Performance Test. Each test is used for specific purposes in stove design and dissemination. Annex B provides a brief description of the three tests and their purposes. Extended stove testing, using the above mentioned procedures, is becoming an integral part of many stove programs. Starting from traditional stove models, such testing leads to improved models in terms of fuel efficiency and avoids past mistakes of assuming stoves to be "improved" when in fact they consume more fuel than traditional models (Geller, 1982; Gupta, 1983; Ouedraogo, 1983). Substantial average fuel savings of 30 to 50 percent have been reported in some projects where new well-designed stoves are in use. Examples are a program in Karnataka involving high-mass sand-clay stoves (Ravindranath, 1984) and a program in Niger disseminating low-mass portable metal stoves (Strasfogel, 1984).

High Stove Costs and Limitations of Subsidies

Economic constraints also hampered early stove programs. Stoves were often too costly for the target population and had to be subsidized as a necessary condition for acceptance and diffusion. However, while some level of subsidy may be justified in the initial pilot phase of a stove dissemination program in order to facilitate institution building, training, promotion, the program should stand up on its own after a while. Extended subsidies may stifle the development of local fabrication capability and make it difficult for local entrepreneurs to compete (Wood, 1982; Deschambre, 1983). Also, recipients appear to be careless because they have smaller personal stakes in the new stoves.

Focus on Rural Areas

Many of the earlier stove programs focussed on the rural poor and emphasized custom-built and owner-built stoves. This was based on the belief that the need for welfare improvements was greatest in this poorest segment of society and influenced by the romantic self-help philsophy of the "appropriate technology" movement. Actually, the rural poor appear to be a more difficult target to satisfy with improved stoves. Studies indicate that the apparent problem of fuelwood scarcity is either not perceived by them or where perceived is very low in their priority of needs. They have little income to invest in a new stove and hence it must be fully subsidized or built by themselves at little cost. Finally, the poor tend to collect the firewood and hence collectors do not tend to ascribe a monetary value to the fuel or time saved as alternative opportunities for the time saved do not seem to be many.

In fact, the results of more detailed studies of the users of woodfuel, their sources and methods of acquisition and use has led to a shift in focus as to the most appropriate target groups. Except in certain limited regions and locations, shortage of biomass is not (yet) widespread. Rural populations usually have access to woods nearby, they also often supplement their needs with crop residues (although this is not always desirable). Also in rural areas, there is rarely a market for woodfuel and most fuel is collected during "spare" time and so does not acquire a monetary value. It is therefore more difficult for this population to place a high value on an innovation which saves on a plentiful resource or to make a cash investment for a gain in leisure. Both of these conditions disappear in peri-urban and urban areas. In these areas, woodfuel is usually collected from outside the region and sold to most users. It is now considered that these populations should provide the first target group; besides the few selected locations where significant biomass deficits exist and where this is also the perception and experience of the resident population.

Further, woodfuel fired stoves are not only used in households. Significant amounts of wood and charcoal are burnt in the kitchens of institutions like schools, hospitals and the military as well as in commercial enterprises such as bakeries, restaurants and butcheries. Small-scale industrial activities including beermaking, tobacco curing, tea and coffee drying, fish smoking and drying, brick making are other major woodfuel users in a number of developing countries. In countries heavily dependent on energy from biomass, total non-domestic woodfuel consumption is estimated to be 10 to 15 percent of the total national wood energy budget (Wood, 1983).

These applications represent opportunities for improvements that carry less risks and promise to have a faster impact and return for all involved, for two reasons. First, both the stoves and the fuel are commercialized and the stoves rarely have multiple functions. As a result, it is relatively easy to motivate people to accept stoves solely on the grounds that they are demonstrably more energy efficient and therefore save money. Moreover, stoves can be sold and bought commercially in the market. Second, the amount of woodfuel burnt in an institutional, commercial or industrial stove is much larger than in a household stove. Thus fuel performance improvements in a small number of stoves yield large fuel savings. The opportunities for improved stove development and dissemination in the institutional, commercial and industrial sector are substantial. One of the few initiatives in this direction is a project in Kenya supported by the Centre (see Annex A).

