Moving Ahead with Solar Cookers

Acceptance and Introduction to the Market

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Foreword

South Africa is a country endowed with abundant energy resources, none more so than the Sun. The irony of the situation is that this plentiful resource remains almost completely unused, while another equally plentiful resource which is used extensively - coal - has considerable negative impact upon our environment.

Firewood forms the main energy source in the rural domestic sector but there are signs that it is becoming scarce.

Throughout Africa deforestation is increasingly placing a burden upon women who are responsible for collecting this fuel as they forage further and further from their homes.

While solar power technologies are steadily being developed and promoted for use in developing countries such as South Africa, these have hitherto been only available for low load applications such as photovoltaic systems. Some solar device was still lacking to fill the gap for cooking needs.

Therefore when solar cookers began to be promoted in South Africa, the Department of Minerals and Energy was the first to recognize their significance for improving the quality of life of people in rural areas. Following the results of the first phase of the joint South African/ German Solar Cooker Field Test, the White Paper on Energy Policy now states that rural villages should be targeted for installation of solar cookers for households, schools and clinics.

Certainly the social acceptance of solar cookers by the three communities involved in the Field Test lead us to be optimistic about the possibilities of solar cooker technology. We are committed to finding such solutions which bring about socio-economic development, job creation and alleviate poverty in undeveloped rural areas. We wish you well in your endeavours to commercially disseminate this product and penetrate the rural communities of South Africa to impact on their living conditions.

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Preface

It is fascinating to cook food using only direct solar power, which is inexhaustible, clean and free. While this shop report introduces the approach to and initial findings of a solar cooker project, it is hoped that the reader will experience the intrigue of those involved in the project.

Many inventors and developers have been busy designing numerous imaginative devices with which to capture the sun for cooking. Their contribution is laudable and we are grateful to them for their pioneering spirit and personal commitment.

In arriving at their places of use in low-income areas of tropical countries, solar cookers have followed many different paths. However, they have not evolved into commercially viable products that "sell" themselves. Only in Tibet, at extreme altitudes, where there is no wood and where dried dung and sod are the most valuable - indeed, the only – sources of domestic energy, are solar cookers reported to be used extensively. Most other attempts to get solar cookers successfully established on a large scale have ended up as case studies for future project archeologists.

But still the technology offers good opportunities – particularly against the backdrop of the steadily worsening fuelwood scarcity – and therefore invites renewed dedication to the solar cooking cause. If that which is physically possible can be implemented in a technically sound, economical, user-friendly manner, innumerable families stand to benefit from the results. Poor families, for example, will then have to spend substantially less time, effort and money on firewood, charcoal and kerosene. They may even have enough money left over to fill their cooking pots with something other than "walkies-talkies" (cf. page 21).

The Federal German Ministry for Economic Cooperation and Development undertook to join forces with the Federal German Ministry for Education and Research in a systematic shakedown of available solar cookers with regard to performance and convenience of operation. First, a technical test was conducted in Almería, Spain; then, GTZ and its South African partner, the Department for Minerals and Energy, investigated the cookers' acceptance in a developing country by way of a field test.

Having concluded the first phase of the solar cooker test, the subject of this report, the basic acceptance problems and the issue of appropriate conditions for use may be regarded as understood. In the right context, solar cookers find acceptance by low-income communities as an option for cooking and baking. Therefore, further investigations will focus on local manufacture, commercial dissemination, and reducing the cost of production. The decisive factors governing dissemination and use will be primarily of an economic nature, e.g., the purchase price and the local availability of services and small loans. Such conditions can be influenced. With Germany and South Africa as partners, the second phase of the project aims to find a way to turn this fascinating idea into reality.

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1. Introduction

In many emerging countries, it is becoming increasingly difficult to secure energy for cooking. In areas where fuelwood is the traditional source of energy, particularly in the more arid regions of the African Continent, many people suffer from depleting wood resources. Intensive deforestation and erosion cause irreversible environmental damage. This is compounded by high population growth.

Cooking with fossil fuels – coal, gas and kerosene (in South Africa known as paraffin) - carries a high price. It is expensive both directly to the user and indirectly, to the national economy as a result of currency drain and/or subsidization. The security of supply is also often questionable. This is worrying as the quality of life deteriorates and there are negative effects on local economies.

Most notably in areas with ample sunshine, i.e. with high levels of insolation, cooking with solar energy can help alleviate such problems. Unfortunately, past solar cooker projects in developing countries have tended to achieve only modest results. The following is still unclear:

- Will solar cooking remain a niche phenomenon in the field of development assistance, and if so, then why?
- Is it possible to commercially disseminate solar cookers, making them available to broader sections of the population on a sustainable basis?

To find an answer, the Governments of Germany and South Africa are providing joint support to a solar cooker pilot program that includes a comparative field test under real-life conditions. This entails a prolonged period of proof testing by the users themselves. This publication deals primarily with the empirical results that have been gleaned from that pilot program to date.

At the time of printing (06/99), the South African Rand, as quoted here, was valued at US$ 0.162.
During the field test, the exchange rate fluctuated between US$ 0.157 and 0.274 per Rand.

2. The Fuelwood Problem

Around the world, fuelwood is a leading source of energy. Fuelwood accounts for 15 - 18 % of global primary energy consumption – more than nuclear energy and hydropower combined [FAO, 1998a].

Each year, some 2 billion tons of wood are "energetically utilized" (read: burned) [FAO, 1998b], mainly for cooking purposes.

Fuelwood accounts for 15 – 18 % of global energy consumption – more than nuclear energy and hydropower combined.

This has had myriad consequences, from polluted air in people's kitchens, and the respiratory ailments it can cause, to deterioration of the earth's entire atmosphere. Other effects include such local environmental damage as deforestation, erosion and the increasing scarcity of wood, as manifested by rising prices and the need to spend more time gathering fuelwood. At present some 2 billion people around the world are suffering from fuelwood shortages.

Fortunately, fears that such immense consumption of fuelwood could quickly culminate in global deforestation have not been confirmed. People prefer to burn dead wood that is generated incidentally by deforestation activities: clearing of forests to obtain farmland, for example, or commercial logging operations serving the housing construction and furniture industry. Nevertheless, the local impacts can be devastating. Consider the following case examples:

- A total, broadscale lack of fuelwood is a seldom occurrence. In Tibet, for

Gathering fuelwood in Onseepkans

example, there is no wood to be found across large swathes of land. People are forced to buy high-priced firewood hauled in from the eastern forests. Yak dung and sod are therefore used as fuel, causing irreparable damage in the form of erosion.

