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Epidemiological, Social and Technical Aspects of Indoor Air Pollution from Biomass Fuel

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WHO, Geneva, 5-8 June 1991

INTRODUCTION

Wood, crop residues, animal dung, and other forms of biomass are used by approximately half the world's population as cooking and/or heating fuels, often in poorly ventilated conditions leading to high exposures to health-threatening air pollution. In addition, dependence on such fuels can lead to other health problems due to greatly increased time and effort required for gathering and preparing them in many parts of the world. Precise correlations between use of these fuels and specific health effects have rarely been pinpointed, unfortunately, due to the large numbers of confounding factors, and also to the modest amount of resources available for such research. Given the numbers of people involved and the exposures experienced, however, there is reason to believe that more research would be justified.

The traditional approach to problems created by use of biofuels is to encourage movement up the "energy ladder" to cleaner and more efficient household fuels such as bottled gas. Unfortunately, this route is unavailable at present to hundreds of millions of people because of its high cost and low reliability of supply. Other methods of alleviating the problems, such as programmes to disseminate improved biomass stoves which use less fuel and cause less smoke exposure, have proved to be more difficult than anticipated because of a range of technical, cultural, economic, and administrative barriers.

As has been pointed out by a number of international studies, the socio-economic and environmental problems caused by tightening biomass supplies are escalating in many areas. Urgent attention is thus needed to find the long-term goal of providing high quality fuel supplies to the poor, and to the immediate task of accelerating the application of presently available interventions.

The nature of these problems is such that efforts to improve understanding and implement solutions will be most successful if they take into account the perspectives and insights of a range of disciplines. This consultation was held to investigate these problems further and to provide guidance for a multi-disciplinary approach to the required research.

The working papers prepared by the participants have been published as a companion document to this report. The report, however, comprises the discussions and recommendations developed at the consultation by the three working groups: Health, Technical, and Social. The central issues that entered into the determinations of all the groups have been summarized in Figure 1. In this figure, the problems related to poor quality household fuels are set in the context of general societal concerns: poverty, inequity, and poor health. Examples of both short term and long term solutions are highlighted, details of which are found in the discussions of the three working groups below.

Overall recommendation of the consultation

In addition to the specific recommendations of the three working groups, the Consultation agreed on the following statement:

It is recommended that decision and policy makers, and professional and scientific bodies, encourage their governments to introduce and support resolutions in appropriate international fora calling for research and action to reduce excessive exposure to indoor air pollution, which is a particular problem in poor communities of developing countries.

It was also agreed that the United Nations Conference on Environment and Development, planned for June 1992 in Brazil, would be an especially appropriate forum.

Figure 1. This illustrates some of the linkages between the problems commonly identified by the working groups. Starting with the important issues on the left, poverty, inequity, and poor health, the figure lays out a framework of goals and both short term and long term solutions.

LINKAGES

PROBLEMS		GOALS		SOLUTIONS	
General	**Specific**		**Short Term**	——▸	**Long Term**
	Fuel scarcity	To conserve fuel and/or increase supply ▸	Stoves (fuel conservation) ▸	Tree planting	▸ Improved access to fuel supply
Poverty					
	Pressure on women's and children's time	To release time ▸	Stoves (fuel conservation and faster cooking) ▸	Tree planting	▸ Affordable

Inequity					alternative fuel technologies
	Indoor air pollution	To reduce levels of pollutants ▶	Stoves (lower smoke emissions) ▶	Chimneys	
			▶	Improved ventilation	
				▶	Cleaner fuels
Poor Health	Poor working and living conditions	To improve household environment ▶	Stoves (safe, comfortable, convenient) ▶	Better kitchen design, equipment and culinary activities ▶	Better housing

HEALTH EFFECTS OF BIOMASS FUEL USE

Pollutants and health risks

The provision of air that is safe to breathe is just as important as safe water or food. Yet many millions of people, predominantly women and children in the poorest developing countries, are obliged to breathe air that is heavily polluted with biomass emission products.

Air pollution in general and indoor air pollution in particular have been associated in many people's minds with industrialization and urbanization and thus with the cities of developed countries where most of the measurements have been made. Recently, however, the UNEP/WHO Global Environment Monitoring System (GEMS) has demonstrated quite convincingly that the worst ambient conditions reported today exist in the cities of developing countries. Similarly, although most studies of indoor air quality have been carried out in developed-country buildings, the greatest indoor concentrations of and exposures to many important pollutants are found in both rural and urban households of developing countries.

Of the four principal categories of indoor pollution (combustion products, chemicals, radon, and biological agents), research in developing countries has focused on combustion-generated pollutants, and principally those from solid-fuel-fired cooking and heating stoves. On a global basis, it is estimated that more than half of the world's households cook daily with unprocessed solid fuels, i.e. biofuels or coal. An unknown, but significant, proportion of this activity takes place in conditions where much of the airborne effluent is released into the living area. Although ventilation rates are often relatively high, the emission factors for such fuels are so great that indoor concentrations and exposures can still be quite significant. Compared with gas stoves, for example, even stoves using one of the cleaner biofuels - wood - typically release 50 times more particulates, carbon monoxide, and simple as well as polyaromatic hydrocarbons in cooking an equivalent meal.

Although there were pioneering efforts in Africa and Papua New Guinea in the 1970s, most of the epidemiological studies focusing on the health effects of such stove smoke were published in the late 1980s. Even now, however, the total number is small. The majority have been done in India or Africa in homes burning biomass fuels or in China with coal-burning homes, although a sprinkling of studies have been conducted to examine the burning of biomass in Latin America and Southeast Asia. The survey of current knowledge which follows this section briefly lists and summarizes the available studies directly related to health effects caused by air pollution from biofuel combustion in developing countries.

The adverse effects of biomass use on human health are not restricted to problems of air pollution. Each part of the fuel cycle (production, collection, processing, and combustion) has its hazards, as shown below.

FUNCTION	POSSIBLE HEALTH EFFECTS
a) **Production**	
Processing/preparing dung cakes	Faecal/oral/enteric infection Skin infection
Charcoal production	CO/smoke poisoning Burns/trauma Cataract
b) **Collection**	
Gathering fuel	Trauma
	Reduced infant/child care

continued overleaf

Cont'd

	Bites from venomous snakes, spiders, leeches, insects
	Allergic reactions
	Fungus infections
	Severe fatigue
c) **Combustion**	
i) Effects of smoke (acute and subacute)	Conjunctivitis, Blepharo conjunctivitis
	Upper respiratory irritation/inflammation
	Acute respiratory infection (ARI)
ii) Effects of toxic gases, eg. CO	Acute poisoning
iii) Effects of smoke (chronic)	Chronic Obstructive Pulmonary Disease (COPD), chronic bronchitis
	Cor pulmonale
	Adverse reproductive outcomes
	Cancer (lung)
iv) Effects of heat:	
- acute	Burns
- chronic	Cataract
v) Ergonomic effects of of crouching over stove	Arthritis

Although there are a number of potential ill effects, most concern and research has been directed towards those related to the smoke exposures produced by traditional biofuel combustion. Of the health effects that might be expected from such exposures, little if any work seems to have been done on eye problems although there are anecdotal accounts making the connection. Decreased lung function has been noted in Nepali women who reported more time spent near the stove, as it has been for Chinese women using coal stoves compared to those using gas stoves. Respiratory distress symptoms have been associated with the use of biofuel in India, Malaysia, and in several Chinese studies among different age groups using coal, some with large population samples. Acute respiratory infection in children, one of the chief causes of infant and childhood mortality, has been associated with Nepali household-smoke exposures. Woodsmoke has also been identified as a significant risk factor for ARI in three parts of Africa. A recently reported study of pregnant women in India has noted that biofuel smoke was a significant risk factor for stillbirth.

