Reducing exposure to indoor air pollution

The solution to indoor air pollution is relatively simple: either stop smoke getting into the home or remove it from the home. The healthiest option is to cook with a cleaner fuel. However, for the foreseeable future, many poor people will have little option but to cook on low-grade fuels. The best option for them is to safely remove the smoke from the kitchen. Experience shows that there is no 'one size fits all' technical fix. A lasting solution depends upon the active participation of those at risk, poor women.

As poor people's incomes increase they tend to switch to cleaner fuels for cooking and heating. In time, as poverty levels are reduced, lethal levels of indoor air pollution will fall. But poor people cannot afford to wait for a rising tide of prosperity to clean up the air in their homes, and the international community has an obligation to ensure life is made more tolerable for today's generation. There are actions that can be taken in the short term, that will ensure long term benefit for those at risk.

In a review of ways of reducing smoke levels, undertaken for the WHO and the United States Aid (USAID), alternatives were considered according to three areas. These comprise: interventions at the source of smoke; interventions directed towards the living environment; and interventions aimed at the user.

Cooking on a cleaner fuel

The most effective means of reducing indoor air pollution is to switch to cleaner fuel that produces significantly lower emissions. While this may not currently be an option for many people due to high costs, lack of access to the fuel and other barriers, for those who are able the switch fuels, the benefits are great.

In many urban areas cleaner fuels, such as kerosene and LPG, cost less per unit of fuel than biomass. However, there is often a larger cash investment needed to purchase the fuels and the stoves. For example LPG must be bought each week or month by the bottle, but poor people usually purchase fuel daily in small quantities. Making fuel available in smaller quantities would benefit poorer customers. Mechanisms such as micro-

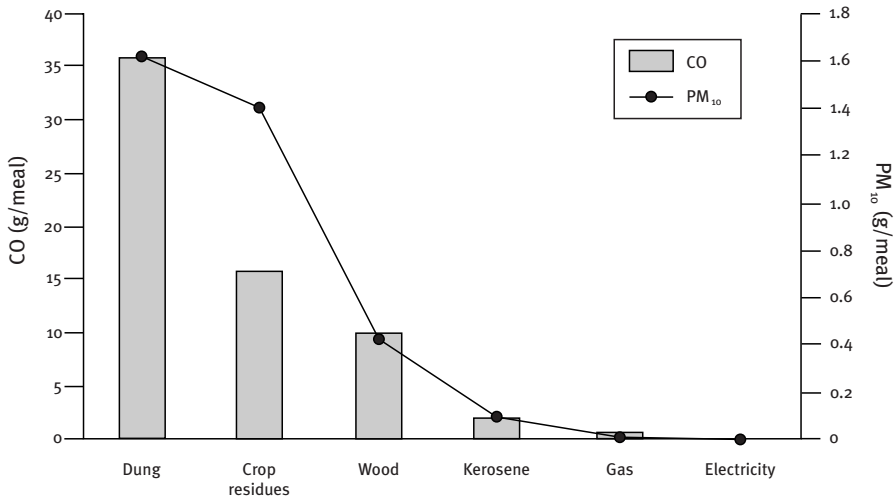
Source of smoke	Living environment	User
Improved cooking devices Chimneyless improved biomass stoves Improved stoves with chimneys **Alternative fuel–cooker combinations** Briquettes and pellets Charcoal Kerosene LPG Biogas Producer gas Solar cookers (thermal) Other low smoke fuels Electricity **Reduced need for fire** Efficient housing Solar water heating	**Improved ventilation** Hoods/fireplaces Windows/ventilation holes **Kitchen design and placement of stove** Shelters/cooking huts Stove at waist height	**Reduced exposure through operation of source** Fuel drying Use of pot lids Good maintenance Sound operation **Reductions by avoiding smoke** Keeping children out of smoke

Table 2: Potential interventions for the reduction of exposure to indoor air pollution.[53]

Figure 8: Emissions along the energy ladder.[29]