- Relative scarcity on a broad scale is much more frequent. In Tamil Nadu, India, for example, felling trees is a punishable offence. Trees are so valued that where they grow along avenues, they are numbered. Even so, goat herds can be seen climbing up high trees and chopping off leafy branches. The goats eat the leaves, and the stripped branches are taken along as fuelwood.

- Local scarcity is common. It often occurs around towns and villages where wood is an important fuel. Large refugee camps can also produce broadening zones of deforestation. In Makalle, Tigray (Ethiopia), for example, during the famine of the mid-1980s, all the trees were removed within a very short time. To survive, fuelwood supplies were brought in both by long caravans of donkeys from areas controlled by rebels and, so severe was the situation, by airfreight from Europe.

- Scarcity due to interdictions and regulations is also quite common. In South Africa, the owners of some forested property have forbidden people to gather fuelwood there – and have stressed the point by brandishing firearms.

At present some 2 billion people around the world are suffering from fuelwood shortages.

All these forms of fuelwood scarcity foster, to different degrees, the introduction of new cooking technologies. It should be noted here that the gathering of fuelwood does not count among the primary causes of deforestation. The notion that our planet's forests are being literally burned down for the cooking needs of poor rural folk in developing countries is incorrect. Reality is a lot more complex than that.

3. Introducing New Household Technologies

History shows that the introduction of new technologies can be both time-consuming and tedious. Back when coal was first being introduced as a substitute for wood in cooking, people received free coal to overcome their distrust. That did not work at first, because the era's wood-burning stoves were unsuitable for burning coal, and many people succumbed to carbon monoxide poisoning as a result. Subsequent conversions to electricity and gas were less dramatic but just as wearisome. Even microwave ovens, which have been on the market for some 20 years now, are still in their introductory phase.

New technologies do not just establish themselves simply because they are economical, environmentally sound or practical.

Nor are introductory processes irreversible. During and after World War II, many people relied on their "fireless cookers" (an insulated box in which already hot food remains hot enough to continue cooking). Even though such cookers required no supervision while they kept the food warm with no danger of scorching, and despite the fact that they saved their users lots of energy, especially when long cooking processes were involved, they eventually passed into oblivion.

The following observations can therefore be made:

- No new technology will just establish itself, simply because it is economical, environmentally sound or practical;
- The users must be convinced that this is the right decision to make: their social context must be conducive to the new technology;
- The users must be able to depend on getting help if problems arise (technical or otherwise);
- "All-or-nothing-at-all" decisions regarding new household technologies are the exception to the rule. Technological innovations tend to be looked upon as supplementary cooking options and, as such, are expected to prove themselves by way of comparison.

4. Cooking Traditions

Generalization would be out of place here. For example, it would not be fully correct to flatly state that "Africans eat their warm meal at supper time", or that "outdoor cooking is frowned upon". The only thing that all cooking traditions have in common is that they are all different. Consider the following case examples:

4.1 A Rural Family in Tamil Nadu, India

The Rajagopalan family in Tamil Nadu lives in a hut with a thatched roof and reed-mat walls in Kizhmeni, a little village in Tamil Nadu. The six-member family (parents, grandfather, three children) draw income from a small plot of cropland that Mr. Rajagopalan farms with some occasional help from his wife.

Most days, Mrs. Rajagopalan cooks two meals on her chulha, a traditional mud stove installed beside the house. The stove has two enclosed hearths, i.e., combustion chambers, that are fueled with wood, dung or rice chaff.

If the family decides to eat breakfast, which often is not the case, they sit down at about 7 a.m. to a meal of cold, slightly fermented Indian rice that was soaked in water overnight. They may also slake their thirst with tea or coffee.

Around noon, Mrs. Rajagopalan cooks up a batch of curry rice, and the evening meal, which is taken at about 6 p.m., most likely will consist of rice and dhal (pigeon peas). Each such meal, which takes about an hour to prepare, also includes water or milk to drink. Special dishes are served on holidays and when there are visitors. Once in a while, a chicken enriches the family's diet.

The Rajagopalan family is not poor. Their neighbors, though, who are very needy, can only afford one meal a day, usually in the evening (acc. to Sodeik, 1991).

4.2 An Affluent Family in Kaolak, Senegal

Mr. and Mrs. Soumaré, with their two children and five grandchildren, live together with their servants and various visitors in a prosperous neighborhood in the city of Kaolack, Senegal. The family's income consists of Mr. Soumaré's civil service pension, his wife's modest earnings from her textile dyeing shop, and some help from their grown-up children, who live in Dakar.

They cook their meals on a gas stove in the kitchen. If an empty gas bottle can not be refilled right away, the next few meals are cooked over coal, which the family always keeps for making their traditional afternoon tea. Due to subsidies, gas is cheaper than coal.

Breakfast is taken between 7 and 8 a.m. and consists of tea or white coffee and bread. Dinner is served at about 2 p.m., when the children arrive home from school. Usually, this meal is made up of ceebujen (rice, fish and vegetables in a sauce), though sometimes white rice with a peanut sauce or gravy is served for variety's sake. At each meal enough food is cooked for about a dozen people.

All cooking traditions have one thing in common – they are all different.

The family gathers for supper around 7:30 p.m. This meal is generally more varied and likely to consist of couscous, milk, beans and/or peanut rice, or of bread and meat. The evening meal is cooked for fewer people (less visitors). Bread and cake are never baked at home for lack of utensils (acc. to Bänninger, 1993).

4.3 A Typical Family in Quetzaltenango, Guatemala

The Lopez family lives near Quetzaltenango in Western Guatemala in a hut made of scrap metal and cardboard. The family of eight consists of Mr. and Mrs. Lopez, the latter's parents, and the couple's four children. Mr. Lopez is a construction worker, and his wife earns a few pesos now and then doing laundry.

The family's meals are cooked over a wood fire in a three-stone indoor hearth. A neighbouring family recently purchased an improved stove with an enclosed combustion chamber that will burn sawdust, cardboard and even plastic bags.