Studies of chronic disease endpoints are difficult because of the need to construct exposure histories over long periods. Nevertheless, chronic obstructive lung disease has been associated with the daily time spent near the stove for Nepali women and found to be elevated among coal stove users compared to gas stove users in Shanghai. Cor pulmonale has also been found to be unusually prevalent in biofuel-using non-smoking women of India and Nepal. In contrast to early reports, there seems to be little or no risk of naso-pharyngeal cancer from cookstove smoke. Several studies in China, however, have found coal smoke to be a strong risk factor for lung cancer among non-smoking women and one in Japan has related lung cancer to past use of biofuels for cooking. In addition, severe fluorosis has been observed in several parts of China where coal fluoride levels are high. More details and exact citations are given in the survey of current knowledge following this section.

The high indoor concentrations and the potentially large, poor and thus vulnerable populations at risk, argue for more resources to be devoted to epidemiological studies of large numbers of exposed populations, using appropriate quality control measures in order to generate reliable quantitative dose-response information. In the meantime, however, enough is known to warrant household, community and government efforts to reduce exposures through education, and introduction of improved stoves, cleaner fuels and enhanced ventilation.

In order to better understand the links between smoke and ill-health and to establish which is the most efficient and appropriate intervention in a particular community, research on many fronts is needed.

Critical knowledge gaps and needed research

Populations at risk

Although there has been concern and research in developed countries about the use of gas as a cooking fuel, the concentrations of pollutants it generates are many times lower than those of interest here. The populations at risk due to solid fuel used for cooking are fairly well defined through a range of energy use surveys taken since the mid-1970s. As mentioned, these fuels are used by about half the world's population - some 2.5 billion people. The fraction of these people cooking in poorly ventilated conditions is significant, but not known in detail. It seems reasonable to say, nevertheless, that hundreds of millions of people are affected.

Global, regional, and national estimates about the general dimensions of the health problems are useful for establishing research and intervention priorities, although of course, local surveys will be needed before any actions are taken. Local surveys can identify which members of a given community are at risk of adverse effects, as listed above. Development of simple survey instruments which could be used by village-based primary health care workers has high priority.

There are strong indications of a connection between indoor air pollution and acute respiratory infection (ARI) in infants and young children (<5 years); however, the strength of this connection is not yet quantified. Given the large numbers (4-5 million per year) of children from developing countries who die from ARI (pneumonia), this is a very high priority for research.

The reproductive health and outcomes of expectant mothers and their babies are also important research areas. For example, does smoke inhalation increase the risk of low birth-weight or miscarriage? Other suspected adverse effects include damage to the eyes (conjunctival irritation, etc.), ultimately leading to impaired vision.

Epidemiological and other health studies

A high research priority is to conduct epidemiological studies to identify and quantify the relationships between ARI, indoor air quality (biomass smoke, tobacco smoke), nutritional status, other infections, family/household composition, socio-cultural variables, and so on.

Possible research strategies for epidemiological studies include:

i) Case control studies to establish relationships, identify dose-response and dose-effect relationships: some studies have been done but more are needed.

ii) Studies of "natural experiments," in which the incidence rates of ARI episodes might be examined longitudinally in relation to such changes as introducing stoves with chimneys in dwellings previously lacking chimneys.

iii) Intervention studies in which health status is assessed with and without interventions such as improved stoves.

All such studies, of course, should meet accepted scientific standards for quality control and ethical conduct.

Case control as well as cohort studies can also be used for examining possible relationships between smoke exposure and reproductive outcomes.

A principal chronic effect of smoke inhalation is impaired lung function, ultimately leading to chronic obstructive pulmonary disease (COPD). Clinical and pathophysiological studies of lung function are another avenue of research.

A variety of multi-disciplinary research strategies will be required to clarify and delineate these delayed and chronic effects. Case-control studies could help establish causal relationships for COPD and cancer although one must be aware of potential sources of bias and confounding variables. Cohort studies of populations containing groups exposed to varying and known levels of indoor smoke have the potential to allow more quantified inferences to be made. For example, large populations could be observed for prolonged periods. Suitable locations for such studies can be found in China and Indonesia. A retrospective cohort design might be feasible if a suitable setting and database exist.

Case control studies might be a suitable method to examine the relationship between radiant heat and cataract, with careful consideration of confounding variables.

Since the potential health effects of biomass smoke, especially ARI and COPD, are common to all developing countries, and are influenced by numerous risk factors, epidemiological studies in many different settings should be encouraged. Experience in other settings, however, has shown that it is difficult and often unrewarding for international collaborative studies to attempt exact replication of methods and procedures. It is probably wiser to permit, indeed, to encourage, variation of study design, methods and procedures according to local environmental, socio-demographic and cultural conditions, recognizing that these variables are "fixed" in any given setting, rather than susceptible to manipulation to fit a common underlying research design. Afterwards, they can be considered together.

It is however, important for different laboratories and research teams to collaborate in the development of similar methods to measure exposure and health effects, incorporating inter-laboratory quality assurance procedures in order to make the results as comparable as possible. For example, pulmonary function test results could usefully be compared among study sites, using standardized instruments and quality assurance procedures.

In order to maximize scarce resources, research should, where possible, be linked to existing research projects that have already gathered some of the crucial information on ARI, birth-weight, or other outcomes in the target groups (examples include vitamin A deficiency and family planning projects).

Work is needed to improve the quality of existing data and to facilitate the collection of new data. The most accurate available indicator of indoor air pollution is personal and area monitoring for respirable suspended particulates (RSP). Further work is required, however, to improve the capacity to simply and quickly assess exposure to indoor air pollution. It is difficult to assess exposure to RSP in children 2-5 years old with existing methods; time-weighted area monitoring might be the best choice. There is also the possibility of utilizing appropriate biological markers, another research priority.

Another research task is the development of a rapid, simple method for early detection of damage to health - a screening test such as a modification of the British Medical Research Council's respiratory symptom questionnaire. This would help in deciding when health effects require intervention.

Other methods of assessing health effects include maintaining a diary of activities and symptoms, simple questionnaires, utilization of existing clinical data (e.g. birth-weight data). All data-gathering instruments must record social, cultural, and environmental factors, so that these potentially confounding variables can be duly considered in the analyses.

Epidemiological, toxicological, engineering, environmental, and anthropological research in this area should be directly coordinated. The combined effect of a multidisciplinary approach greatly enhances the power of research to produce results that can be acted upon.

Information and awareness

Present knowledge about the effects of indoor air pollution should be used to:

- justify further research in required areas, including developing and testing intervention measures;
- justify action in order to reduce indoor air pollution; and
- increase public awareness and provide information and education on risk avoidance.

To do this, a number of different actors have to be influenced, often by different means: individuals, public health authorities (national and international), and politicians.

Ways of influencing the health sector and authorities can be defined as presenting existing information through publications, personal communication, conferences, and policy seminars.

In many instances, national authorities require evidence specific to their country before accepting the existence of a problem. To this end, the above research methods and procedures are proposed as effective ways of assessing the situation within each affected political jurisdiction.

Individuals can be influenced through awareness campaigns in the press and other media. Health and other extension workers could make an important contribution.

In presenting information about respiratory diseases linked with biomass air pollution, it is important to point out ways of alleviating the situation. Such measures could include fuel substitution, improved kitchen and stove design, and behavioural changes; further work is required on all of these.

Conclusions

Epidemiological research can contribute much to assessment and clarification of the health problems associated with biomass production, collection, and combustion.

This research would best be conducted through a multidisciplinary approach which coordinates input from physicians, social scientists, air quality specialists, and technical experts on improved stoves and housing design.