Woodstoves and Deforestation

The earlier view that the use of wood for cooking was an important cause of deforestation is not widely accepted any longer. Recent evidence suggests that usually the main contributors to deforestation are agriculture and commercial timber exploitation, not woodfuel consumption. Only in countries or regions where forests have nearly disappeared and biomass productivity is low (e.g. Sahel or Ethiopia) does woodfuel consumption significantly enhance deforestation at a national or regional level. Fuelwood in rural areas can be obtained from dead wood or cut from parts of the tree without killing it. For this reason, fuelwood consumption in the rural areas is much less destructive than agriculture clearing, urban fuelwood and charcoal demand, and timber operations. Unlike fuelwood gathering, charcoal burning usually implies removal of whole trees. This can cause serious <u>local</u> deforestation where charcoal is produced for consumption in local markets. For instance, most towns and cities in Sub-Saharan Africa, where charcoal is the main or only household fuel, are surrounded by belts of completely denuded land.

At the same time, it must be stated here that even in other countries where at the national level the use of woodfuel is not a significant factor for the loss of forest cover, there are localised areas where the two are closely linked (India, 1986). On the other hand, while use of woodfuel is no longer seen as the major problem for forests, reforestation is certainly one of the solutions to the woodfuel scarcity which can complement an improved stove program.

<u>Reforestation</u> has been a major focus of governments and development-assistance agencies. A large number of pilot fuelwood plantation and agroforestry projects have been

funded and sizeable land areas have been replanted with trees. However, according to the World Bank, even if demand for wood were to be reduced by 30 percent through conservation and replacement by other fuels, this would require 50 million ha. of trees to be planted between now and the year 2000, or a fivefold increase over current planting levels worldwide. The World Bank concludes that this is impossible due to a number of constraints associated with both donor agencies and recipient countries (Floor, 1985).

RECENT TRENDS

The results of the experience, mainly of the past decade, has led to improved programs where the mistakes of the past are being avoided and the rationale and objectives of the programs have also shifted. It is recognized today that successful implementation of a stove dissemination program depends not only upon the development of technically sound stove models but also on the knowledge of the socio-economic conditions and cultural characteristics of the target group and area. The dissemination strategy must be based on a thorough examination of a number of factors which are crucial to user acceptance. These include eating and cooking habits; the role of the fireplace in family/community life; the degree of fuelwood commercialization; the target group's purchasing power; the social and economic status of women; and receptivity to innovation. The more successful programs recognize the importance of user acceptance and field testing and surveys have begun to be widely employed (Bhattarai, 1983; Kinyanjui, 1983a and 1983b; Navarathna, 1983a and 1983b, Sepp, 1983; Ravindranath, 1984).

A variety of different extension strategies are possible. In Kenya, improved charcoal jikos are diffused utilising existing market channels for artisan products (Kinyanjui, 1983a and 1983b). In Sri Lanka and Indonesia, portable ceramic stoves are being promoted by extension workers with the assistance of local Surdjarwo. In India, the Karnataka government has organised a program for widely disseminating site-built stoves (Shailaja, 1984). In Guatemala, a national committee has been formed under the leadership of the Energy Ministry to coordinate the LORENA stove training and promotion activities of a number of agencies and non-governmental groups (MEM, 1985). Strong government support and leadership is essential for distributing large numbers of stoves in a short period of time.

Many of the earlier stove programs suffered from a lack of national commitments. Governments saw the stove programs as a hobby of donor agencies and had little interest or perhaps faith in the objectives. The newer studies have convinced a number of governments besides those cited earlier, that there is a need for a national program on improved stoves to meet the needs of specific rural areas and of urban and peri-urban areas. These have resulted in larger and better coordinated national programs. At the same time, the improved knowledge and information is beginning to flow more efficiently to all actors through improved coordination, networking and dissemination efforts.