The Lopez family eats breakfast between 6 and 7 a.m. – usually a meal of beans and meat plus cornmeal patties, and, sometimes cornbread with a cup of coffee. Dinner is eaten between noon and 1 p.m. and normally consists of either a bone soup and vegetables or boiled meat and vegetables, with atole (a thin cornmeal drink) or some other cool, homemade beverage to drink. The evening meal, which is taken between 6 and 7 p.m., is usually made up of fried eggs and beans, perhaps some cheese or bananas, and coffee. It takes Mrs. Lopez about an hour to cook breakfast, 2 1/2 hours to cook dinner, and 1 1/2 hours to cook supper. Most dishes are either boiled or fried and heated up as necessary (acc. to Alvarado Mérida, 1996).

5. Cooking Profiles

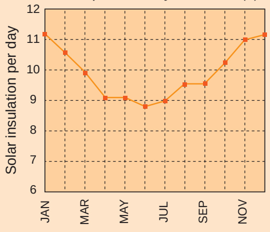
The dissemination of solar cookers must begin with an analysis of the local situation, i.e., of traditional cooking habits and local needs – not with the selection of a certain type of cooker.

In view of all the different cooking traditions, the following must be stressed: The dissemination of solar cookers must begin with an analysis of the local situation, i.e., of traditional cooking habits and local needs – not with the selection of a certain type of cooker from among the more than 160 different models available worldwide. When a cooker is first selected then an area of need identified for its use, it can be said that "solar cooking is a solution looking for a problem".

The main aspects of local cooking traditions and conditions can be compiled in "cooking profiles" (cf. Table 1). These facilitate the search for suitable types of cookers, the selective accommodation of cookers to local circumstances, and trying out of special recipes. All are designed to make the cooker easy to use. Cooking profiles help avoid serious mistakes in the selection of solar cookers.

Table 1: **Cooking Profile for Onseepkans (Northern Cape, South Africa)**

GTZ-DME SOLAR COOKER FIELDTEST SOUTH AFRICA

Cooking Profiles Families (State: January 1997)	
Location	ONSEEPKANS (Northern Cape), a five-mile-long town comprising three settlements (Melkbosrand, Viljoensdraai, Sending), 50 km from Pofadder. Surroundings: green belt on the Oranje, with some farming, but otherwise semi-desert (very stony)
Typical housing	Thatched houses with corrugated sheetmetal roofs, often fenced in, with an occasional vegetable garden
Income	Average monthly income of R 650 (c. 100 US$) with most families earning between R 250 (40 US$) and R 500 (80 US$) per month (2)
Size of family	1 - 14 (2)
Main diet	Porridge, soft porridge, rice, vegetables, meat, tripe and other innards and head, legumes, fish, bread, incl. "rusks", spaghetti, soup, macaroni, potatoes, tea, eggs, milk (1)
Cooking techniques	Boiling, frying, baking, simmering, steaming (1 and 2)
Preparation techniques	Mincing, soaking (legumes/pulses), stirring (e.g. for porridge dishes, which require vigorous stirring); rice added to cold water (1)
Beginning of cooking	Between 6 a.m. and 10 a.m.; noon: between 10 a.m. and 1 p.m.; and between 4 p.m. and 8 p.m. (2)
End of cooking	Between 7 a.m. and 11 a.m.; noon: between 11 a.m. and 2 p.m.; and between 6 p.m. and 9 p.m. (2)
Meal times	Between 7 a.m. and 11 a.m.; between 12 a.m. and 2 p.m.; and between 7 p.m. and 9 p.m. 2)
Existing cooking equipment	Mainly woodstoves or three-stone hearths, some gas cookers and a few kerosene cookers; some families have more than one cooking facility, e.g. a woodstove and a gas cooker (2)
Cooking area	Mainly indoors or under cover (incl. open fires), but rarely outdoors (1)
Number of cooking pots	Often two pots with a capacity of 5 to 8 liters (1)
Fuel (purchased/gathered)	Mainly wood (mostly of it gathered along the river, but some purchased); some paraffin and gas (1 and 2)
Fuel costs	1 l kerosene = 1 R; 9 kg bottle of gas = 38 R; 1 bundle of wood (ca. 15 kg) = 7 R (2)
Climate	Very sunny October through March; partially cloudy and windy in April and May; partly sunny with some light rain in June and July; very sunny and windy, with little rain, in August; sunny, with some clouds and wind, in September (2)
Suitable place for a solar cooker	Close to the kitchen, for fear of food theft or damage to the cooker (1)
Families interested in acquiring a solar cooker (e.g. on a credit system)	Yes (1)
Daily insolation	6100 Wh/m^2/d (4)
Solar insulation location Onseepkans, 10 year-mean (3) 	Remarks: * Some data (e.g., who decides what the family is going to buy; is someone prepared to keep the cooker well tracked, ...) are difficult to obtain on a regional basis and therefore should be determined individually by way of questionnaires.
	Sources: (1) Local inquiries (2) Questionnaire survey (3) South African Meteorological Service, Pofadder Station (4) W. D. Cowan (ed.), "RAPS Design Manual", EDRC, University of Cape Town, 1992

6. Solar Cookers Somewhere Between Utopia and Reality

There is something fascinating about solar cookers: Anyone who has ever watched a pot of water being boiled "just" by the sun is sure to have been very impressed.

Likewise, the principle behind solar cooking is as fascinating as it is simple: rays of sun, bundled or not, are converted to heat and conducted into the cooking pot.

Anyone who has ever watched a pot of water being boiled "just" by the sun is sure to have been very impressed.

The causal connection behind the use of solar cookers is even more fascinating: areas marked by drought and poverty are where the sun shines at its brightest, providing an inexhaustible supply of clean energy for cooking.

It is no wonder, then, that solar cookers are a very popular subject of discussion, not only in tropical places where the sun stands high in the sky. The American organization "Solar Cookers International" has identified 653 organizations and individuals in 70 different countries who are actively involved in solar cooking.

The range is broad, extending from grass-roots Non-Governmental Organizations (NGOs) that help rural users build their own cookers to associations that propagate and disseminate either certain types of solar cookers or the idea of solar cooking per se. Around the world, scientists and engineers are at work designing and evaluating solar cookers (e.g., within ECSCR, the European Committee for Solar Cooking Research). In many countries, parliamentarians are actively promoting the dissemination of solar cookers, and UNESCO is busy preparing a "World Solar Cooking Program".