The energy ladder

The energy ladder is a scale which rates the quality of household fuels. At the lower end of the ladder are the traditional biomass fuels: dried animal dung; scavenged twigs and grass; through to crop residues, wood and charcoal. Moving up the ladder, coal is next, followed by kerosene, bottled and piped gas, biogas (from digesting animal dung) and electricity. Gaseous fuels are the cleanest burning household fuel. In general, as households climb the ladder there is an associated increase in the sophistication of the cooking technology, its cleanliness, efficiency and its cost.[29] Cooking with electricity is too costly for poor households.



credit loans or subsidies may also help to reduce the cost of fuel switching.[42]

In rural areas there is less incentive to switch fuels, as biomass is gathered at no financial cost to the user. Cost issues aside, there are other concerns about fuel switching. Many of the poorest members of society in developing countries make their living from collecting and selling biomass fuel. The result of a wholesale shift from biomass fuel could be the removal of a vital source of income for some of the most vulnerable people in society.[43]

The United Nations Development Programme's LPG Challenge aims at overcoming the barriers for rural communities to access LPG in countries where it is readily available in urban areas.

Cleaner fuel and climate change

There may be concerns about the climate change impact of switching to a non-renewable, petroleum-based fuel. Professor Kirk Smith, from the University of California, tackled this argument in a paper entitled 'In Praise of Petroleum',[45] published in *Science* in December 2002. He argues that if the two billion or so people currently reliant on biomass were to shift to LPG, emissions of greenhouse gases would increase by less than 2%. Professor Smith goes on to illustrate how the smallest of increases in efficiency in the world car fleet could counter this rise. If an improvement of just 0.5% per year (5.1% over 10 years, not much more than one mile per gallon) were made, this would free up annually sufficient fuel energy for the cooking needs of all the two billion currently burning biomass.

Over-consumption of fossil fuels is primarily a problem for the industrialized world. As Professor Smith puts it:

> 'Rather than excluding petroleum, some of this one-time gift from nature ought actually to be reserved to help fulfill our obligation to bring the health and welfare of all people to a reasonable level: an essential goal of sustainable development, no matter how defined.'[45]

'Kerosene and LPG actually produce fewer greenhouse emissions per unit of energy service than biomass fuels used in traditional ways.'

UNDP World Energy Assessment[21]

Ghana LPG[44]

Promotion of LPG started in Ghana in 1990 to reduce the wastage caused by flaring constituent gases at the refinery, and to reduce dependence on charcoal and fuel wood. The Ministry of Energy took the lead in promotion and price control of LPG use for cooking. The programme involved: public awareness raising to increase demand for LPG; door-to-door delivery; reduced cost cylinders; encouragement of LPG use in schools and hospitals; promotion of LPG with commercial food vendors.

Elements of the traditional cook stove were used in the design of the locally promoted LPG stove. Between 1989 and 1997 cylinder sales increased from 80 000 to 600 000 per year, with 22.7% of households in the capital city, Accra, using LPG. Promotion of LPG to lower income households and in rural areas has not been so successful, however.

The UNDP LPG Challenge is now planning to work with local stakeholders in Ghana to overcome the barriers for LPG promotion in rural areas, and to encourage private companies to sell to rural customers.[69]

Using solid biomass fuel can, in fact, produce higher greenhouse gas emissions per meal than fossil fuels, kerosene and LPG,[26] even where the biomass fuel is harvested sustainably. This is due to inefficient combustion of the biomass fuel, which releases products of incomplete combustion, including methane, which have a greater greenhouse potential than carbon dioxide. In some situations, therefore, fuel switching to fossil fuels may be recommended to reduce greenhouse gas emissions.

Biogas from dung and other waste

Biogas is extremely effective, as it converts a renewable material (dung and other organic waste materials) into a gaseous, clean fuel. While biogas is being introduced in parts of Asia very successfully – there are over 120 000 bio-gasifiers in Nepal alone – the culture in much of Africa makes it harder to introduce there. Further research and development of renewable, clean cooking fuels will be essential for longer term cooking options.