The research priorities include epidemiological studies to confirm the causal relationship of biomass emissions to ARI (very high priority); on adverse reproductive outcomes (high priority); on COPD (high priority); and various other health outcomes specified above.

A powerful application of epidemiological methods lies in the evaluation of interventions, such as the provision of improved stoves.

Biomass smoke and health: a brief survey of current knowledge

Biomass fuels (wood, crop residues, dung, and grass) are used daily in about half the world's households as energy for cooking and/or heating. As discussed in the Health Group Report, this can lead to a number of potential health problems [Smith, 1990]. This section, however, focuses only on the health impacts from the air pollution which is released in large amounts when such fuels are burned in simple household stoves. Found in biomass smoke, for example, are respirable particulates, carbon monoxide, nitrogen oxides, formaldehyde, and hundreds of other simple and complex organic compounds, including polyaromatic hydrocarbons. In many parts of the world for all or part of the year, these pollutants are released from stoves in fairly unventilated homes or in enclosed courtyards. As has been shown in a growing number of air pollution monitoring studies, the resulting human exposures to these pollutants often exceed recommended World Health Organization levels by factors of ten, twenty, or more [Smith, 1987; Pandey et al., 1989a].

Because of these high concentrations and the large population involved, the total human exposure to many important pollutants is much more substantial in the homes of the poor in developing countries than in the outdoor air of cities in the developed world, which has received the vast majority of attention in the form of air pollution research and control efforts [Smith, 1988]. As a result, it has been necessary to extrapolate from the urban studies to estimate what the health effects might be in biomass-using households [de Koning et al., 1985; Smith, 1987]. In recent years, however, there have been a small number of studies which directly focus on these households and which generally confirm what has been extrapolated [Chen et al., 1990]. Following are brief summaries of the major health effects.

Acute respiratory infections in children (ARI)

ARI, as pneumonia, is one of the chief killers of children in developing countries. At 4-5 million deaths per year, it is equal to or marginally less than deaths from diarrhoea [Monto, 1990; Leowski, 1986]. ARI in general is also responsible for more episodes of illness than any other disease category. It is well known to be enhanced by exposures to urban air pollutants and indoor environmental tobacco smoke (ETS) at levels of pollution some 10-30 times less than typically found in village homes [USNRC, 1986].

The first published study of woodsmoke and ARI in young children was based on examinations of 150 infants coming to a hospital in South Africa [Kossove, 1982]. Significantly more of (double) the children with ARI symptoms lived in homes using wood-fires than those without symptoms. A number of more detailed studies were initiated in the mid-1980s, which are now being published. One that focused on school-age children in Malaysia found no relationship with the use of a woodstove, but did find increased prevalence of symptoms with ETS and use of mosquito coils [Azizi & Henry, 1991]. This negative result is similar to that of an earlier study in Papua New Guinea which also worked with school age children, who had much lower rates of serious ARI than children under 5 years [Anderson, 1978]. The only ARI study to actually measure air pollution levels was in Kenya, but this unfortunately only had resources to examine 36 households [Wafula et al., 1990]. They found high levels of pollutants in all of the houses, with little variation; thus it was not surprising that they found no association with ARI rates.

The most interesting studies now available were done in Nepal, Zimbabwe, and Gambia. The Nepal study examined about 240 rural children under 2 years each week for 6 months for incidence and severity of ARI [Pandey et al., 1989b]. They found a strong relationship between the maternally reported number of hours per day the children stayed by the fire and the incidence of moderate and severe ARI cases. In Zimbabwe, 244 children under 3 years reporting at the hospital with ARI were compared to 500 similar children reporting to a Well Baby Clinic [Collings et al., 1990]. Presence of an open wood-fire was found to be a significant ARI risk factor. In a study of 500 children in Gambia, girls under 5 years carried on their mother's back during cooking (in smoky cooking huts) were found to have a 6 times higher risk of ARI, a substantially higher risk factor than parental smoking. There was no significant risk, however, in young boys [Armstrong & Campbell, 1991].

These studies are extremely suggestive, but do not yet allow quantified conclusions because ARI has so many other risk factors for which it is difficult to account. What is most needed is a study measuring both ARI and air pollution levels in households before and after introduction of smoke-reduction measures, such as improved stoves. Only this kind of intervention study can provide the scientific information needed for answering the policy-relevant question of "How much can we reduce ARI by reducing indoor air pollution from biomass combustion"?

Adverse pregnancy outcomes

Low birth-weight, a chronic problem in developing countries, is associated with a number of health problems in early infancy, as well as other negative outcomes such as neonatal death. Several risk factors are associated with low birth-weight, most notably poor nutrition. Since active smoking by the mother during pregnancy is a known risk factor and ETS exposure is suspected, there is also cause to suspect biomass smoke as it contains many of the same pollutants. Under particular suspicion is carbon monoxide, which studies in Guatemala [Dary et al., 1981] and India [Behera et al., 1988] found in substantial amounts in the blood of women cooking with biomass. Another recent study in India found that pregnant women cooking over open biomass stoves had almost a 50% greater chance of stillbirth [Mavalankar, 1991].

Chronic obstructive pulmonary disease and cor pulmonale

Chronic obstructive lung disease, for which tobacco smoking is the major risk factor remaining in the developed countries, is known to be an outcome of excessive air pollution exposure. It is difficult to study because the exposures that cause the illness occur many years before the symptoms are seen. Nevertheless, there were studies in Papua New Guinea [Anderson, 1979], Nepal [Pandey, 1984], India [Malik, 1985; and Behera & Jindal, 1991], which led the investigators to conclude that non-smoking women who have cooked on biomass stoves for many years exhibit a higher prevalence of this condition than might be expected or than similar women who have had less use of biomass stoves. Indeed, in rural Nepal nearly 15% of non-smoking women (20 years and older) had chronic bronchitis, a high rate for non-smokers.

Cor pulmonale (heart disease secondary to chronic lung disease) has been found to be prevalent and to develop earlier than average in non-smoking women who cook with biomass in India [Padmavati & Arora, 1976] and Nepal [Pandey et al., 1988].

Cancer

There are many chemicals in biomass smoke which are known to cause cancer in laboratory animals and are found in mixtures known to cause cancer in humans [Cooper, 1980]. In the 1970s, based on a small study in Kenya, it was thought that naso-pharyngeal cancer might be associated with biomass smoke [Clifford, 1972], but newer studies in Malaysia [Armstrong et al., 1978] and Hong Kong [Yu et al., 1985] have failed to confirm this. Based on risk extrapolations from animal studies, lung cancer which might be expected to be common in biomass-using areas, is relatively rare [Koo et al., 1983]. Indeed, some of the lowest lung cancer rates in the world are found in rural non-smoking women in developing countries. This is somewhat of an anomaly, and can only be partly explained by poor health records. A recent study in Japan [Subue et al., 1990] on the other hand, found that women cooking with straw or wood-fuel when they were 30 years old have an 80% increased chance of having lung cancer in later life. (Cancer, like chronic lung disease, takes many years after exposure to develop.)

In contrast to biomass, there are many studies of the air pollution levels and health impacts of cooking with coal on open stoves, almost all done and published in China, where coal use for cooking is common [Hong, 1991]. A range of effects are found, including quite strong associations with lung cancer. Even in China, however, biomass use is much more prevalent, and yet has not received adequate scientific and policy attention.