All the more surprising, then, that past solar cooker projects in developing countries have met with only moderate success. Most such endeavors have had roughly the following structure:

- Stipulation of a certain type of cooker, usually by an inventor or developer in the intention of promoting its dissemination
- External definition of a target group without systematic analysis of needs or acceptance
- Import or local manufacture/assembly of a short series, sometimes with incomplete guidance and use of unsuitable materials
- Free distribution of cookers among the target group, but without adequate familiarization with solar cooking and its peculiarities
- Inadequate support
- Project termination, often with negative impacts on the image of solar cookers.

As a rule, as soon as the project has ended, most users – with the exception of a few enthusiasts – stop using their cookers regularly.

Few projects are independently evaluated, usually due to cost considerations. This makes it difficult to determine why success was only limited, and it precludes a systematic experiential learning effect.

The following three open questions have always served to benchmark the solar-cooking knowledge base:

1. How do the technical characteristics of the various cookers compare with each other?
2. Do the users show acceptance for solar cooking under favorable conditions?
3. Can solar cookers be successfully produced and sold on a commercial scale?

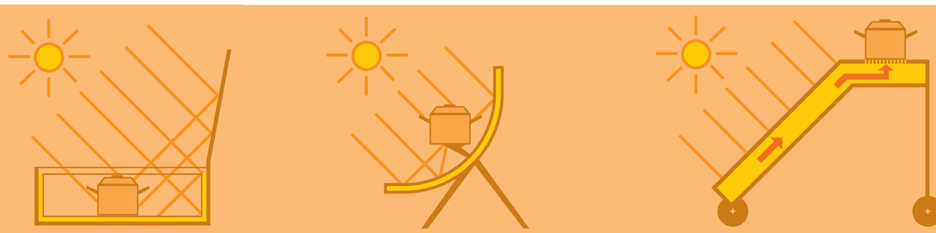
An answer to the first question was found in 1994 by way of a comparative technical solar cooker test conducted by ECSCR with the support of the Federal German Ministry for Education, Science, Research and Technology (BMBF) [ECSCR, 1994]; cf. page 16 (Table 2).

The other two questions are the subject of a pilot project in South Africa (DME/GTZ, 1997) that is being implemented by GTZ and the South African Department of Minerals and Energy (DME) on behalf of the German and South African governments.

7. The Technical Side of Solar Cooking

Within the scope of two studies (GTZ, 1991 and GTZ, 1998) a total of 168 different solar cookers were catalogued. Many of them were prototypes or hand-crafted small-lot products, and some of them proved useless in practice. Despite the global scale of the studies, it may be assumed that some models were overlooked and, hence, not counted. Of the 168 different solar cookers catalogued by GTZ, the most frequent type, accounting for 95 models, was the box cooker, followed by 51 kinds of concentrator-type and 22 collector-type cookers.
Basically, however, each of those many cookers fits into one of the following three categories:

Figure 1: Types of solar cooker



Box cookers
are insulated boxes with a glass top, often with a directionally adjustable reflective lid, designed to surround a cooking pot. Box cookers exploit both direct and diffuse solar radiation. They require little intervention by the user and are characterized by widely divergent thermal performance.

Concentrator cookers
concentrate direct insolation on a cooking pot. They are quite efficient but require the user's attention for keeping them aligned with the sun and maintaining good performance.

Collector cookers
are made up of two parts that often share a single casing: a collector for gathering heat and a cooking range for exploiting the yield. These powerful devices make use of diffuse and direct solar radiation. They are, however, rather complicated to build.

Power spectrum

- The biggest of all known cookers holds enough for between 800 and 1000 helpings, while the smallest measures 30 cm in diameter and uses a 500-ml jelly jar as its cooking vessel.
- The thermal output of solar cookers also varies widely (cf. Table 2 for an excerpt of ECSCR test results):
While the more powerful models can boil water in just a few minutes, the weakest never reaches boiling temperature. It merely heats the water to about 80°C in two hours' time.

Table 2: Performance data of various solar cookers (ECSCR test, 1994)

	Best results	Poorest results
Heating time 40 - 80°C (water)	6 minutes	118 minutes
Heating time 40 - 96°C (water)	11 minutes	81°C after 2 hours
Maximum temperature (oil)	198°C	91°C

8. Solar Cookers in Practice – A Comparative Field Test in South Africa

8.1 The Field Test

The goal at the outset was to find answers to the following questions:

- Why aren't solar cookers in more widespread use?
- What kind of technical problems, if any, do today's solar cookers pose?
- Can traditional dishes be prepared at the right time with solar cookers?
- Is the use of solar cookers acceptable for the users?
- Are potential users interested in solar cooking, and what kind of cookers do they favor?
- Are solar cookers economical?
- Is there a market for them, and, if so, how can it be reached?

Test areas

Since 1996, within the scope of a pilot program, GTZ and DME have been conducting a comparative field test in the dry, northwestern part of South Africa. Five potential test areas were investigated in advance, and 200 families were interviewed. The following three test areas were then selected on the basis of cooking profiles and a range of socioeconomic parameters:

- **Onseepkans** is representative of small, rural villages in which gathered firewood is the primary fuel.
- **Pniel** also is a small rural village, but it is situated only five miles from the next city. Here, roughly equal shares of wood and kerosene are used for fuel.
- **Huhudi** is an urban township with access to electricity, but it is still heavily dependent on kerosene. Here, wood is a market commodity and therefore used only on a relatively small scale.

REM5 in Onseepkans

Field-tested solar cooker models

Also on the basis of the pertinent cooking profiles, seven different solar cooker models were selected for testing: four box cookers, one concentrator and two collector-type cookers. In a practical-application test, all dishes considered typical of the test areas were prepared in the various cookers. All seven types of cooker proved able to handle the traditional dishes. These models are presented in the appendix.
With a view to obtaining seasonally relevant results (solar season), the solar cookers were tested by 66 families and 14 institutions, for an entire year. Thirty families cooking without solar cookers

served as the control group. Each family used one type of cooker over two months' time before switching to the next model. Users and non-users alike filled out on-the-spot questionnaires and

ULOG in Pniel

were interviewed by the team's sociologists. At the end of the test period, the users living within each test area were invited to participate in a workshop. Votes were taken to identify the most popular type of cooker. Finally, waiting lists for the purchase of used cookers were drawn up as a useful indicator of user preferences.

