PRACTICAL ANSWERS TO POVERTY

technical brief

SOLAR COOKING

Introduction

In the rural areas of most developing countries cooking is usually done on open fires fuelled by wood. In the cities stoves are more common, fuelled by wood, charcoal, kerosene (paraffin) or sometimes butane. In many regions (notably the Sahel, East Africa and the Himalayas) oil-derived fuels are expensive, and wood-based fuels are becoming increasingly scarce as rising demand presses on dwindling numbers of trees. Cooking is the main source of demand for woodfuel and can be an important cause of deforestation.

There are four possible ways of remedying an insufficient supply of woodfuel. The first is to increase supply by promoting the planting of trees. The second is to decrease demand, for example by introducing more energy-efficient stoves. The third is to develop alternative sources of fuel, such as indigenous coal resources, or biogas. The fourth is to promote the replacement of fuel-using techniques by solar cooking, the subject of this technical brief.

Solar cookers are devices that use the energy of solar radiation to cook food. They are not new: a design is described in an 1878 edition of Scientific American, and continuing development and assessment has been underway since the Second World War. There are now many designs that 'work' in the sense that they can indeed cook food, and some of these are not expensive, but attempts to promote their use in the rural areas of developing countries have in general been unsuccessful. There are a number of disadvantages to solar ovens that can, very easily, negate the benefits. These factors are:

- The time taken to cook a meal can be very long.
- The time of day when a meal can be prepared, the cooking has to be carried out during the middle of the day but hot food may be required much earlier or later in the day.
- Cooking has to be undertaken outside when traditionally it has been done in doors.
- It is not always sunny.

Indeed, solar cooking is sometimes now held up as a cautionary example of inappropriate technology. Solar cookers can be short-lived, inconvenient and unpleasant to use, dangerous, and may produce unpalatable food or not succeed in cooking it at all.

There have been projects which, at first sight, seem to have succeeded in introducing solar cookers but, on closer scrutiny, it is clear that the idea is not sustainable. For example, a project in Pakistan successfully introduced solar cookers at a selling price of US$18 in 1987. The manufacturing cost, however, was US$56 (rising to US$65 as improvements were added). In a sustainable commercial environment, the manufacturing price would be inflated by producer's profits, wholesaler and retailer mark-up and the selling price would be at least US$150. In other words, when the huge subsidy is removed at the end of the project, it will undoubtedly collapse.

In some circumstances, solar cookers have proved to perform satisfactorily and to be acceptable to the users (e.g. Peshawar refugee camps) but there is no evidence that the apparently successful technology is readily transferable to other locations and conditions.

Two main types may usefully be distinguished, solar hot boxes (and solar ovens) and concentrating cookers; these have very different characteristics and will be considered separately. The essential difference is the same as that between conventional stoves or open fires, and ovens. Stoves apply heat directly to the bottom of a cooking pot, whereas ovens provide a space of hot air, which heats a pot or the food directly.

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Requirements for cooking

There are three main types of cooking process:

- The food may be cooked in hot or boiling water or steam. This may be done on a stove or in an oven. Meat or pulses require temperatures close to 100°C, while rice can be cooked at 70°C. For grains and pulses the addition of water is an integral part of the process.
- The food may be baked. This is most easily done in an oven. For bread and cakes temperatures of 150°C and higher are normal but may not be essential.
- The food may be shallow-fried in oil. This is usually done for a short period at high temperatures and with frequent stirring. A stove-type cooker is essential.

In all cases the food cooks faster with higher temperatures.

There are two stages in the cooking process:

First, energy must be added to the pot and its contents to bring it up to temperature. The amount of energy required (assuming no heat loss from the pot) is given by:

Energy required (kJ) = mass of pot, food and water (kJ) x Temperature rise (°C) x average specific heat capacity (kJ/kg/°C).

For example, bringing one litre of water to the boil from 30oC requires at least 1 x 70 x 4.2 = 300kJ. To bring to the boil a pot containing 3kg of food and water (enough for about 8 people) requires about MJ (excluding heat loss). This energy may be added at high power over a short period (e.g. 1kw for 17 minutes) or at low power over a longer period (e.g. 100W for nearly 3 hours). In practice, heat losses will result in much larger energy requirements.

Second, the required temperature must be retained for some time. This is achieved by adding energy at the same rate as it is being lost. Heat is lost by convection, conduction and radiation. Heat loss is made worse by high temperatures in the pot or oven, large surface areas, and highly conductive materials. Energy can also be lost if water vapour is allowed to escape -for a pot with no lid boiling on a stove this could well be the most important source of loss. (It takes as much energy to evaporate just 10% of a litre of water as it does to raise the temperature of a whole litre by 55°C. So where energy is scarce lids should be used whenever possible.)

Somebody using a gas stove is well aware of these two stages. To boil potatoes, for example, the flame is turned up high until the water boils and then right down while it simmers. The same effect is achieved by a thermostatically controlled oven. For a solar oven the situation is different. Power input is more or less constant throughout (clouds permitting) and temperature rises until power loss equals this power input.