Studies in developed countries

Woodsmoke exposures studied in developed countries are principally those resulting from smoke from metal heating stoves leaking into the home [Pierson et al., 1989]. A single case of recurrent severe respiratory illness in a Michigan infant was linked to such exposures [Honicky et al., 1983] and was followed by a study of the prevalence of symptoms in preschoolers in 62 homes, one half with wood-stoves and the other half without. A much greater proportion of the children in wood-stove homes (84% versus 3%) was found to have at least one severe symptom [Honicky et al., 1985]. In contrast, a similar study with about 400 older children (6-12 years) in Massachusetts found no such association [Tuthill, 1984]. A study of 58 case-control pairs of Navajo children under 2 years found that the presence of a wood-stove increased the risk of lower respiratory infection by almost a factor of 5, and along with respiratory illness itself, was one of only two risk factors that remained significant after multiple logistic regression [Morris et al., 1990].

The wide-scale long-term Six Cities studies found that the use of wood-stoves was associated with a 30% increase in respiratory illness in children aged 7-10 years in the cities, where wood-stove use varied from 5-46% [Dockery et al., 1987]. A recent study in Oregon found both indoor and outdoor wood-smoke particulate levels to be associated with lower lung function in 410 children ages 7-14 years [Heumann et al., 1991]. It is important to remember that the pollutant concentrations found in these developed country studies of households using metal heating stoves are normally substantially less than those found in village homes using unvented cooking stoves [Marbury, 1991]. Typical peak values during cooking, for example, are several thousand micrograms of respirable particulates per cubic metre as compared to, at most, several hundred in developed country homes during peaks. Daily averages are also much higher.

Conclusion

In summary, there is growing scientific evidence to support the numerous anecdotal accounts relating high biomass smoke levels to important health effects. More research is sorely needed, however, before meaningful quantitative estimates can be made of how much ill-health would be reduced by smoke reduction activities such as the promotion of improved stoves. Given the scale of the problem, the relatively small investment necessary to conduct such research is well worthwhile.

Research recommendations: health group

1. Descriptive epidemiological studies are recommended to define more precisely the populations at risk of health effects from biomass use: their numbers, their geographic distribution according to age and sex, and the socio-cultural and environmental risk factors or determinants of risk. Such surveys should cover the different effects referred to in the preceding report taking into account local conditions.

2. Analytic epidemiological studies are recommended and should focus on:

a) Evaluating the health benefits of various exposure reduction methods (intervention studies, either as "natural experiments" or "randomized controlled trials" when suitable).

b) Identifying and quantifying relationships between biomass smoke and respiratory disease

   Priorities are chronic respiratory disease, including cancer (case control studies and cohort studies), and acute respiratory infections in infants and children.

c) Identifying and quantifying relationships between biomass smoke and non-respiratory disease. Priorities are adverse reproductive outcomes, and eye problems.

   Experimental laboratory research on the biomedical mechanisms that result in effects from biomass pollutants will be of value, if it is guided by the research needs identified in these epidemiological studies.

3. The studies should be part of a coordinated multi-disciplinary research approach with social/behavioural

scientists, and scientists specializing in air quality measurements, stove design, etc. WHO should promote and facilitate such collaboration, utilizing whenever possible existing "networks".

4. Research designs should be developed to study the interlinkages between housing design, fuel, stoves, water, food, and health. Such research designs should take into account socio-economic and cultural factors, as well as the available appropriate technologies.

5. There is also a need for research on the most efficient ways of promoting appropriate preventive solutions to the biomass pollution and effects problems at a local level. This research would review the role of community development workers, extension workers, primary health care workers and others.

6. Health effects and intervention studies should be conducted in many settings, with methods and procedures that are validated and checked by inter-laboratory quality assurance in order that results should be comparable.

7. WHO should prepare guidelines for applied epidemiological, technical and social science research on the health effects of biomass and coal smoke, linking the research to preventive actions. Such guidelines should also clearly present the ethical considerations involved.

8. WHO should prepare environmental health criteria for <u>indoor</u> exposures to the pollutants occurring in biomass and coal smoke. These should be based on available research and should provide the most accurate guidance possible on the levels of pollutants which may be associated with health effects.

9. Although it is not the particular focus of this working group, unventilated household use of coal seems to represent a substantially worse health hazard than most biofuels. Given that this practice is increasing in some parts of the world, e.g. China, Botswana, India, and Haiti, coordinated international research efforts to identify and quantify the health effects of coal use would also seem to be appropriate.

TECHNICAL ISSUES RELATED TO BIOMASS FUEL AND HOUSEHOLD ENERGY INTERVENTIONS

Indoor air pollution from biomass combustion has been recognized as an environmental health risk affecting hundreds of millions of people. There are many ways of reducing indoor air pollution, including the introduction of stoves with hoods and chimneys, altering kitchen ventilation and layout, fuel substitution, and improving combustion efficiency. In terms of achieving increased fuel efficiency, biomass stove technology is well-developed. Other parameters such as emission levels (both indoor and outdoor) have not received the necessary attention in relation to the types of cookstoves used in developing countries, although considerable work has been done on the type of metal heating stoves now used in developed countries.

Among cookfuel alternatives, kerosene, liquid petroleum gas (LPG), and electricity are seen as the most desirable substitutes, but their feasibility is constrained by economic factors. Biogas, or biomass fuel upgrading (e.g. briquetting) may be appropriate in certain areas. In spite of significant research and development efforts, solar cookers have had limited feasibility. Given current global economic trends, it is likely that the vast majority of those presently using biomass fuels will continue to rely on these fuels in the short and medium term. Appropriate interventions would include the introduction of improved cookstoves, hoods, and chimneys; cleaner household fuels; and the modification of kitchen ventilation and layout. To achieve a significant intervention level, research and development on these options should be accelerated. Many of the points made here regarding biomass fuels and biomass-fuelled stoves are applicable to alternative fuels and stoves as well (i.e. better information is also needed about air pollution from kerosene cookstoves before massive fuel substitution programmes can be encouraged).

Stoves and similar technologies are used for a range of specialized activities such as baking, alcoholic beverage preparation, and the smoking of fish, as well as for domestic cooking. In these other circumstances, significant localized indoor air quality problems may also exist.

The research and development needs in the household energy field are extensive. As well as identifying major gaps in the state of the art, priorities should also be set to assist in this process. A framework was thus developed starting with the stove and fuel and working outward in spatial terms to the kitchen, household, community, national, and, finally, to global boundaries.

Stoves and fuels

Since the energy crises of the 1970s, governments and other non-commercial institutions have been engaged in funding improved biomass stove research and development, which has resulted in the dissemination of over 150 million stoves globally. However, nearly ninety percent of these stoves are in China. Although most improved stoves have chimneys, many have been designed mainly for the achievement of fuel savings. Lower indoor concentrations have sometimes been achieved coincidentally because less fuel is used. Furthermore, few seem to reduce total emissions significantly, although they release a larger fraction outdoors where they create less of a health hazard.

In this respect, knowledge and understanding needs to be improved through further research and development. There are currently no commonly accepted guidelines for testing emissions from simple biomass cookstoves, the most common combustion device in the world. It is therefore necessary to establish these procedures and specify which pollutants need to be measured. These guidelines should lead to the rating of a stove's level of cleanliness under laboratory and field conditions. In the medium term, they would help national governments to set standards.

Guidelines for stove design frequently fail to address the trade-offs among the four major goals of improved stoves: fuel savings, time savings, pollution-free use, and low cost. Further research on optimization is essential to identify short term solutions for different groups, for example poor households which tend to purchase low-cost chimneyless stoves.

Dissemination strategies

Distribution and dissemination strategies also need further investigation if benefits are to be widespread. In this area, a movement towards local commercialization looks promising, and is likely to be sustainable and responsive in the medium term. Subsidies should not be abandoned for poor and disadvantaged groups, however, for they would otherwise not be able to benefit from such improved technology for decades.