A technical evaluation of the cookers' safety, user friendliness and durability showed all the cookers to be in need of technical improvement. Their designers have since implemented most of the necessary changes. Some cookers were found to require maintenance, and more cookers were damaged at the beginning of the test than toward the end, by which time the users had drawn their conclusions and ordered or purchased their own cookers.

8.2 Regarding Acceptance

Intensive monitoring of solar cooker use by the families - with more than 400,000 individual bits of information comprising the end-of-test database - in the three test areas over a period of one year was undertaken. Analysis of the results showed that:

- on average, the solar cookers were used at least once a day 38 % of the time,
- the families were satisfied with 93 % of all solar cooking processes.

The average family has two or three non-solar cooking options. Solar cookers do not completely replace those other options, but merely supplement them.

Solar cookers were shown to be the most frequently used cooking implements along with wood (open fires, woodstoves and coal-burning stoves that can also be fueled with wood). These were followed by cookers that operate on gas, kerosene or electricity. The results indicate good acceptance of solar cookers among the test families – whereas "acceptance" is defined as follows: "Solar cookers are used at least as frequently as other household cooking options."

Figure 2 illustrates the frequency of use of the various solar and non-solar cooking options. The fact that the sum of percentages exceeds 100 % is attributable to the use of more than one cooking option on any given day.

SK14 in Barkly West

SunStove in Pniel

Figure 3 is the corresponding frequency-of-use diagram for the control group without solar cookers.

The study of institutional acceptance of solar cookers (in schools and kindergartens) has not yet been concluded. The preliminary results read as follows:

- Major incentives for the use of solar cookers include highly motivated cooks, opportunity for management personnel to reduce fuel-specific expenditures, and added incentives for cooks who use solar cookers;
- Important reasons for not using solar cookers include their safety deficits, lack of budgetary control by the cooks, and supervision by external organizations.

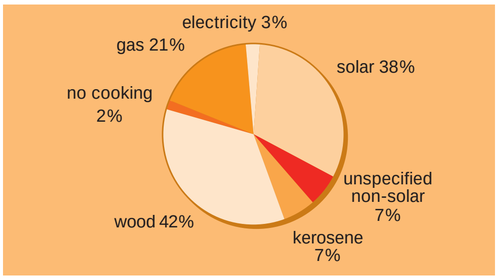


Figure 2: The daily use frequency of different solar and non-solar cooking appliances (test users)

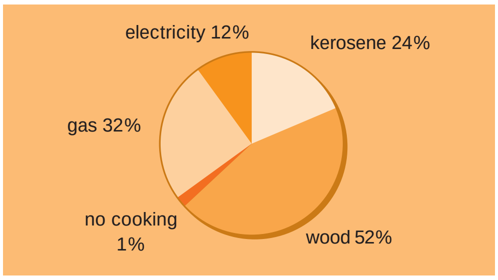


Figure 3: The daily use frequency of non-solar cooking appliances (control group)

8.3 Profitability and Economic Aspects

The average family's monthly expenditures on fuel for cooking purposes amount to the equivalent of 8 US$. Table 3 lists the fuel-specific expenditures for all three locations.

	Huhudi	Pniel	Onseepkans
Wood	1	3	3
Kerosene	3	2	0.5
Gas	3	3	2
Electricity	4	0	0
TOTAL	**11**	**8**	**5.5**

Table 3 : monthly expenditure on fuel in US$

Table 4 reflects the average monthly savings for the various locations.

During the solar cooker test period, the average family with a solar cooker saved 38 % on fuel (i.e., 33 % on kerosene, 57 % on gas and 36 % on wood). In absolute terms, the test users saved nearly 60 tons of wood, over 2 tons of gas and more than 2000 liters of kerosene in the course of the test year. The families in Huhudi, where most fuel has to be bought instead of gathered, saved the most, while those in Onseepkans, where gathered wood is a major source of energy, saved the least. Savings in the Pniel area, where a mixture of purchased and gathered fuel is used, were situated in between.

The average payback period (the time it takes to pay back the cooker price by fuel savings) is 18 months, but of course depends on the test area and the type of cooker in question. This data is based on estimated mean-series end-user prices for the four most affordable, locally producible cookers, priced between 40 and 120 US$, in combination with the customary practice of purchasing expensive household appliances on credit, i.e., with 10 % down and 24 monthly payments at 30 % annual interest.

The test users were asked how much they would be willing to pay for their solar cookers. All of them were willing to pay more than either the estimated cash & carry price or the equivalent of 24 monthly payments on a cooker-financing loan.

In order to verify those findings, the test users were given an opportunity to purchase their cookers at the end of the test – and all of the families did just that! Indeed, waiting lists had to be drawn up, and an independent market study documented widespread interest in the purchase of solar cookers.

	Pniel	Onseepkans	Huhudi
Average savings, all fuels (%)	36.3	40.2	39.1
Average monthly fuel expense (US$)	8	5	11
Average monthly fuel savings (US$)	**3**	**2**	**4**

Table 4 : monthly fuel savings in US$ by region

8.4 Case Examples for the Use of Solar Cookers

Mrs. Bontnael, whose husband died recently, lives alone in a typical thatched hut in Onseepkans on the South African side of the Namibian border. The Bontnaels' income consisted of Mr. Bontnael's old-age pension, which was relatively high for people in this area. Their grown children live elsewhere.

Before the solar cooker field test began, Mrs. Bontnael prepared each day's meals on a wood-burning stove. Each month, the Bontnaels bought about 45 kg of wood. This is atypical for the region in question, where most fuelwood is gathered.

A breakfast of bread and tea is taken at about 7.30 a.m. For dinner, at about 1 p.m., Mrs. Bontnael often cooks up a soup or dried peas. She occasionally adds some potatoes and chicken, or instead opts for afval (a stew of tripe, various innards and the head of, say, a goat, with chicken feet and beaks added as "walkies talkies"). No evening meal is eaten. Mrs. Bontnael also uses her solar cooker for baking bread

It takes Mrs. Bontnael about a half an hour to prepare breakfast. Right after breakfast she spends about an hour cooking for dinner.

In fond remembrance of her deceased husband, Mrs. Bontnael still prefers to use the old cooker on which she and her husband learned to do their solar cooking – even though she knows that more efficient models are now available. Having and using a solar cooker has not substantially altered her daily routine, though she does appreciate the resultant savings on fuelwood purchases. She also realizes that it is not necessary to keep a steady watch over the cooker.