ITDG/Simon Dunnet

A household biogas plant in Nepal.

Getting smoke out of the house

The biomass trap

While switching to a cleaner fuel is the most effective means of reducing indoor air pollution, abject poverty will mean many hundreds of millions of people worldwide will have no access to fossil fuels for a very long time to come. They will be trapped into using biomass as their primary fuel. The barriers to accessing clean fuels are many, for example:

- For extremely low-income households the up-front costs of purchasing new cooking technologies, as well as the on-going cost of fuel, are beyond their means.
- Where biomass is collected free of charge, even though it takes a considerable amount of time to collect, using limited cash income to purchase cooking fuel is not given priority in many very low-income households.
- In extremely remote areas it is very difficult to provide a reliable supply of fuel, and transport costs will increase the price of fuel supply.
- Many developing countries do not yet have sufficient infrastructure to distribute LPG or kerosene on a wide scale.

Where biomass fuels will remain the dominant domestic fuel, it is essential to maintain a reliable and sustainable supply of fuel wood. Fuel wood collection for use in rural areas is not a significant cause of deforestation as women generally collect dead wood and twigs and rarely chop down trees.[26] However, in environmentally stressed areas, fuel wood collection has a significant impact. Where deforestation has occurred, often due to either commercial logging or land clearance for agriculture, there is a need to provide sustainable fuel wood sources for rural populations.

In many countries trees are often felled unsustainably to provide fuel wood and charcoal to supply urban demand. Urgent policies and measures are required here to curtail the loss of forestry. Many people make a living, legally and illegally, in the supply of fuel to cities in the developing world. It will be essential to maintain these livelihoods, while restoring forest resources.

For those trapped into using biomass as their main domestic fuel, options for reducing exposure to indoor air pollution will entail safe ways of getting smoke out of the home.

Smoke hoods, eaves and windows

For the foreseeable future billions of people will continue to use biomass as their main fuel. Therefore it is essential that efforts to reduce exposure to indoor air pollution be directed at the reality people face now. Smoke will continue to be produced, so it needs to be removed from the house.

Substantial reductions to smoke exposure have been obtained with relatively simple methods. For example, an ITDG project in Kenya reduced particulate and carbon monoxide pollution in homes by nearly 80% through the use of smoke hoods and improved ventilation in the home.

Smoke hoods work on the same principle as flues and chimneys, but have the advantage of being freestanding and independent of the stove.[47] Smoke hoods have been shown to achieve substantial reductions (80% in some homes) in respirable particulates and carbon monoxide.

By enlarging the eaves spaces in a traditional house, substantial benefits can be achieved. For example, in the Kenya project respirable particulates were reduced by 60%. The number of houses showing very high levels of smoke pollution was also reduced significantly.[46]

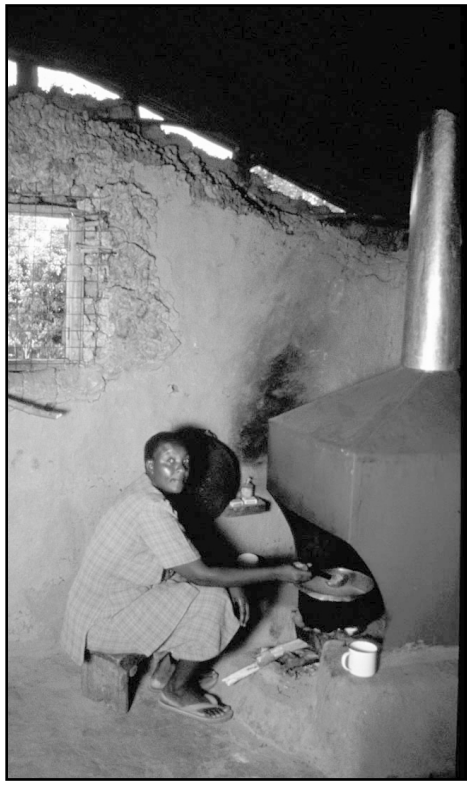
However, the enlargement of windows in the same project seemed to have little impact on indoor air pollution, although windows are required in houses with smoke hoods to allow an air flow through the house.[46] The enlarged windows did have benefits, such as improving lighting in the houses, but did not add significantly to the reduction of smoke.