The problem of quality control and the necessity to produce large numbers of stoves have recently led to a general shift in emphasis away from owner-built high-mass mud stoves toward commercial production, by artisans or central factories, of low-mass metal and/or ceramic stoves for urban or peri-urban consumers and possibly advanced rural economies. As a rule, increased centralization of production of stoves or stove components raises the quality and technical standard of the stove. However, experience has shown that a monopoly in a given area can adversely affect quality and cost.

In addition to quality control and high production rate, more centralized production can provide reduced costs as a result of economies of scale and design efforts. The cost of professionally constructed stoves is now in the range of 1 to 12 $US (Baldwin, 1985). In the lower range, such costs mean payback periods of only a few months, which makes them economical and attractive to consumers. The costs for training, distribution and promotion can in cases exceed the cost for the stove alone.

The CILSS/VITA regional stove program (including eight Sahelian West Africa countries) has shown in initial efforts in Burkina Faso, Mali and Niger that high-quality efficient sheet-metal stoves are being constructed and sold for as little as 2 to 3 $US. This is an order of magnitude less than the cost of the high-mass concrete stove previously promoted in Burkina Faso. A field survey in 1984 indicated 30 to 35 percent average fuel savings relative to the use of the traditional metal stove in use (Strasfogel, 1984). Kenya has had considerable success with the commercial production and sale of the improved "jiko" which adds an insulating ceramic liner to the traditional metal charcoal jiko. Annual stove production and dissemination rates are approaching 100,000. This is perhaps the largest diffusion rate and most advanced program found anywhere at the moment. The ceramic liners are produced in factories while stove bodies are produced by traditional jiko artisans. A double-wall metal stove is being constructed by artisans for a price of about 10 $US and commercialized in Botswana (Geller, 1983a; Baldwin, 1984). Projects in Indonesia, Nepal and Sri Lanka are producing low-cost high-performance ceramic stoves or stove liners at appreciable rates (100-1000 per month) (Baldwin, 1985).

Urban areas and commercial markets offer obvious advantages for cookstove production and dissemination and unlike earlier programs many recent cookstove programs focus on urban consumers. This is not to say, however, that rural areas are or should be completely excluded as targets for stove promotion. Innovative design on the basis of existing models (without changing valued features), careful construction (using templates and other methods of quality control) and the existence of an effective system of extension, maintenance and supervision can produce successful stoves. In the state of Karnataka, India, for example, an innovative high-mass sand-clay stove with a grate, chimney and three pot openings have been developed by ASTRA and begun to be disseminated with apparently considerable success. Kitchen performance tests showed average fuel savings of 52 percent relative to the traditional wood burning stove used in the region. The stove now costs the equivalent of about 7 US$. Diffusion takes place by trained stove builders. Certain parts of the stove (grate, firebox door, chimney sections) are fabricated centrally and templates are used to ensure that the critical dimensions of the stove are maintained. By the end of 1984, over 10,000 stoves had been built and 25,000 were planned for 1985. Field performance is monitored and follow-up studies carried out on a continuing basis (Geller, 1982; Lokras, 1984; Ravindranath, 1984; Shailaja, 1984). As another example, in Guatemala close to 20,000 Lorena stoves have been installed in six years (by 1983) (Caceres, 1983; Estrada, 1983). This program hailed as a success is now having a rigorous field evaluation study carried out.

Smoke Reduction and Health Impact

The earliest concern of stove designs has received renewed emphasis in the last few years (though many of the more successful stove programs do not involve smokeless stoves). There is a small but growing body of evidence that in village homes, indoor levels of noxious pollutants (carbon monoxide, particulates and hydrocarbons) can be higher than in the outside air of even the dirtiest industrial cities. A few studies of human exposure in village homes show that cooks and other household members can receive exposure to hazardous indoor pollutants such as carbon monoxide, formaldehyde and the carcinogenic compound, benzo(a)pyrene in excess of those suffered by heavy cigarette smokers (Smith, 1983).