Johanna Bock together with her three daughters and her grandchildren, also lives in a thatched hut, but at the other end of Onseepkans. The male members of this nine-person family have out-of-town jobs and rarely get a chance to come home. The Bock family has a gas stove and a coal-burning stove that can also be fueled with wood. Like Mrs. Bontnael, the Bock family counts among the few local families who purchase wood (approximately 80 kg each month) instead of gathering it.

The eldest daughter does most of the cooking. Breakfast (served at about 7.30 a.m.) consists of bread or vetkoek, a kind of fried roll baked a day in advance. Cooking for dinner begins right after breakfast, because it takes about four hours. A typical meal will include bread or dombis (a sort of dumpling), dried peas, lentils and/or some other legume, or chicken. Preparations for supper begin about 5 p.m. and take about an hour. The evening meal often comprises tomatoes, rice and fish (either canned or caught in the nearby Oranje river). Miss Bock also bakes bread or cake and, on Sundays, serves a dessert.

The Bock family also participated in the solar cooking test. They were very happy with the first kind of solar cooker they received. At the end of the first two months, like the other test families, they were expected to try a different model, but they vehemently refused to do so. Their main argument against the new cooker was that it was too large to leave standing around the house when it was not in use and could therefore be easily damaged by children at play. Presumably, however, the family did not wish to have to get used to a new kind of solar cooker. The family signed the waiting list in hopes of (re)obtaining their first cooker at an affordable price at the end of the test.

9. Macroeconomic Impacts

Should solar cookers ever achieve large-scale commercial dissemination, the probable consequences in terms of the economic and social impacts were investigated:

Solar cookers have a distinctly positive pollution/energy balance, i.e., the environmental burdens resulting from their production and transport are completely compensated for by conservational effects within a very short time.

- cumulative savings (cf. Table 5),
- less air pollution (both in the kitchen and outdoors) and
- savings on time spent gathering fuelwood.

Additional impacts could include:

- a reduction in the degree of atmospheric pollution caused by combustion of fossil fuels,
- fewer cases of kerosene poisoning (among children in particular) and
- fewer cases of fires and burns caused by paraffin accidents.

The reductions in greenhouse gas emissions (carbon dioxide, etc.; cf. Table 5) resulting from the use of solar cookers were estimated. With the aid of the Environmental Manual for Power Development (GTZ, 1996) it was found that solar cookers have a distinctly positive pollution/energy balance, i.e., the environmental burdens resulting from their production and transport are completely compensated for by conservational effects within a very short time (Fritsche, 1998).

	Per Household	**Per 50,000 households**
Savings on kerosene	30 liters/year	1,500 cbm/year
Savings on LPG (gas)	30 kg/year	1,500 tons/year
Savings on fuelwood	900 kg/year	45,000 tons/year
Reduction in CO_2 emissions (all sources of energy, 50% deadwood)	approx. 1,000 kg/year	approx. 50,000 tons/year

Table 5: Savings on fuel and reductions in CO2 emissions attributable to solar cookers

10. Outlook: Solar Cookers now on the Market

In all three South African test regions, it was demonstrated that, under suitable conditions, solar cookers are accepted by users. Also demonstrated was the dual fact that it pays to use solar cookers. Furthermore it was shown that potential users are generally interested in purchasing such cookers.

These results, however, still do not guarantee that solar cookers will meet with success on the market. This is one of the main prerequisites for their sustainable large-scale dissemination.

Some partial market achievements can be found:

- In India, where more than 100,000 box cookers have been disseminated at 50 % subsidized prices, the cookers' utilization rates, durability and performance have been unsatisfactory (Philip, S.K. et al.). Also, progress has been relatively slow, i.e., there is still only one cooker in India for each 10,000 people.
- In Tibet, where a similar number of Chinese-made concentrator-type cookers have been sold, market saturation has already been reached in some areas (Integration, 1997). The question is "Are we dealing with a genuine market here or not?" In addition, people there are practically forced to use solar cookers: there are only few places in the world where the scarcity of fuel is as extreme, and people are suffering accordingly.

Consequently, the second phase of the South African pilot project aims to determine how and to what extent solar cookers can be rendered commercially successful:

- Four different models – one South African and three European – are to be placed on the market. The models in question will be those which achieved the best results during the first-phase field test.
- All these cookers will be produced in South Africa; two small enterprises with the capacity to manufacture high-quality solar cookers have been selected by way of competitive bidding.
- Intensive efforts to achieve the requisite transfer of technology are under way: the European designers and South African producers work together to improve the solar cookers and prepare them for local production. Thermal tests designed to compare the locally produced prototypes with the original versions have already been conducted (cf. Appendix).
- A pilot batch of 30 of each type of cooker is to be distributed during the second quarter of 1999. By year's end, several hundred solar cookers will have been shipped out by their producers, and, if all goes according to plan, a minimum of 2,000 solar cookers will have been commercially disseminated by the end of the year 2000.
- All possible market mechanisms for the cookers' sale, financing and user support will be tested in the northwestern part of South Africa.
- A mobile demonstration unit is being used to assist in disseminating information in general and about the four locally-made cookers models in particular.
- An intensive multimedia advertising campaign is to be conducted with the support of selected industrial associations (e.g. in Germany: Gesamtverband der Deutschen Aluminiumindustrie and South African Aluminium Association)
- At the end of its second phase, after two and a half years, the project intervention will be phased out.
- Intensive monitoring of all significant processes will, it is hoped, enable identification of determining factors for the cookers' successful commercial dissemination and the project's potential for transfer to other countries.

11. Outlook: What Still Needs to be Done?

Up to this point, achievements in the field of solar cooking and the present range of ongoing activities, particularly in South Africa, have been discussed. Let us now consider the following examples in contemplation of what still needs to be done.

Further reduction in solar cooker purchase prices

At the beginning of phase 2 it was already becoming apparent that people attach more importance to the cooker's purchase price than had been previously assumed. Thus, it will be of decisive importance for the future of solar cookers that they be mass produced in order to achieve lower prices without sacrificing quality.

Bringing products up to technical maturity

Anyone who has taken a close look at the available types of solar cooker will have noticed how close some of them are to the prototype stage. And anyone who has compared them with the kind of technically mature industrial products that are being turned out in large numbers can have little doubt that a comparable mass-produced cooker should have an over-the-counter price of not more than 30 to 60 US$.