Kenyan study[46]

The ITDG Smoke Project was launched in 1998. Working with 50 households in rural Kenyan communities, the project aimed to reduce exposure to indoor air pollution. The participatory approach adopted for this work meant that the project workers arrived willing to listen to the needs of the households rather than to impose specific interventions.

The interventions chosen were: smoke hoods; increased ventilation through windows and eaves; and more efficient combustion through improved stoves.

- Smoke extraction through smoke hoods was selected in favour of chimney stoves, based in part on the successful operation of smoke hoods in a previous project and on the failure of the chimney stoves installed during a government scheme.
- Increasing the amount of ventilation involved installing a window or cutting eaves spaces into the wall at roof height.
- The Upesi stove has been shown to reduce fuel use by about 40% compared with traditional three-stone fires. Households that have used them state that the kitchens are cleaner, children are safer from accidents and there is a considerable saving in the use of fuel wood.



ITDG/Dr Nigel Bruve

A West Kenya kitchen with smoke hood, large eaves space and windows.

An important component of this programme was the exchange visits that allowed local dissemination of ideas. Initial reluctance on the part of many cooks turned to enthusiasm once they had seen the interventions in place in other people's kitchens.

The results showed substantial reductions in particulate matter and carbon monoxide levels in the households after the installation of interventions. The most effective intervention was the use of smoke hoods, which reduced particulate pollution by an average of 75% and carbon monoxide in the room by 78%. The personal exposure experienced by the women in the study was reduced to about one third.

Additionally there were some very positive impacts on poverty. Community members observed that they felt healthier; there was more time to engage in economic activities when the stoves were used; and local artisans increased their income from the manufacture of interventions. There were significant improvements for women, above and beyond their health. Participating women were found to have increased confidence and improved status in the community.

These changes are not without their problems, with some reports that houses were now cooler, concerns about privacy and security which were overcome by using wire mesh over openings, and some financial problems for households who were contributing to the costs of the programme.

This was the first stage of a programme of work with the target communities. The on-going work is now aimed at achieving wider use of the interventions through public awareness, developing local markets for the interventions and establishing local financing mechanisms to help households afford the necessary changes in their homes.

Responses to interventions in the Kenya study

'I can now do my studies in the kitchen,' one boy, Sironga Masur, told the team. 'I never used to study with the fire on due to choking smoke.'

'Now I can have a breath of fresh air. No more tearing, no more red eyes, bye-bye to headaches.'

'You no longer suffocate while in the kitchen cooking.'

Cutting smoke volumes

Improved biomass stoves

Improved stoves were primarily designed to increase energy efficiency. The Upesi stove, for example, has been promoted throughout Kenya and can reduce fuel use by about 40%.[46] These stoves were developed with good reason. Reducing fuel requirements will ease demand on forestry, lessen the burden on women collecting fuel, and in urban areas cut expenditure on fuel.

Some improved stoves can also help reduce emissions of smoke. Studies have shown a small decrease from certain improved stoves, although many stoves in fact increase emissions if air flow to the fuel is restricted.[53]

If an improved stove incorporates a flue or chimney, one would anticipate smoke would be reduced. There are some very effective chimney stoves, which have been designed to remove smoke from the house, and tested in the home to show a significant reduction in smoke. Good examples are the rocket stove[48] and Ecostove,[49] which are increasingly being used in Central America.

However, there are also potential problems with many chimney stoves. Flues may not perform well if they are not installed properly, they can be poorly designed and can be fragile. Chimneys are expensive and may be ineffective if the smoke returns through doors and windows.[47] They can also block up quickly with soot and require regular cleaning.