Feedback concerning the real benefits to households from stove projects is still inadequate, although where commercial sales have been established, growing acceptance is a strong indicator that stoves are at last meeting some household needs. A number of stove programmes have found that users derived the greatest satisfaction from the reduction in smoke levels. In some areas, this was true even when the improved stoves saved little or no fuel. More knowledge is needed, therefore, to develop monitoring and evaluation tools for determining the success of improved stoves or other programmes designed to improve indoor air quality.

Chimneys

Although there are many anecdotal accounts of reductions in indoor smoke levels from chimneys, there are few actual measurements. The existing studies have found that although some stoves reduced indoor smoke levels, other so-called "smokeless stoves" have not. The smoke still leaks into the room in substantial amounts even though a chimney has been installed. In those households where smoke reduction has occurred, the best achievable on a programme basis with inexpensive systems seems to be about a two-thirds reduction. This is an improvement, but still leaves a significant level of smoke.

Chimneys have proven an expensive option and remain problematic in some areas due to poor durability and difficulties in maintenance. During use, unburned particles often settle on the inside surface of the chimney. These particles are highly flammable and pose a serious fire hazard. It is widely accepted, however, that by increasing prices, greater performance and durability can be achieved. This worked in China, but may not be a feasible option at present for many poor households in other parts of the world.

Fuels

Biogas plants are a desirable solution to household and community energy needs and should be further promoted. Unfortunately, however, their successful application is situation-specific and likely to have limited widespread use because of the need to have a significant number of large animals.

The processing of fuels to upgrade their combustion characteristics is another potential area and research needs to focus upon their technical feasibility and costs. The following specific fuels need particular attention: residues made into charcoal or liquid fuels, biomass briquetting, and processing of coal to lower emissions, for example through the addition of lime.

Solar energy remains an attractive option but is not likely to have widespread application. Here, research needs to focus on developing special sites and market niches. Other specific technologies for the long term include alternative stoves such as low wattage electric slow cookers.

The most readily available option in many places is simply to encourage the natural movement up the "energy ladder," which has led people from the relatively dirty solid fuels to the higher quality fuels, kerosene and gas (usually LPG). History has shown that people will move up if the fuels are available and affordable. Because of the health and environmental problems of biofuel use, it may well be worth investing in programmes to enable people to shift to these modern fuels sooner than they might otherwise be able to do. This might entail some costs, but not necessarily so. Indeed, there are a number of areas in the developing world where the price of such fuels is not the stumbling block; they may even be cheaper than wood. Rather, it is being assured of supply on a regular basis to be worth the investment in a kerosene or LPG stove.

Although such modern fuels are generally cleaner burning, there is still need for research to pinpoint the amount of improvement that might be expected from fuel substitution. There are also options within each fuel type that have indoor air quality implications. To give an example, there are several different types of kerosene stoves available in many places, with quite different combustion arrangements and prices. It would be valuable to better understand the emissions implications of a choice among these devices.

Kitchen/household

Within the spatial boundary of the kitchen and household, the following three important indoor air quality research subject issues were identified:

- hoods
- ventilation
- kitchen system studies

Hoods

Hoods would seem to be one of the most flexible tools for reducing pollutants in kitchens. With a hood, the user can prepare food utilizing a wide range of cookstoves, cooking styles, and fuels without exposure to unduly high emission levels. Unfortunately, however, there seems to be little information or research available.

Hoods often require major changes to existing housing and roofing structures, and may be too expensive for the majority of poor populations both in rural and urban areas of developing countries. In addition, little is known about the most appropriate designs, materials, and methods for constructing and maintaining hoods. Top priority should be given to the development of affordable hoods suitable for use in low income households.

Ventilation

Since indoor concentrations are as much a function of ventilation rates as of emissions, changing the former might seem to be as attractive as addressing the latter. Unfortunately, most housing in the developing world is already quite well-ventilated by global building standards, i.e. typically much greater than 10 air changes an hour. Although some improvement is possible by changing ventilation alone, the great reductions in concentrations that are needed may not be achievable using non-mechanical methods.

There are, of course, rather extreme situations in which there is no window or gap for smoke escape at all. Significant improvement in these cases can be expected from simple changes in ventilation arrangements, although there can be cultural or social (security) constraints to some interventions. Ventilation, therefore, is probably best viewed in a broader kitchen systems context.

Kitchen system studies

Any effort to introduce hoods or chimneys is less likely to be successful if the role of ventilation and kitchen layout is not clearly understood. Good ventilation and kitchen layout design can offer low-cost options for reducing indoor air pollution and should be a main feature of healthy housing design. This research would also investigate the most effective combination and permutation of chimney, hood, ventilation pattern, and kitchen layout under various conditions.

Effective removal of pollutants in the kitchen also needs to take account of the wider aspects of the cooking environment. Examples include location and type of hoods and chimneys; ventilation; functional layout of the kitchen; general house layout, and cooking practices and preferences.

Although the focus of this workshop has been on air pollution, kitchen system studies have the additional advantage of being able to incorporate consideration of some of the other health impacts of cooking with biomass. These include heat exposure, risk of burns, efficient use of time, and ergonomic issues.

Kitchen system studies are also crucial to the identification of opportunities and scope for interventions, thus ensuring that site-specific factors such as cooking habits, construction practices and materials, climatic conditions, and socio-economic considerations are incorporated. Although the results of each kitchen system study are likely to be specific to a particular location, the methodology for such studies may be universally applicable to a global research initiative. It is thus recommended that research be initiated to develop a methodology for kitchen system studies, supporting interventions to reduce indoor air pollution and other potential health problems.

Considerations at community level

At the community level, research should be focused on the interactions that contribute to problems of indoor air quality and affect its amelioration. We first consider the implications of the relationship between indoor and outdoor air quality. Indoor air pollution in one household can influence indoor air quality in neighbouring houses depending on housing construction material, settlement patterns, and meteorological conditions. Indoor air pollution affects ambient air quality as well.

Given affordability considerations, it is probably impossible to design a biomass cookstove which eliminates smoke altogether. The best that can be done is the removal of smoke from the indoor environment. This may, however, turn an indoor air quality problem into an ambient air quality problem. In this view, chimney stoves can only be an interim solution. The ambient air pollution problem may prove to be especially severe under certain conditions, particularly in densely populated urban areas with clustered housing and areas which are prone to low level temperature inversions that trap pollutants. These may be urban or rural.

In regions where there is a limited movement of ambient air, the introduction of chimneys may result in only partial reduction of the levels of indoor air pollution. This is because increased outdoor air pollution eventually raises the level of pollutants indoors. Research on chimneys should be a priority item on the indoor air pollution agenda, but so should ways of improving combustion efficiency, in order that a smaller absolute amount of pollution is emitted per meal.

The relationship between indoor and outdoor air is complex and not well understood for areas using biomass fuels. The severity of the ambient air pollution problem has not been systematically documented either. It is suggested, therefore, that research should focus on identifying areas particularly susceptible to ambient air pollution and obtaining an estimate of air pollution concentrations and exposures.

Other concerns at the community level are less directed toward research and more action-oriented. These relate to training and institutional development. There is a lack of technical training necessary to support proposed interventions at the household and community levels. Interventions such as improved stoves are unlikely to be operated and maintained as intended unless users are trained to do so and are able to find technical support in the community when the need arises. In order to achieve this support, it is necessary to develop, test, and disseminate technical training and user education materials. Some of this work has already been done, but much still remains.

There is also an urgent need to strengthen the institutional development necessary to sustain proposed interventions at the community level. The sustainability of proposed interventions over the long term will depend significantly on adequate institutional support and a community's acquired ability to solve technical problems. Reliance on external expertise will make the long term acceptability of the intervention uncertain. Hence, local institution building must be given priority.

Of secondary priority is the examination of community energy resources and information needs in order to understand the social and economic factors affecting indoor air quality, such as fuel prices and availability. This is, of course, site-specific and requires the development of appropriate methods.