Drawing up recommendations

Something else that still needs to be done is to generalize the results and experience gained in different countries, because their validity as yet counts only for their respective locations. Generally applicable recommendations for future solar cooker activities in other emerging countries will also be compiled in a compendium. The transferability of the compendium's basic data will be discussed with representatives of other interested countries at the end of the year 2000.

If solar cooking is to fulfil its potential, a number of conditions will have to be met:

- Solar cookers must be high quality products, user friendly, high performance, durable and cost-efficient. No cooker on today's market completely satisfies all of these requirements.
- Secondly, dissemination, financing and user support must comply with the standards set by other economic or development activities.
- Finally, the political framework must be conductive to sustainable success, favouring the most promising technologies without crippling healthy competition.

Therefore, a combined effort is required. This implies the following:

- Solar cooker developers should identify and further develop the most promising solar cooker concepts.
- Manufacturers, particularly in the field of household appliances, should produce cost-efficient high-quality cookers for mass-production. Prices will come down, provided the right steps are taken.
- Private sector companies, in the fields of commercial distribution and financing, must strive at getting these products out to the user and providing user support.
- NGOs should ensure non-commercial distribution modes for the most needy.
- National Governments must aim at creating favourable political and fiscal environment and providing initial financial support where necessary.
- International organisations, for example GTZ, are needed to help spread these efforts over all concerned countries.

Clearly, a combined North-South effort is required in order to improve the energy supply situation of a large portion of humanity without rapid depletion of resources and without deterioration of the environment.

12. Outlook: On the Potentials of Solar Cooking

Any attempt to precisely predict the future potential of solar cooking would be presumptuous. but even a few simple clues would be interesting. However, it can be of interest to estimate some magnitudes.

Let us assume that the annual consumption of fuelwood for cooking, which amounts to 2 billion tons annually at present, could be reduced by five percent through the use of solar cookers. This amounts to potential savings on the order of 100 million tons of fuelwood per annum. In terms of pure magnitude, this is comparable to Germany's entire annual consumption of petrol. While that is still only a fraction of global energy consumption, it is nevertheless worthy of serious consideration.

The production capacity required for making the number of solar cookers to achieve is also noteworthy: it would take 100 million solar cookers to achieve the targeted savings. That would equate to maximum annual proceeds of several billion US$ (assuming saturation of the potential global market with cookers designed to last five years). While the estimate does not come close to matching that of either the motor vehicle industry or the computer sector, it is nevertheless nothing to be scoffed at.

It is the people involved who make solar cooking so important. There are many potential users, many of whom are needy. Solar cooking can improve their quality of life and provide them with clean household energy where they need it most. Solar cooking can generate local jobs and protect the environment where it is most necessary.

All in all, it is well worth the trouble to turn solar cooking from a concept into a reality.

Technology transfer: Manufacturing solar cookers in Johannesburg

Appendix:
Technical Data of South African Test Cookers

ULOG
Type of cooker: Conventional box cooker with wooden frame

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test and 1998/99 Tests in South Africa

Dimensions (cooking pos.):	66 x 67 x 104 [cm]
Number of pots and nom. volume:	1 removable pot (5 l)
Test pot content:	2.5 l
Aperture surface:	0.24 m^2 (without reflector)
Heating time (water):	
- cold start (40 - 80°C)	*94 minutes
- cold start (40 - 96°C)	*takes 120 minutes to reach 91°C
- hot start (40 – 80°C)	*66 minutes/**77 minutes/***91 minutes
- hot start (40 – 96°C)	*107 minutes
Max. temperature (oil):	*124°C after 130 minutes
Continuous cooking:	*boils 7.5 l of water in a day
Heat loss with lid open:	*cools from 95°C to 80°C in 5 min
Comments:	average thermal performance for a box cooker; very large nominal pot volume for this aperture; rarely requires tracking
Handling:	two-step access to pot; easy tracking; easy to use, easy to transport, comes with instructions
Application:	family-size cooker
Evaluation for technology transfer/local production:	easy small-series production; recommended performance-enhancing measures for SA model: low-iron glass and conductive absorber
Contact address:	Gruppe ULOG, Morgartenring 18, CH-4054 Basel, Switzerland Tel: +(41) 61-3016622 ; Fax: +(41) 61-3014959
Legend:	*ECSCR; tested in SA; **European model, ***prototype built in SA

SunStove
Type of cooker: Box cooker with plastic casing without external reflector

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test and 1998/99 Tests in South Africa

Dimensions (cooking pos.):	66 x 63 x 38 [cm]
Number of pots and nom. volume:	one, two or three removable pots
Test pot content:	1.5 l
Aperture surface:	0.28 m^2
Heating time (water):	
- cold start (40 - 80°C)	*90 minutes
- cold start (40 - 96°C)	*takes 120 minutes to reach 87°C
- hot start (40 – 80°C)	*78 minutes/**62 minutes/
- hot start (40 – 96°C)	takes 120 minutes to reach 93°C/**90 minutes/***76 minutes
Max. temperature (oil):	*114°C after 130 minutes
Continuous cooking:	*boils 3 l of water in a day
Heat loss with lid open:	*cools from 90°C to 80°C in 5 min
Comments:	*low thermal performance for a box cooker; average pot content for the aperture; rarely requires tracking
Handling:	easy, two-step access to pot; very simple to track and use, easy to transport; light wind can open transparent cover, which could be more securely mounted.
Application:	cooker for small families; adapted for low-temperature cooking
Evaluation for technology transfer/local production:	Is already produced in South Africa
Contact address:	SunStove, 1 Parklands Saldahana Street, 1501 Benoni, RSA Tel/Fax: +(27)119692818 R. Wareham, 3140 North Lily Rd, Brookfield, Wi 53005, USA Tel +(1)4147811689; Fax +(1)414810455
Legend:	*ECSCR; tested in SA; **original model, ***original model with absorber

REM5
Type of cooker:
Conductive box
cooker

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test and 1998/99 Tests in South Africa