Recent data indicate (i) the likelihood of a significant degree of ill-health from measured indoor exposures in village homes (Smith, forthcoming); (ii) several types of chronic and acute respiratory diseases associated with domestic smoke exposure (Dekoning, 1985); (iii) a strong relationship between chronic bronchitis and domestic smoke exposure (Pandey, 1985); and (iv) respiratory disease as the largest source of mortality in developing countries (WHO, 1984). There has been seen an increasing, though small, number of field studies focussing on smoke emissions of cookstoves. One such ongoing study is being supported by the Centre (3-P-84-0348).

The health consequences have so far been estimated by extrapolation of knowledge about the effects of the same or similar pollutants from different sources such as cigarettes. The importance of the issue has now been recognized by health experts and significant efforts are now underway to gather first-hand empirical data relating to the health impacts. The World Health Organization has started a 10 country comparative study to examine acute respiratory illness and other health effects related to indoor air pollution caused by wood burning cookstoves (Marwick, 1986). Recent woodstove programs have begun to take these concerns into account.

CONCLUSIONS AND RECOMMENDATIONS

Improved cookstoves do have an important role to play in the economic and social advancement of people in developing countries. After initial mistakes and frustrations, significant progress in stove design, production and dissemination has been made in the last few years. This progress has been achieved by systematically applying scientific methods to stove design, testing and promotion and by setting up appropriate institutional mechanisms for stove programs at the national and international level. While most national stove programs are still in the pilot phase, some (like those in Kenya) are now entering the diffusion phase.

In spite of this progress, many questions remain unanswered and there is considerable scope for further work. Promising research areas include:

(a) review and improvement of testing procedures in order to determine how different design and usage parameters affect fuel efficiency and other performance aspects;

(b) relationship between laboratory and field performance of stoves, field assessments (preferably periodic) and long term studies of stove programs to determine stove performance, usage and acceptability;

(c) institutional constraints and opportunities for stove production and dissemination, role of and mechanisms for subsidies in stove program initiation and longer-term stove diffusion and evaluation of extension strategies, in specific local contexts;

(d) determining factors for smoke emissions and exposure levels and health impacts of smoke exposure;

(e) development of testing standards for smoke emission, and study of health impact;

(f) design and dissemination of improved institutional, commercial and industrial stoves;

(g) impact of stove diffusion on nutrition, household economics and biomass availability;

(h) substitution between woodfuel and other energy sources where relevant for cooking in households, relative costs of fuels to the consumer and to the nation.

ANNEX A

THE CENTRE'S ACTIVITIES RELATING TO IMPROVED COOKSTOVES

Cookstoves related research and ancillary activities have been supported by the Centre since the late 1970s. Table 1 and 2 provide lists of Centre supported projects and DAPs, respectively. The Science, Technology and Energy Policy (STEP) Program in the Social Sciences (SS) Division and the Forestry Program in the Agriculture, Food and Nutrition Sciences (AFNS) Division have been the Centre units to have funded projects (a total of nine) in which cookstoves are the central research topic or an important component. Relevant DAPs (a total of seven have been funded by the Forestry Program, the Office of Planning and Evaluation (OPE) and the Communications Division. These DAPs have supported research type of activities (evaluations, surveys, reviews, project design, etc.), several workshops, as well as the proceedings of one of the workshops.

Total Centre funding on cookstove related research has reached approximately $600,000 CAD. This represents nearly 10 percent of total Centre support for energy research to date in terms of numbers of projects and close to 5 percent in terms of funding. All but three studies supported by project or DAP funding were carried out or initiated in the last two years and eight of the nine research projects are still active. About half of the studies (seven out of thirteen) have been in Africa, especially Kenya, Tanzania but also Sierra Leone. The other six are equally split between Asia (India and Indonesia) and Latin America (Haiti, Mexico and Guatemala). The distribution of funding by continent is roughly even.