These points indicate that improved stove must be more rigorously designed and monitored to demonstrate a significant impact on IAP in the home.

Reducing the need for fire

Hay boxes

A very simple technology can reduce the need for fuel for cooking – this is the fireless cooker, or a 'hay box'. This acts like a slow cooker, and is good for making soups, rice or stews. The food is heated to boiling, then placed in a box filled with insulating material, such as hay or crumpled newspaper.[50] The food continues to cook slowly. The development organization Winrock found that the hay box was very popular with the women's groups they worked with in Nairobi, where hay boxes are proving as popular as improved stoves.[51]

The success of the Ecostove in Nicaragua[49]

After diarrhoea, acute respiratory illness is the greatest cause of death in young children in Nicaragua. In both rural and urban parts of the country, three-stone fires are still commonly used. In urban Managua and smaller towns, a new stove is making inroads to replace the traditional stove. This is the energy efficient Ecostove, developed by the NGO Proleña, with technical support from Aprovecho.[48] The Ecostove is an innovative woodstove which is insulated, with hot emissions (smoke) vented through a chimney. The stove is sealed, preventing nearly all indoor air pollution, and reduces consumption and expenditure on wood fuel by 50%. It is common for women to increase their income by creating a small business to cook tortillas and soup to sell at their back door or from small stalls. This requires long periods by the stove. The Ecostove has been particularly beneficial to these households.

Rogerio Carneiro de Miranda

Woman cooking on an Ecostove in Nicaragua.

Solar water heaters and cookers

Solar water heaters, which absorb the heat of the sun, can fairly consistently provide water at 60°C. This has been estimated to result in a 30% reduction in the amount of fire use and therefore, potentially, a 30% reduction in exposure to air pollution. They need not be costly as effective systems can be constructed from black piping and plastic drums.[53]

As much of the need for improved cooking comes from countries with abundant sunshine, it would seem a logical step to move towards solar power, and there are some very strong advocates for this technology. However, there are also some serious concerns.

Solar cookers, which concentrate sunlight directly to cook food, have been seen as a clean alternative way of cooking. Unfortunately there has been limited success in practice. The use of solar energy means preparing a meal at midday, which does not coincide with the main family mealtime in many cultures. It also requires the cook to work out of doors, which reduces privacy while cooking and makes cleanliness difficult.[16] For solar cookers to be used more widely, they must be developed along with the users to ensure greater acceptance from the target community.

Photovoltaic solar home systems, which produce electrical power, are not capable of delivering the levels of power sufficient to cook a family meal. They are also, currently, very expensive for most poor people.

Changing patterns of behaviour

Simple changes in the way the cook behaves can reduce exposure to smoke. For example, making sure that fuel wood is dry cuts emissions. The use of a pot lid can reduce the fuel consumed during simmering by a factor of three and overall emission levels by almost a half. Keeping children away from the fire is also an obvious way of reducing their exposure – but if they are habitually carried on their mother's back, or the mother is the only childminder for toddlers, this can be very difficult.[53]

Cooking outdoors would, in many instances, reduce exposure to indoor air pollution, and in some parts of the world, for example the aborigines in Australia, this is the norm. However, for most cultures cooking indoors is normal practice.

There are some practical objections to cooking outdoors. There is a need to keep cool (when the sun is hot outside); there is the need to keep warm (when the fire is required for heating); there is a need to keep the fire sheltered from the wind as the heat is directed away from the pot; there is a need to keep the food clean from wind-blown dirt; and there is the need to keep safe (a closed kitchen keeps food safe from thieving people and dogs).[52]

There may also be cultural objections in some societies – people do not like to have others see what they are eating – and the fire is sacred, a source of life, and therefore needs to be at the heart of the household.