Dimensions (cooking pos.):	88 x 101.5 x 96 [cm]
Number of pots and nom. volume:	2 removable pots (5 l / 1.5 l)
Test pot content:	2.5 l
Aperture surface:	0.36 m^2 (without reflectors)
Heating time (water):	
- cold start (40 - 80°C)	*48 minutes
- cold start (40 - 96°C)	* 66 minutes
- hot start (40 – 80°C)	*22 minutes/**35 minutes/***45 minutes
- hot start (40 – 96°C)	*42 minutes/**48 minutes/***62 minutes
Max. temperature (oil):	*147°C after 130 minutes
Continuous cooking:	*boils 12.5 l of water in a day
Heat loss with lid open:	*cools from boiling temperature to 80°C in 5 min
Comments:	excellent thermal performance for a box cooker; average nominal pot content; rarely requires tracking
Handling:	one-step access to pot; easy to track, use and transport; comes with instructions for use
Application:	family-size cooker
Evaluation for technology transfer/local production:	original model: high-quality materials and complicated assembly; SA model (simplified) requires iron-free glass for better performance
Contact address:	Synopsis, Route d'Olmet, F-34700 Lodève, France Tel: +(33)467440410; Fax: +(33)467440601; Email: synopsis@wanadoo.fr
Legend:	*ECSCR; tested in SA; **European model; ***prototype built in SA

Schwarzer 1
Type of cooker:
Flat plate
collector cooker

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test

Dimensions (cooking pos.):	273 x 135 x 110 [cm]
Number of pots and nom. volume:	2 non-removable pots (2 x 5 l)
Test pot content:	2 x 2.5 l
Aperture surface:	1 m^2 (without reflectors)
Heating time (water):	
- cold start (40 - 80°C)	46 minutes
- cold start (40 - 96°C)	54 minutes
- hot start (40 – 80°C)	26 minutes
- hot start (40 – 96°C)	39 minutes
Max. temperature (oil):	*157°C after 130 minutes
Continuous cooking:	boils 30 l of water in a day
Heat loss with lid open:	cools from boiling temperature to 80°C in 7 minutes
Comments:	excellent thermal performance; small pot volume for the aperture; rarely requires tracking
Handling:	easy, one-step access to pots; acceptable tracking; practical power control; cleaning can be difficult due to the fixed pots; cooker not easy to transport, but operation easy to learn
Application:	cooker for families and in modular applications, for institutions; suitable for cooking and roasting
Contact address:	Prof. K. Schwarzer, FH Aachen, Ginsterweg 1, D-52428 Jülich, Germany Tel.: +(49)2461993177; Fax: +(49)2461993199

SK12/SK98
Type of cooker:
"Deep Focus"
concentrator

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test and 1998/99 Tests in South Africa

Dimensions (cooking pos.):	143 x 163 x 125 [cm]
Number of pots and nom. volume:	1 removable pot (12 l)
Test pot content:	6 l
Aperture surface:	1.54 m^2 (reflector)
Heating time (water):	
- cold start (40 - 80°C)	*27 minutes/**27 minutes/***30 minutes
- cold start (40 - 96°C)	*44 minutes/**38 minutes/***39 minutes
- hot start (40 – 80°C)	-
- hot start (40 – 96°C)	-
Max. temperature (oil):	*198°C after 130 minutes
Continuous cooking:	*boils 48 l of water in a day
Heat loss with lid open:	*cools from boiling temperature to 83°C in 15 min
Comments:	excellent thermal performance for a concentrator-type cooker; small nominal pot content for this size of aperture; requires regular tracking
Handling:	easy, one-step access to pot; easy tracking, but level ground required; acceptable operation, but difficult to relocate
Application:	cooker for large families and, in modular application, for small institutions; suitable for cooking and roasting
Evaluation for technology transfer/local production:	easily reproducible; reflector material must be protected against corrosion; a folding type of steady stand is under development; transport and assembly require optimization
Contact address:	Dr. D. Seifert, Siedlungsstrasse 12, D-84524 Neuötting, Germany Tel./Fax: +(49)867170413, Email: bdiv.seifert@t-online.de
Legend:	*ECSCR; tested in SA; **European model, *** prototype built in SA

REM15
Type of cooker: Conductive box cooker

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test

Dimensions (cooking pos.):	114 x 117 x 179 [cm]
Number of pots and nom. volume:	3 removable pots: one 15-l pot and two 2.5-l pots
Test-pot content:	7.5 l
Aperture surface:	0.60 m^2 (without reflectors)
Heating time (water):	
- cold start (40 - 80°C)	40 minutes (moderately preheated)
- cold start (40 - 96°C)	66 minutes
- hot start (40 – 80°C)	32 minutes
- hot start (40 – 96°C)	55 minutes
Max. temperature (oil):	157°C after 130 minutes
Continuous cooking:	boils 37.5 l of water in a day
Heat loss with lid open:	cools from boiling temperature to 80°C in 8 min
Comments:	excellent thermal performance for a box cooker; very large nominal pot content for the aperture; rarely requires tracking
Handling:	one-step access to pot; tracking mechanism could be improved, e.g., better wheels; easy to use and, in transport position, to transport; operation easy to learn
Application:	cooker for large families and, in modular application, for small institutions
Contact address:	Synopsis, Route d'Olmet, F-34700 Lodève, France Tel: +(33)467440410; Fax: +(33)467440601; Email: synopsis@wanadoo.fr

Schwarzer 2
Type of cooker:
Flat plate
collector cooker

Selected Results of the 1994 ECSCR Comparative Solar Cooker Test

Dimensions (cooking pos.):	302 x 192 x 175 [cm]
Number of pots and nom. volume:	2 non-removable pots (10 l / 5 l)
Test pot content:	5 l / 2.5 l
Aperture surface:	2 m^2 (without reflectors)
Heating time (water):	
- cold start (40 - 80°C)	50 minutes
- cold start (40 - 96°C)	64 minutes
- hot start (40 – 80°C)	6 minutes (large pot) / 14 minutes (small pot)
- hot start (40 – 96°C)	11 minutes (large pot) / 88 minutes (small pot)
Max. temperature (oil):	182°C after 130 minutes
Continuous cooking:	boils 65 l of water in a day
Heat loss with lid open:	cools from boiling temperature to 80°C in 14 minutes
Comments:	excellent thermal performance; small nominal pot content for this size of aperture; rarely requires tracking
Handling:	easy, one-step access to pots; acceptable tracking; practical power control; cleaning can be difficult due to the fixed pots; cooker not easy to transport, but operation easy to learn
Application:	cooker for families and in modular applications, for small institutions; suitable for cooking and roasting
Contact address:	Prof. K. Schwarzer, FH Aachen, Ginsterweg 1, D-52428 Jülich, Germany Tel.: +(49)2461993177; Fax: +(49)2461993199

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