About half of the studies (projects #1, 2, 5, 6, 8, 9 and DAP #1) fall broadly in the category <u>cookstove design and testing</u>, however, this generally involves laboratory and field testing of existing or new designs of cookstoves for households to improve the designs, fabrication and distribution of a few of the improved models and examination of their acceptance by stove users. However, there are significant differences in focus, scope and scale between the studies. The first Centre funded cookstove project ("Charcoal Stoves" in Tanzania) concentrated on basic new design. It started from the assumption that the existing metal stoves in Tanzania and Africa were fuel inefficient, and was aimed at designing new ceramic charcoal stoves on the basis of Southeast Asian models, using lab and field tests. The other early completed activity in Kenya (Testing and Evaluation of Charcoal/Wood Stoves) started from an

* Projects are listed in Table 1; DAPs (Divisional Activity Projects) are listed in Table 2.

existing design (The Kimaki Kiln Jiko) and focussed on improving this design through testing and users' inputs. Both activities belong to the early generation of stove projects and used what are now considered to be inadequate or incomplete testing and evaluation procedures although they probably contributed to the recent advances in stove design and testing. In the Tanzania project, some reports and stove prototypes were produced although the latter were not disseminated and are faulty due to failure to continue the project and to involve either users or producers in the problem definition, technology design or assessment phases (IDRC, 1985). By contrast, the Kenya activity appears to have had a lasting impact as skills were developed and experiences gained which were later used in the development of other jikos, including the highly successful ceramic jiko (IDRC, 1986).

The more recent five projects of the category (all ongoing) also include adaptive stove design (improvements of existing designs through lab and field testing). However, they differ from the two completed activities in placing much greater emphasis on examining factors relevant to user acceptance and stove dissemination strategies, in their different national contexts. This reflects recent wide-spread recognition that user acceptance and appropriate dissemination strategies and methods are crucial for the success of a stove. The Indonesia project focusses on the dissemination of the Tungku Sae woodstove and is carried out by the well-known NGO Yayasan Dian Desa. Like the completed Kenya activity (see last para), it relates to a major national stove program, both institutionally and in its research objectives. The other four projects (Haiti, Mexico, Tanzania and Sierra Leone) are in countries where there have not been major stove projects before or (in the case of Tanzania) where stove projects are many but unco-ordinated. In these cases, the IDRC project is helping to develop skills, create institutional capability and sensitize people to the issue, or draw the lessons from past activity (as in the case of Tanzania).

The three remaining ongoing projects (Kenya (#3), India (#4 and #7)) have components that are focussing on aspects and issues other than stove design, testing and dissemination and appear to be at the forefront of cookstove related research today (see main text). The Kenya project is one of the very few today to be looking at institutional cookstoves and kitchen design. It involves design as well as lab and field testing of a prototype stove for hospitals and schools and lab performance tests for heat radiation, temperature, humidity and carbon monoxide designed to identify improvements in the kitchen environment. The project was designed on the basis of a survey of institutional stoves in Kenya (DAP #5). One of the two Indian projects (#4) has a component which is examining smoke emission characteristics of traditional and improved woodstoves, a subject not systematically research anywhere until very recently. On the basis of field surveys and measurements in climatically and socioeconomically different areas, the effects of fuel type, stove design, house design and climatic conditions on smoke emissions, composition and indoor air pollution levels in rural huts are being studied, as are the relationship between length of exposure and dietary preferences and patterns. The other Indian project (#7) focusses on the role of women as the principal wood fuel gatherers and users and examines the effects of the changing availability of fuel on women's household activities and time expenditure patterns. This study has a component which on the basis of field surveys evaluates the impact resulting from the introduction of a new "Chullah" cookstove on women's time expenditure patterns and fuel consumption. This research will add to the important body of empirical evidence and information on the role of women in energy related activities of rural households in the Third World (Cecelski, 1984; Tinker, 1985).

The Centre funded a national survey of the status of wood stove dissemination activities in Guatemala in 1984 and a subsequent workshop in 1985 (DAP #4) (MEM, 1985). It followed the creation in early 1984 of a national committee on improved cookstoves by the Ministry of Energy, the first serious effort to coordinate the activities of the large number of different stove groups and projects in Guatemala. The purpose of the workshop was to elaborate a national strategy for improved cookstoves. Guatemala is one of the dozen or so countries with currently major national cook-stove programs and like Kenya and Indonesia is to be a regional focal point of the international stove network (see Annex B).

