SOLAR COOKING COMPENDIUM

Scarcity of Household Energy and the Rationale of Solar Cooking

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Abstract

Scarcity of household energy, notably of fuelwood in rural areas, is a key issue almost everywhere in Sub-Saharan Africa. For this reason one interesting option to address this problem is the use of efficient solar stoves. They have a history of more than 200 years. Nevertheless, until the 1990s, when genuine marketing efforts were made for the first time, they remained in an environment of research and development focusing exclusively on technical matters.

So far about 600,000 solar stoves have been disseminated worldwide, most of them in Asia (with only few modern stove types), less than 10% in Africa (with many modern stoves). There is an array of some 200 different solar stove models, each of them characterized by pros and cons. Thus, the paramount question is whether these stoves have the potential for a commercial mass market, or are they liable to maintain their present niche market status.

The global market potential is estimated to be in the order of 10 billion USD in equipment and 1 billion USD in yearly replacement at market saturation.

Given this situation, a pragmatic open approach for conducting the DME/GTZ solar stove field test was introduced. It started with a social acceptance test followed by the manufacture and test marketing of selected solar stoves.

Keywords: household energy, fuelwood, solar stoves history, solar cooking worldwide and in Africa, solar cooker market potential, DME/GTZ solar stove field-test

Foreword

The Solar Cooking Compendium (SCC) is about the viability of solar stoves as a solution to the scarcity of household energy. Viability is measured in commercial terms. It means manufacturing and marketing of solar stoves without subsidies. In the future, this will be the criterion for judging projects promoting solar cooking.

The SCC is based on the experience gained in implementing the Solar Cooker Field Test (SCFT) in South Africa from 1996 to 2003. It consisted of Phase 1 – Global market situation of solar stoves and social acceptance test (1996 - 1998) and Phase 2 – Estimate the market potential in South Africa, manufacture of solar stoves, and test marketing (1999 - 2003). The SCFT, a pilot program, was performed under a bilateral Technical Cooperation Agreement between the Governments of the Federal Republic of Germany and the Republic of South Africa (RSA). Executing agencies were the Department of Minerals and Energy (DME) and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

What were the reasons for implementing the pilot program in South Africa? The answer is as simple as the related challenge was difficult to meet: The will and commitment of both Governments to significantly contribute to solving the shortage of household energy, and more specifically the fuelwood problem, by coming up with a market oriented solution in South Africa; once and for all it had to be shown that solar stoves are not only a niche solution. Ideally such a solution is expected to be suitable in principle for replication in other countries where similar fuelwood problems prevail. Moreover, the SCFT is in line with the energy policy heralded in the White Paper on Renewable Energy (RE) compiled by the DME in 2002 to bring renewable energy into the mainstream energy economy of South Africa.
It also responds to improving the extent of basic energy needs satisfaction addressed by the Bundesministerium für Wirtschaftliche Zusammerarbeit und Entwicklung (BMZ). Finally, it contributes to achieving the goals of the Agenda 21.

Household energy shortage is an issue in many regions of the world with an estimated two billion people being affected. In the past two to three decades, fuelwood scarcity became a major constraint for people in rural and semi-urban regions, notably on the African continent. The problem involves social, economic, technical, health, and environmental aspects.

In turn, an array of solutions has been offered and discussed time and again by politicians and specialists alike. Some follow conventional patterns; others focus on new technologies, in particular tapping renewable energies. One option is solar cooking.

The magnitude and complexity of this global challenge call for an integrated, multidisciplinary approach, addressing the associated issues from various angles and putting equal emphasis on all-important features. In doing so, the underlying basic rationale is clear: In countries with high solar irradiation of 500Watt per m^2 (this is 50% of the usual maximum irradiation) the use of solar stoves as an additional cooking option can contribute to alleviating energy shortages. The vision for the future is the availability of low cost solar stoves of high quality so that they will be affordable for everyone on the African continent.