In a tropical country, the power received in solar radiation can reach 1kW/m^2. Over the eight hours or so during which solar cooking is feasible, an average power of 600W/m^2 is typical. Most solar cookers designed for household use received solar radiation over an area of 0.5-1.5m^2. The power input from a solar cooker or oven is equal to the solar irradiance x the area of the cooker x the efficiency. For example, a 1.2m^2 cooker of 25% efficiency will produce 800 x 1.2 x 0.25 = 240W in solar irradiance of 800W.

The nature of the relationship between cooking time, temperature, power input and tendency to lose heat (a function of surface area arid degree of insulation) is shown in Figure 1.

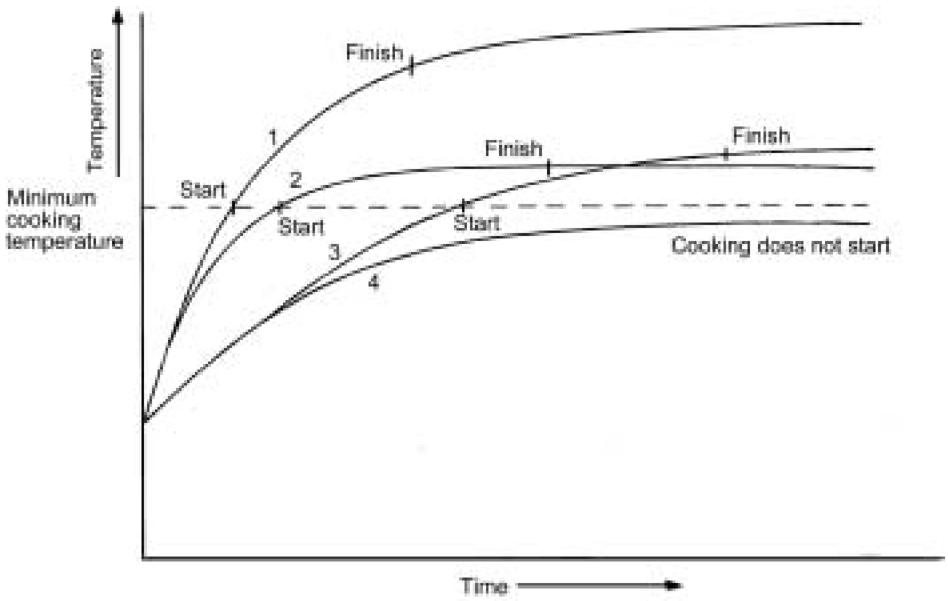

Figure 1: Graph showing the relationship between temperature and cooking time

Case	Power Input	Heat Loss Characteristics
1	High	Small area, well-insulated
2	High	Large area, well insulated
3	Low	Small area, well insulated
4	Low	Large area, well insulated

Comparing cases 2 and 3, final temperature is the same in both cases, but overall cooking time is less for case 2 because the initial heating-up period is shorter.

From this technical viewpoint of achieving high enough temperatures for sufficient periods, some solar cookers are successful, if the sun shines.

There are however, many other factors to be considered:

- Can meals be produced reliably at the desired time of day?
- Does the cooker enable the desired type of cooking to be carried out?
- How long does cooking take?
- Where does cooking take place -indoors, outside in the shade, or in the sun?
- Is the cooker safe?
- Does the cook sit, stand or squat?
- Does the cooker fulfil any functions other than cooking? For example, open fires may provide warmth and drive away mosquitoes, as well being of cultural significance.

The technology may be unsuccessful because it has characteristics that are inherently undesirable (e.g. unreliability) or that involve changing established routines and customs (e.g. long cooking times may necessitate a change in mealtimes).

Oven-type solar cookers

The essential features of an oven-type solar cooker are:

- An airtight enclosure - the oven - with well insulated walls.
- A transparent window which allows sun light to enter the oven, but does not transmit the low-frequency heat radiation emitted by hot surfaces inside the oven.

Most types have in addition one or more reflective panels that direct solar radiation into the oven from a wider area. 'Ovens' are distinguished from 'hot boxes' by having more reflective panels, smaller surface area, and therefore higher internal temperatures.

The hot box would cook rice, dhal and meat in 2 to 4 hours on fine days in India; the oven would take one to two hours. The oven needs frequently to be oriented and tilted toward the sun; adjustment is less important for the hot box.


Figure 2: A solar hot box in Kenya ©ITDG

The main disadvantages of hot boxes are their inability to reach higher temperatures and the length of cooking times. Only certain types of meal can be prepared and preparation must be done several hours before mealtime. On the other hand, there is little risk of burning food and so little attention is required, and many dishes, such as curries, sauces and soups, actually benefit from lengthy cooking.

Successful cooking is of course dependent upon the weather, but the combined heat capacity of food, pot and oven does at least prevent too rapid a fall in temperature during short cloudy periods.

Likewise, food will stay hot after the sun has gone down and so evening meals are possible.

Finally, storage may be a problem since the cookers are fairly bulky and it is often necessary to bring them inside at night.