Finally, the IDRC/UNU supported Energy Research Group (ERG) has devoted a section on solid fuel stoves in the chapter on energy conservation of the final synthesis report (ERG, 1986). Five of the consultancy reports prepared for the ERG have examined issues concerning cookstoves (Tinker, 1985; Smith, 1985; Owino, 1985; Delepeleïre, 1985; Kaale, 1985). Three of them will be published (Tinker, 1985; Smith, 1985; Kaale, 1985).

Table 1. Cookstove Related Projects Funded by IDRC

	Number	Title	Country	Responsible Unit	Amount/Duration of Funding	Recipient Contribution	Status
(1)	3-P-77-0106*	Charcoal Stoves	Tanzania	Forestry	$44,300 (24 months)	$20,400	Completed
(2)	3-P-82-0024**	Fuelwood Production and Conservation	Haiti	Forestry	$332,400 (48 months) a/	$141,875	Active ***
(3)	3-P-84-0275	Institutional Woodstoves	Kenya	Forestry	$137,550 (24 months)	$67,580	Active
(4)	3-P-84-0348**	Energy Planning and Rural Energy Studies	India	STEP	$90,200 (18 months) b/	$50,425	Active
(5)	3-P-85-0106	Woodstoves	Indonesia	Forestry	$79,500 (22 months)	$11,250	Active
(6)	3-P-85-0176**	Energy Use and Technology Assimilation	Mexico	STEP	$41,335 (12 months) c/	$39,555	Active
(7)	3-P-85-0216**	The Management of Household Fuel in Rural India: The Role of Women	India	STEP	$128,330 (20 months) d/	$8,240	Active
(8)	3-P-85-0323	Dissemination of Improved Cookstoves	Tanzania	STEP	$64,490 (30 months)	$34,470	Active
(9)	3-P-86-0045	Utilization of Firewood Stoves in Rural Areas	Sierra Leone	STEP	$84,490 (30 months)	$35,415	Active

* Regional Evaluation Meeting was held in August 1983 (3-P-80-0185; $3,743)

** Cookstoves are an important component of research

($1,002,592) e/
(total amount of funding)

($409,210)
(total recipient contribution)

*** Cookstove component already completed

a/ An estimated $100,000 for cookstove component

b/ $15,400 for cookstove component

c/ An estimated $15,000 related to cookstoves

d/ An estimated $30,000 related to cookstoves

e/ Thereof an estimated $570,000 strictly for cookstove related research

Table 2. Cookstove Related DAPs Funded by IDRC

	Number	Title	Country	Responsible Unit	Amount of Funding	Status
(1)	3-A-81-4187	Testing and Evaluation of Charcoal/ Wood Stoves	Kenya	OPE	$13,000	Completed
(2)	3-A-82-4072	Cooking Stoves	Haiti	Forestry	$ 6,300	Completed
(3)	3-A-83-4162	Woodstoves Workshop***	Netherlands	Forestry	$13,380	Completed
(4)	3-A-84-4122	Woodstove Survey Workshop	Guatemala	Forestry	$28,330	Completed
(5)	3-A-84-4176	Woodstoves**	Kenya	Forestry	$4,700	Completed
(6)	3-A-84-4288*	Jiko Stoves Case Study	Kenya	OPE	$11,750	Completed
(7)	3-A-84-4372	"Woodstove Dissemination" - The International Workshop on Woodstove Dissemination	Global	Communications	$11,608	Completed

* Material for Chapter 4 of IDRC-246e (G1)

** Survey of institutional woodstoves

*** International Workshop on Woodstove Dissemination

DAP - Divisional Activity Projects

STOVE DESIGN PRINCIPLES, FUEL EFFICIENCY AND PERFORMANCE TESTS

The efficiency of a cookstove depends upon how well the heat is transferred from the hot gases of the woodfuel fire to the pot (convective heat transfer). As much pot surface as possible should be exposed to the fire. The distance between the fire and the grate is a critical design parameter. In some designs, the stove wall-to-pot distance must be kept as closely as possible (within a few millimeters) to that of the lay-out. If this distance is increased, hot gases escape more easily. Larger fires are then possible and the total heat flux to the pot is increased--but at the cost of significantly lower efficiency. If, on the other hand, the passage is narrowed too much, the flow of gas may be excessively restrained, the fire choked and the efficiency again reduced.