Heating the home

Most of the interest in the impact of indoor air pollution has concentrated on the use of stoves primarily as devices for cooking in the tropics. However, in even the hottest countries, there may be a need to heat the home, especially at night. And in a number of regions, for example the Himalayas and the Andes, space heating is essential. In northern Pakistan, for example, summer temperatures can reach 45°C yet fall to –40°C in the winter. Exposure to smoke is exacerbated enormously when members of the family spend longer by the fire during the winter. The increased need for fuel creates another burden for women. Unfortunately, stoves that are well insulated, though more efficient at cooking, will release a smaller amount of energy into the room. And the addition of chimneys will conduct heat away from the space where it is needed. These needs have not been well catered for in the development of stove technology.[16]

Some reasons why women do not cook outside

- Climate – need to keep cool (when it is blazing hot outside), need to keep warm (when heating is required) and the need to keep dry (during the rainy season). There is often switching between inside and out depending on the weather conditions.
- Gender – the kitchen is a woman's domain, where she keeps her utensils and food ordered and clean, implying the need for a private space.
- Cultural – people do not like other people seeing what they are eating. People regard the fire as sacred – and so it has to be at the heart of the household.
- Energy – cooking outdoors burns much more fuel due to the wind. The wind also blows dirt and dust on to the food.
- Safety – the need to keep safe and to stop food being stolen by other people or animals.

Where there is a need to heat the home, thermally-efficient housing can reduce, or even eliminate the need for heating, reducing the family's exposure to pollution. There are some measures, such as correct solar orientation, that cost nothing at the time of construction. Where insulation is installed, smoke must be vented from the house.[53]

Identifying appropriate solutions

Cooking is a deeply cultural and private affair, as it occurs in the home. Experience has indicated that there is no point trying to dictate a solution to a community. This is a view supported by a WHO and USAID-supported consultation on indoor air pollution and health: 'A single issue, technology-driven approach to indoor air quality is doomed to failure … Such an approach would limit the choices available to the local community and frequently demands of them changes that affect numerous aspects of their lives.' The authors argue that 'the key to success is to adopt project approaches that broaden the range of secure and sustainable choices available to the local actors and thus to enable them to devise their own solutions'.[53]

Any programme must be based on what is acceptable to the community. There is no point investing massive resources into something that will not be used. For example in Sri Lanka, early stove projects were aimed at what the 'experts' assumed was the key issue. But the emphasis on fuel-efficiency at the cost of users' priorities often resulted in low acceptance amongst households.[54] This is a common factor in the failure of many unsuccessful stoves programmes around the world.

Selecting appropriate technologies – comparing experience in Sudan, Kenya and Nepal

ITDG is working in three very different locations to develop locally appropriate solutions to indoor air pollution.[55] Participatory approaches have enabled the community to select solutions that suit their own needs. Their choice of technology, in each location, was influenced by cultural aspects, cost of both the technology and the fuel, geographical location, access to fuels and climate.

In the refugee settlement in Kassala, Sudan, the community identified LPG as an appropriate solution once microfinance was made available to cover the initial cost of the stove. The scheme is popular, and already others outside the project are using the credit system to buy stoves. Fuel costs are much lower for LPG than for charcoal and wood in Kassala, so repayments can be offset by reduced fuel costs.

In the communities around Kisumu town in Kenya, wood fuel is much cheaper than LPG or collected 'for free', so most households have elected to continue using biomass. Smoke hoods and eaves spaces are proving effective. A few households could afford to choose LPG.

In the remote, cold mountain village of Gatlang in Nepal, solutions have been more difficult to identify as energy is needed to heat the house as well as to cook the food. It is remote, making LPG or kerosene unavailable, so biomass is the only solution. Home insulation has been identified as a possible means of retaining room heat whilst reducing the need to burn fuel wood for space heating. Ways of venting the smoke are currently being developed, along with metal stoves to reduce fuel use.

Country	Location	Solutions chosen by communities[56]
Kenya	Kisumu, town	Upesi improved stove, smoke hoods, eaves space, hay boxes, LPG
Sudan	Kassala, refugee settlement	Mostly LPG
Nepal	Gatlang, remote mountain village (cold area)	Venting smoke, improving home insulation

Table 3: Solutions chosen by three different communities.