Large numbers of single-reflectors hot boxes have been sold in India, partly as a result of State and Government subsidies amounting to up to 60% of the price. It has been reported by the Brace Research Institute that 5000 were in use in the State of Gujarat in 1981, and more recently, that supermarkets in Delhi were selling 50 or 60 per day.

Concentrating cookers

Concentrating solar cookers are of the stove type. Their essential feature is that solar radiation incident upon a fairly wide area is concentrated onto the under-surface of the cooking pot, by a reflector of suitable shape. One ideal form is a parabolic dish but many designs use other shapes that may not produce accurate concentration but are easier to manufacture. An example is shown in Figure 3.

Most concentrating cookers are of similar size and can deliver up to about 700 watts to the cooking pot. They may bring 3 litres of rice and water to the boil in about 1 hour. This power input is within the normal range of open fires and conventional stoves, and so standard cooking techniques may be used. Power input is often reduced by spillage of food onto the reflecting surface.


Figure 3: A solar parabolic cooker being used in Nepal ©ITDG/N. Bruce

Concentrating cookers are vulnerable to cloudy periods, especially if a high temperature cooking process such as frying is being used. Mealtimes can be earlier in the morning than is the case with hot boxes or ovens, but not so late 1n the evening.

The cook has to attend to the cooker, to stir food and to adjust its orientation. He or she will normally have to stand in the hot sun, and may experience unpleasant glare or even suffer eye damage from the reflecting surface. There is also the potential for serious burns-temperatures at the focus may be as high as 850°C. There should be no danger with proper use, but, for example, children might be tempted to experiment.

Almost all designs suffer from instability in wind. They are usually less convenient to store than hot boxes or ovens -folding 'umbrella' cooker being a notable exception!

In general, attempts to introduce solar cookers to rural areas in developing countries have been unsuccessful, because of the disadvantages described above. However, it is reported that they are in quite widespread use in China: they have also been advertised for use by campers in the United States.

Larger scale cooking for institutional use, such as in refugee camps in arid regions, may be practical, using a number of tracking mirrors focussed on a large pot, but this has not so far been tried. Certainly larger scale cooking would be technically more efficient as heat losses could be smaller at a given temperature.

Other types of cooker

It may be possible to achieve some of the advantages of both main types of solar cooker with a hybrid design -a concentrating solar oven. The pot is placed in an oven and focussed onto it through a small glass pane.

Another possibility that has been tried is the indirect solar cooker. A working fluid such as water or oil is heated in a solar collector and the steam or hot oil heats the pot or oven. In principle, this could allow the cook to work indoors. But early prototypes were less successful than ovens or concentrating cookers in producing appetising food. More advanced designs that have been suggested would be expensive, but possibly worth considering by institutions such as schools or hospitals.

May solar cookers be appropriate?

Should an individual household consider buying or making a solar cooker? Should a development agency initiate a solar cooker project? Any decision should be taken in the expectation that savings in fuel would be obtained at the cost of loss of convenience. The main factors to be considered are as follows:

Availability and cost of fuel

It is possible for firewood or other fuel to become so scarce that they are literally not available. Solar cooking is then competing with no cooking at all and is there- fore attractive. But in general fuel can still be found, but at greater distances or higher prices. It is difficult to put a monetary value on time spent collecting firewood, but it is often time that could be spent on other economically productive activity. A typical household might use 3000MJ of energy per year for cooking. At a notional 3p/kWhr this would cost £30/year. This is a significant amount for many households. Where fuel is scarce, it is not uncommon for it to account for 10 or 20% of annual expenditure.

Cost and availability of solar cookers

The cost of a solar cooker depends upon its design, the types of materials and skills available locally, on the numbers being produced and upon whether the price is subsidised. Concentrating cookers may cost as little as £10 whereas hot boxes are unlikely to cost less than £20. The cost to a house- hold is likely to be less if a development agency is undertaking a project in their area. There will also be an annual cost for maintenance, especially for replacement of reflective surfaces. With the exception of mirror glass, all widely used surfaces need replacing at least once a year.

Availability of capital and interest rates

The people who are hit hardest by scarcity of fuel usually have little or no spare cash with which tobuya solar cooker or the materials to make one -they many indeed have spent it on the last bundle of firewood. If they can borrow money it will usually be at a very high interest rate. In most field tests solar cookers have been supplied to households

References and further reading

- *Solar Cookers in the Third World* by Klaus Kuhnke, Marianne Reuber & Schwefel. GTZ
- *Moving Ahead with Solar Cookers: Acceptance and Introduction to the Market*, GTZ, March 1999.
- *Something New Under The Sun: A Manual for Solar Box Cookers*, Technology for Life

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This organisation produces *Solar Cooker Review* detailing a wide range of solar cooking equipment and related projects occurring throughout the world.

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The Appropriate Technology Development Association has designed a box type solar cooker, it would seem that they do not manufacture the item but allow the manufacture to be carried out at a local level.

Useful websites

Solar Cooking: http://www.solarcooking.org/

Technology for Life (TFL) http://www.kaapeli.fi/~tep/nepal.html