Considerations at national level

Support at the national level is important for a number of activities and institutions aimed at reducing indoor air pollution. Organizations involved would span a wide range of areas in both the public and private sectors, including health, energy, environment, and forestry departments and research institutions involved in housing development, engineering, and testing.

Ways of influencing policy makers through cost benefit analysis of the effects of indoor air pollution and interventions should be investigated. High priority should be placed on research and development of improved cookstoves which reduce emissions and improve efficiency of fuel use. This work is best carried out by NGOs and research institutions active in stove development, and should be implemented with strict adherence to sound scientific practices. Another area which requires national research support is improved kitchen design and studies of behavioural aspects of kitchen design.

In order to undertake the requisite stove work, institutional and technical support for training and implementation is required. Training can be achieved through courses, workshops, and external technical support. To this end, the donor community must be mobilized. Equipment, education, and infrastructural support should be made available to development groups.

The best institutional framework for planning and implementation of national campaigns to reduce indoor air pollution should be identified. In such campaigns, subsidized interventions should be used where these can be expected to have a major effect.

Considerations at regional and international level

A large number of technical institutions (research, universities, technical centres, etc.) in developing countries possess the required human resources, experience and facilities related to the various aspects of indoor air pollution.

Regional and international efforts involving the above-mentioned institutions (government and NGOs) should be encouraged. International organizations and aid agencies can play an important catalytic role in the development of a joint programme of action. In light of the severity and urgency of the indoor air pollution problem, the areas requiring immediate attention are:

a) Guidelines on indoor air quality

Based on national priorities, establish incremental goals for indoor air quality which countries can work towards.

b) Pilot/demonstration areas

Test these goals in selected pilot communities and undertake the requisite monitoring and assessment.

c) Training activities

To implement the above-mentioned interventions, properly designed training activities, workshops and surveys will be required.

d) Documentation and information

Prepare suitable case and country studies; fuel surveys; feasibility studies undertaken within the orbit of ongoing regional and international activities. These documents will strengthen efforts to influence policy makers and public awareness as well as provide background information for mobilizing donor support.

e) Inter-disciplinary working groups

Inter-disciplinary teams of researchers will be required to establish an integrated approach to indoor air pollution interventions.

In the global context, scientific and policy research is also needed to better understand the role of biofuel harvesting and combustion on the global carbon cycle (buildup of greenhouse gases and the potential for health-damaging climate change). There are particular concerns not only about the carbon dioxide emissions from biomass combustion, but also the emissions of other trace gases as products of incomplete combustion, which are even more powerful greenhouse gases. This may result in a substantial additional incentive to promote clean-burning stoves, since the same products of incomplete combustion are responsible for: 1) loss of potential fuel energy; 2) direct health risk; and 3) extra global warming potential (see following section on greenhouse implications of biomass combustion). More research and policy analysis is needed however before all the implications are confidently known. Since this is a global issue, it is appropriately taken up by global coordination and funding mechanisms.

The greenhouse implications of biomass combustion

Although carbon dioxide, the principal gas produced by biomass combustion is the best known greenhouse gas, it is by no means the only one. Essentially all the products of incomplete combustion (PIC) produced in biomass fires with less than 100% combustion efficiency are also greenhouse gases. These include methane, carbon monoxide, and non-methane hydrocarbons, which are all even more powerful greenhouse gases per gram of carbon emitted than carbon dioxide. Indeed, carbon dioxide is about the least damaging form of carbon from fuel combustion [IPCC, 1990].

Unfortunately, the combustion efficiency of traditional biomass fuels in simple stoves is usually much less than 100%. It is not uncommon, for example, for considerably more than 10% of the carbon to be released as PIC rather than carbon dioxide, which would be the only product if combustion was complete. It is these PIC, mostly in the form of carbon monoxide, particulates, and gaseous organic compounds, that comprise the chief health-threatening materials in biomass smoke [Smith, 1991].

Because PIC on average have higher Global Warming Potentials (GWP) than carbon dioxide, the total greenhouse impact can be substantially higher than indicated by an evaluation based on carbon dioxide alone. A recent pilot study in the Philippines, for example, has shown that the total GWP of wood-stoves may, depending on circumstances, be more than double that of the carbon dioxide. In other words, the GWP of the PIC can equal that of the carbon dioxide. More research is now being undertaken to examine a much larger number of biomass and other fuelled stoves.

There are several tentative but potentially important policy implications of these findings:

- The overall benefit from reduction of GWP which might be assigned to an improved stove programme may be much larger than previously estimated. This depends, however, on the degree to which the improved stove actually improves combustion efficiency, rather than just heat-transfer efficiency.

- Surprisingly, there may be substantial GWP benefits to be derived by switching from various kinds of biomass stoves to modern fuels such as kerosene and LPG. Although these fossil fuels produce significant GWP because they are non-renewable, the overall GWP impact may be lower because of the high emissions of PIC from some biomass stoves. This may provide the extra incentive needed in some areas to shift policy towards fuel substitution rather than improved stoves.

- Although charcoal stoves are more efficient and produce less GWP (and health-damaging) pollution than do wood-stoves, the charcoal manufacturing process is quite a different matter. Another impact of the generally inefficient charcoal kilns in developing countries, besides excessive wood demand, is that a large fraction of the original carbon in the wood ends up as PIC released at the kiln. The resulting total GWP of the charcoal fuel cycle can apparently be many times that of a comparable wood-fuel cycle. This gives additional impetus to improve charcoal kiln efficiencies and may also argue for more efforts to move some charcoal-using populations to other fuels.

The general impact of these findings however, is that the PIC of biomass stoves are an even greater enemy than has yet been recognized. We already know that they rob households of some of the energy contained in the fuel and impose health problems on the householders. Now we have still another incentive to reduce PIC as much as possible.

Consequently, there may be significant global as well as local benefits from efforts to encourage the improvement of stoves and fuels used in that half of the world's household which use simple biomass fuels. This provides an even greater incentive for international efforts to be directed towards this end.

Research recommendations: technical group

1. At the stove level, a) recommend emission testing guidelines that can be used by stove designers to ensure that stoves being disseminated contribute to reducing indoor air pollution; and b) conduct research on emission reduction of improved stoves.

2. At the household level, undertake research on improved ventilation and kitchen layout as well as test the viability of hoods and chimneys and measures to improve comfort, safety, and labour efficiency.

3. At the community level, conduct research to investigate the contribution to human exposure of indoor and outdoor air pollution to assess the effectiveness of suggested solutions.

4. At national level, undertake relevant policy research (e.g. cost benefit analyses) to strengthen the case for proven technical interventions, including research on alternative energy strategies and building codes and norms.

5. Taking national priorities into account, establish regional and international guidelines for indoor air quality, including the provision of incremental goals towards which countries can work.

6. Internationally coordinated research is needed to better pinpoint the role of biofuel stoves in the global carbon cycle and to understand how stove improvements affect net greenhouse gas emissions, and consequently, the risk of global warming and resulting ill-health.

SOCIAL CONSIDERATIONS IN HOUSEHOLD ENERGY INTERVENTIONS

Many countries have launched interventions in the household sector of developing countries based on energy and environmental considerations. Planners and policy makers also recognize that the current pattern of collection, preparation, and use of biofuels result in increased burdens on women and children, in addition to inefficient use of energy and harmful health effects. One of the objectives of many stove and biogas programmes has been to reduce the burdens of time and human energy output. There is little effort to assess these benefits, however, which makes it difficult to include this vital link between technical intervention and social benefits into rationales for supporting large-scale interventions in the household sector, in order to provide a clean and convenient cooking environment. Further studies to examine this link are necessary.