Stoves not only transfer heat to the pot but also to the surroundings. Massive stoves of mud, brick or cement, having thick walls and a high heat capacity, are good thermal insulators but take a long time to warm up and absorb a lot of heat in the process. Light-weight metal stoves have bad insulating features but warm up quickly and absorb little heat. Tests have indicated that only if cooking times are very long (at least 2 hours) do massive stoves lose less energy to the surroundings than low mass stoves. Of course, massive stoves may also be desirable if the absorbed heat is utilized, e.g. for space heating purposes. The insulating properties of light metal stoves can be improved appreciably through double wall construction or fired clay liners, with some concomitant increase in the thermal mass. Heat conductivity also plays a role in the transfer of heat through the walls of cooking pots. Aluminum pans allow food to be heated up more quickly and result in higher efficiencies than heavy clay pots. Of course, use of a lid will enhance efficiency further as evaporation losses from the pot are prevented.

In stoves with a chimney and a flue, the control of air supply is critical. Use of adjustable dampers for controlling the air supply can be a problem due to the need for operating the dampers correctly. Also, deflectors or baffles may need to be built into the path of the gas flow, in order to increase convective heat transfer to the pot. The position of the baffle is critical and must be determined on the basis of a precise understanding of the gas flow pattern. Stoves with two or more holes allow the utilization of "waste heat" and may improve fuel efficiency over an equivalent number of single-hole stoves (Prasad, 1983). However, this depends on whether all heat available is utilized (e.g. for water heating in addition to cooking in the case of the Lorena stove, see main text). Furthermore, the dimensioning and relative positioning of the fire-chamber, gas passages, baffles and other parts can be critically important to the desired functioning and efficiency of the stove (Foley, 1983).

It is difficult to define or interpret "efficiency." Problems with interpreting cookstove efficiency arise from the fact that wood energy inputs often cannot be precisely quantified (they depend on moisture content, type and calorific value of wood, piece size, etc.) and that energy output is equally difficult to determine (the quantity and type of food, the behaviour of stove user and the type of cooking utensils can vary from case to case). Additional uncertainty is introduced by the fact that as a stove ages, its efficiency usually decreases. Furthermore, efficiency varies with power output. The predominant cooking practice is to bring quickly to a boil and then simmer for a long time (e.g. cooking rice or beans). Thus, the higher the range over which a stove's heat output rate can be varied, or its ratio of maximum to minimum power output (the so-called "turn-down ratio"), the greater the potential for fuel economy. Fuel consumption is determined by the maximum power of a stove, its turn-down ratio and its efficiency. The term "specific fuel consumption" (SFC) has been proposed for measuring fuel economy. This is calculated as fuel consumed per family member (per day or per meal) or per unit of food cooked.

Professional stove design relies upon performance testing. Three standardized performance tests have been proposed in December 1982 and widely applied since. The Water Boiling Test (WBT) is carried out in the laboratory and is used to study how variations in stove design affect fuel efficiency or to make a quick comparison of the performances of different stoves. The test consists of a heating up phase (high-power phase) and a simmering phase (low-power phase), in order to simulate the two most common cooking modes. Performance is indicated by three numbers: SFC (or efficiency) during heat-up phase, SFC during simmering phase and average cooking time. The Kitchen Performance Test (KPT) is carried out in the field and measures the relative quantities of woodfuel consumed by two stoves when they are used under normal household conditions. It indicates the overall change in fuel consumption and other impacts in the day-to-day use of the new stove. It normally involves at least five households and takes at least five consecutive days. An intermediate test, the Controlled Cooking Test

(CCT), performed in a laboratory or field demonstration centre, involves the preparation of standardized meals. It sheds light on the cooking performance (fuel used, time spent) of a prototype design and provides user feedback prior to field testing or dissemination.

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