While household energy is clearly crucial to the health and well-being of both rural and urban populations everywhere, international commitment and resources allocated to household energy are declining. One of the reasons may be that many programmes addressing household energy problems have had limited success due to technology-focused and target-oriented macro-planning approaches. Rather than responding to local needs, energy programmes have tended to concentrate on the dissemination of technology.

Funding is often supplied for technological solutions, but is more difficult to obtain for social research, even if it is action-oriented. In order to understand the local sociocultural contexts which dictate energy and environmental priorities, a dialogue between energy users and advisers is essential at the earliest planning stage of each intervention. Global generalizations provide only the crudest framework for planning; specific projects should emerge out of a detailed understanding of each locality.

Introducing technology without understanding its potential social, economic, and political impact can reduce its acceptability or even harm those it intends to help. For example, using improved cooking technology clearly provides benefits, but where women are not involved in planning and design work, they can become displaced from a domain which was previously their own, to their economic and technological disadvantage.

Although women are recognized as the catalysts for development, especially at community level, this recognition is often not reflected in programme design and resource allocation. The household environment - one of women's main workplaces - is a seriously neglected area. This has a negative impact on the health, living environment, and general quality of life for the whole family, but especially for women and children.

Priority areas for social impact

Experience at both macro and micro levels has established the following as priority areas where there are considerable health and social costs, and where the main population groups concerned are women and children. With carefully planned and socially-conscious interventions, these areas could contribute considerably to enhancing health and well-being.

The kitchen

Biomass (and coal) use can be a major contributor to an unhealthy indoor environment. To address this issue, the dwelling itself and the living conditions of householders must be considered. The culinary area - the kitchen - plays an important role in housing design, but its health significance has been overlooked by architects, engineers and other experts involved in the construction process. The kitchen is often placed in left-over space, even in new houses. Even in some modern buildings, poor design of the kitchen is apparent from the point of view of ergonomics, smoke extradition, general ventilation, lighting, hygiene, and comfort.

The kitchen is not always given high priority by the householders themselves. The standard of the kitchen area is often much lower than the rest of the dwelling. The deficiencies in kitchen areas are related to the perception of kitchens as the women's domain, which is frequently undervalued.

Furthermore, there is inadequate research on the relationships between construction practices and kitchen requirements, with the result that these relationships are not taken into account. This is significant because, as explained below, the kitchen should be a key issue in building design.

- Almost all household energy is used in the kitchen. The kitchen is a major workplace which must provide comfort, security, and hygiene if good health is to be maintained. It is often a central focus of family life.

- The kitchen design should take into consideration cooking traditions and habits, and cultural patterns, but should also be adaptable to new energy sources.

- The *placement* of the kitchen has an influence on the rest of the dwelling. It has an impact on the overall functioning of the dwelling and on the indoor climate. High temperatures, vapour, smoke, and odours are produced while cooking and suitable designs have to be found in order to avoid the transmission of these sources of discomfort and risk to other parts of the dwelling.

• A chimney alone cannot solve all problems of kitchen smoke and soot. *Smoke evacuation* and the *general ventilation* of the room are two aspects of the same issue. They are also affected by the position of door and window openings and their relation to the fireplace/stove. When passive climatization is presumed, the kitchen must be carefully planned according to prevailing winds and possible ventilation.

• Besides being a place for cooking and food processing, the kitchen often has *other functions*. It can be used as a sleeping place, a storage place for food, water, and fuel, and a home for domestic animals. There is a flow of *culinary activities* connected to food which has to be identified. These activities need certain *working areas* (space) and *equipment* (fittings) inside as well as outside.

Workload and time constraints

Particularly in rural areas, women perform the majority of household and agricultural labour. This heavy burden has health, energy, and educational repercussions. The demands on women's time are especially acute in the areas of food growing, processing, and preparation and fetching of water and animal fodder. Collecting fuel for cooking increasingly consumes a large proportion of the day in areas of scarcity. One technological solution, which according to users has had some success in releasing time for women, has been the introduction of fuel-efficient stoves. The main improvement has been faster cooking time, but reducing fuel consumption has also alleviated the pressure on the fuel supply as well. More time for women can be translated into increased social benefits, such as more meals, more time for child-care or other household chores, or more time to rest. This is a significant factor as there is statistical evidence to show that on average, women sleep considerably fewer hours throughout the year than other household members [Sims, 1991].

As women are the primary deliverers of health care and nutrition to their families, it is essential that they have adequate time to discharge these duties while remaining in good health themselves. A fatigued, overworked, ill-nourished mother cannot produce or care for healthy children. For these reasons, it is essential that technologies designed for use by the poorer sectors should be socially appropriate, and should reduce, not add to, the time problems of poor households.

Education

Growing out of this lack of time are the educational deficiencies often faced by women which constitute one of the gravest social handicaps for the poor. Literacy rates in the developing world are usually significantly lower for women, particularly in rural areas where the labour of women and girls is at a premium and the education of girls is a low priority. This affects women's access to technology transfer and skills training in many areas, thus lowering their access to income-generating opportunities as well as enhanced knowledge of agricultural practices. It is well documented that rural extension schemes rarely focus on women's activities, even though these may be the backbone of the local economy. Neither are there adequate numbers of female extension workers; this is due to social constraints on women's mobility, and the lack of a pool of local, literate women to start with.

Fuel, food, and nutrition

Fuel scarcity impacts on food availability as household management strategies may include reduction in frequency of cooking, substitution of less nutritious but quicker-cooking foods, eating of cold left-overs, or warming up previously cooked food [Brouwer et al., 1989]. These strategies increase the risk of food-borne diseases, impair the absorption of proteins, reduce the intake of vitamins and energy, and decrease the amount of food consumed. The health and social cost of fuel insufficiency is therefore high, and again has the greatest impact on women and children. Poor women frequently eat less than other household members, while their energy output may be greater.

Legal constraints

The social position of women creates problems over their legal access to land, credit, and other resources. In some countries, women are still regarded as minors. This seriously affects their ability to inherit or own land, and their general access to other resources. It also affects their eligibility for credit and loans. As the onus is on women in rural areas to provide the food, water and fuel needs of the family, these social, cultural and legal constraints are serious handicaps to family and community well-being. To the large and ever-increasing numbers of poor, women-headed households in the world, these constraints can be crippling.

Integrated planning

Each of the five issues described above need to be successfully addressed if development is to be sustainable and environmentally sound. A planning approach based on significant social input, and in which the beneficiaries of any proposed intervention have been consistently involved, will have greater and more sustainable benefits. Such an approach would therefore have its roots at the micro level and interventions planned in this way would provide a platform for the integration of related development goals. The household energy sector, being closely related to both the grassroots and national planning levels, offers great potential for this micro-macro integrated approach based on strong social contributions.

Some elements of this integrated approach would be:

- research to understand the sociocultural setting;

- orientation around the expressed needs of the community;
- participatory project design and implementation, with linkages between designers in the institutions and practitioners in the field;
- consideration of social and environmental sustainability;
- building on local skills;
- provision of training in required skills; and
- follow-up, monitoring, and evaluation at micro and macro levels.

The following section, based on an improved stoves programme in Kenya illustrates the importance and advantages of participatory approaches. As is vividly shown, working along the lines of needs orientation and participatory design rather than imposing technology from top-down means starting with the community and being prepared to work slowly. The payoff comes with the people themselves locating real solutions to problems of poverty and economic constraint which take into account the diversity of their circumstances, and give them greater control over their lives. Taken at macro level, these same problems can be, or can be perceived to be, practically insoluble.

The participatory development process: an example drawn from work in Kenya

The main communication elements which should underpin a participatory development process are (1) a dialogue, involving participant observation, interviews, and discussions, and (2) shared experience and exchange of skills over time. This enables a participatory micro-level approach which gives rise to integrated action rather than externally derived technology-driven solutions. More work is required to develop methods for formulating plans for household energy and environmental projects. There is already evidence of success, however, central aspects of which will be described in this case study from Kenya.

Key elements for success in a rural household energy programme in Kenya included:

- **Understanding the sociocultural setting**

This provides baseline information which dictates priorities for stove design and dissemination. It includes types of foods consumed, fire management practices, cooking patterns, number and size of pots and other utensils, time and/or money spent collecting or buying fuel, household budget, decision-making processes within households, cultural concerns and values connected with existing technology, the stove or hearth's other uses (warming, lighting, drying, smoking), household size, number of household units sharing a hearth, fuelwood supply situation, political framework, settlement patterns, and so on.

In Kenya, this information provided the basis for a stove design and dissemination strategy. It was found that popular cooking practices, especially vigorous stirring of *ugali*, required a strong sturdy stove; long cooking times minimized heat losses from massive stove bodies; the relatively low level of available disposable income for most rural households led to a dissemination strategy that involved standardizing the commercially produced firebox, and training owners to build the stove bodies; the wide range of cooking pot sizes meant that smaller pots could be inserted into the firebox, while larger ones rested on top; and the fuelwood supply situation was so diverse that planners were forced to look at other needs besides fuel saving. The political climate for fuel conservation was positive but owner-built stoves were not favoured. They were recognized as affordable, but not perceived as modern. Consequently, an awareness-raising component became a priority if acceptance was to be assured. The decision-making power of women in the realm of the kitchen encouraged a strategy based upon women's interests. Existing women's groups had already established ways of coordinating people and resources, and of overcoming problems caused by distance between homesteads in a scattered settlement pattern.

- **Project orientation around expressed needs of the community**

This involves determining what a community feels are its own needs before a decision is made concerning the introduction of new technology. These needs might include smoke removal, fuel saving, time saving, safety, hygiene, durability, light or warmth, ease of handling, or maintaining a fire overnight.

There is usually a wide range of expectations on the part of a community, not all of which can be fulfilled equally satisfactorily. The best compromise has the greatest chance of success, although any new technology must have substantial perceived advantages over the old in order to be accepted.

A clear understanding of the advantages and flexibility of the 3-stone fire was the guiding principle in the Kenyan project; the new technology had to be substantially better if the people were to accept it. Smoke removal having been identified as a strong community wish, a chimney-stove seemed the best approach to meeting this need. Experience showed, however, that with an owner-built all-mud design, it was difficult to ensure adherence to the exact dimensions, which is necessary for thermal and combustion efficiency. The care required for chimneys caused extra work, and the women were not happy about this. In the end, a one-pot chimneyless stove was agreed upon; great attention was therefore given to fuelwood storage and the use of dry wood, which would reduce the smoke.

- **Participatory project design and implementation with linkages between designers in the institutions and practitioners in the field**

If orientation around needs is taken seriously, this will involve close interaction with the community, especially the women as the main users of household energy; it will encourage a process of reciprocal learning that results in jointly discovering the most efficient strategies for addressing their needs. This frequently requires a combination of local skills and specialized technical knowledge which may be found in local or external technical institutions. ***The foundation is the creative contribution of the users.*** Realizing this potential strengthens the feeling that the users are in control of their own lives. Experience has shown that as long as action is looked upon as "somebody else's project," implementation cannot be successful.

In the Kenyan experience, recognizing the necessity of a participatory approach for project success led to a redesigning of the project plan right from the start. Instead of a goal of "distributing 10,000 stoves," the new project's emphasis was on "improving the living conditions of women" through the following:

- conserving fuelwood energy through improved cookstoves; and
- increasing fuelwood supply through on-farm tree planting.

Other elements of the participatory project design utilized in Kenya are as follows:

- use of local material and skills, in order to make it a project in people's own control;
- a design based on community identified needs - the only guarantee for acceptance;
- integration into local structures, to ensure long-term sustainability;
- decentralized production, to reduce distribution costs, create more local interests and jobs in rural areas; and
- realistic allocation of time and resources to reflect the research and development demands of a new technology, which are often underestimated.

These are some of the most important requirements for ensuring strong community involvement in projects. It is important to remember, however, that apart from these broad categories, there can be no one "recipe" for social input. Various types and differing methods of involvement will be appropriate depending on geographic location, particular environmental conditions, cultural setting, freedom and mobility of women, and so forth. The success of an intervention strategy will depend on how skilfully the appropriate type of community involvement is arranged, so that the interests of all can be met to some degree.
[Source: Klingshirn, 1991]

Research recommendations: social group

1. Impact studies

The following in-depth impact studies should be carried out in all major household energy and environmental programmes:

a) Social impact studies, including links between fuel scarcity and health effects, such as changing dietary practices, increasing demands on women's time and less access to education;

b) The impact on household energy end-use patterns by switching fuels. This includes nutritional effects, changing use of space and the living environment, and other strategies employed by households to cope with critical energy conditions;

c) Economic and political impact of new technology, including links between access to new technology and income levels over time (for examples, see (d) and (e) below);

d) Cost benefit analyses for different technical options (e.g. solar energy technologies, improved cooking stoves, better kitchen designs, and skills development) at household, community and national level, on the basis of present and projected usage rates.

e) Analysis of other social benefits, which are not easily and perhaps should not be expressed in monetary terms, but which may be essential for the success of a programme as they express the users' personal cost/benefit reasoning, such as released time, reduced workload, increased safety, reduced pollution, etc.

2. *Guidelines for participatory action research*

A framework for action research in the field of household energy and environment should be devised. Building existing guidelines for monitoring and evaluation, this framework should comprise the following:

a) Appropriate qualitative and quantitative methods;

b) Categories of baseline information relating to household energy and environment;

c) The actors involved at each stage of the planning, the research and development process, and implementation;

d) Key indicators for rapid assessment of planned or unplanned impacts.

3. *Social research and technical development*

Research is needed at international, national, and community levels to identify problems with social and technical interlinkages, and to recommend methods of embracing multidisciplinary cooperation and action in the household energy field.

An example of this would be national research on the suitability and viability of building norms and codes for informal and formal sectors, in conjunction with social scientists, to ensure that such codes conform to sociocultural dwelling patterns in general and the requirements for a safe, hygienic culinary area in particular.

4. *The involvement of women in seeking solutions to household energy problems*

In the poor and rural sectors, women are the prime providers and users of household energy. The following points, which are not all directly research-related, should be taken into account when designing household energy programmes.

a) In conducting research on household energy issues (biomass supply and use, improved stoves, kitchen systems, biogas plants, alternative energy sources) it is essential to know the views, needs and priorities of the principal users. Survey instruments (e.g. questionnaires, interviews) should be administered to the end-user and supplier, bearing in mind that this may not be the head of household.

b) Research on alternative cooking technologies and kitchen design should be carried out and tested at grassroots level in conjunction with those who do the cooking and food preparation.

c) Health, agricultural, and other extension workers might incorporate messages on energy and indoor pollution into the context of their work in other areas. This could include pressing for better organization of cooking and food preparation areas.

d) In some countries, there is a great lack of female extension workers. These are essential, as male extension agents are frequently unable to deal directly with women due to cultural restrictions on women's mobility and access to outsiders. Concentrated efforts by governments and NGOs are needed to recruit and train local female extension agents in energy/environmental/health matters.

e) Education for women and girls should be a local and national government priority everywhere, so that they can fully participate in policy and decision-making processes, as well as enter professions that closely concern the household energy field, such as forestry. The majority of forestry personnel are still men, but forest product end-users for subsistence purposes are often women, who not only gather wood for fuel, but use products such as leaves, nuts, fruits and plants as important dietary supplements and medicines.

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