In the past, measures to introduce solar stoves were often effected by enthusiasts favoring a technology driven approach. These activities did not result in the sustainable use of solar stoves because they neglected their social acceptance by the target group, notably low income people living in rural and semi-urban areas, and underestimated the mechanisms of the market. The successful marketing of solar stoves, covering the whole chain from the demand oriented design and production to their appropriate use in households, is a complex endeavor. It involves many players with various tasks and responsibilities.

The challenges, accomplishments, and lessons learnt in implementing the SCFT in South Africa have been channeled into the SCC. It provides a comprehensive account of this pilot program, starting from the project idea all the way to the final assessment of the achievements. Thus, the SCC illustrates

- Why have solar stoves been selected as a means to fight energy scarcity of households?
- What have been the key activities of the pilot program?
- How have they been planned, implemented, monitored, and evaluated?
- Which were the lessons learnt for shaping future programs or projects?

To keep it as a user-friendly manual-type document the SCC has been edited in five volumes. It has been edited in five volumes:

Main Report	Challenges and achievements of the Solar Cooker Field Test in South Africa
Volume 1	Scarcity of household energy and the rationale of solar cooking
Volume 2	Social acceptance of solar stoves in South Africa
Volume 3	Making the case for commercializing solar cookers in South Africa. Justification for the development of a commercially viable renewable energy cooking technology industry.
Volume 4	The solar cooking toolkit. Conclusions from the South African Field Test for future solar cooking projects.

The concept, the various features of implementation, and the accomplishments of the pilot program have already been shared with policymakers and professionals in many fields throughout the last three years, e.g. at the international conferences in Varese, Italy (1999), Kimberley, South Africa (2000), and Adelaide, Australia (2001) as well as the International Workshop on Solar Cooking in Johannesburg, South Africa (2001) as well successfully participating in the World Summit on Sustainable Development (WSSD) during 2002. These events also generated valuable feedback for advancing the SCC. It was also presented to the German Ministry of Development Co-operation (BMZ) in November 2003 with the result that solar cooker programmes have been included in their standard set of development instruments and further proposals have been invited for projects of this nature.

The SCC compendium was updated at the end of 2003 to reflect the development of an expanded approach to the concept of commercialising solar cookers. The expanded approach entailed the broadening of the initial narrow focus on solar cookers, to that of a complete renewable cooking industry (including solar cookers, improved wood and coal stoves). The Energy Development Corporation (EDC), a division of CEF(pty)ltd. of South Africa expressed potential interest to become the champion of a renewable cooking industry provided that the potential commercial viability could be confirmed, calculated and quantified. After successfully demonstrating the "business case", for the development of a renewable energy cooking industry, the project has been incorporated into the structures of the EDC.

The Solar Cooker Field Test has received the attention and appreciation of South African and German politicians alike. They visited solar cooking demonstrations and tasted dishes cooked with the sun. The most prominent of them are:

- Ms Phumzile Mlambo-Ngcuka
  Minister of Minerals and Energy, South Africa

- Ms Susan Shabangu
  Deputy Minister of Minerals and Energy, South Africa

- Mr Johannes Rau
  President of the Federal Republic of Germany

- Ms Heidemarie Wieczorek-Zeul
  Federal Minister for Economic Cooperation and Development, Germany

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Abbreviations

AIDS	Acquired immune deficiency syndrome
ARI	Acquired respiratory illnesses
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung
CO	Carbon dioxide
DEM	Deutsche Mark
DME	Department of Minerals and Energy
ECSCR	European Committee for Solar Cooking Research
FAO	Food and Agricultural Organization
GEF	Global Environment Facility
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HIV	Human immunodeficiency virus
NGO	Nongovernmental organization
OECD	Organization for Economic Cooperation and Development
PC	Personal computer
RPTES	Research and Protection Technologies
RSA	Republic of South Africa
SADC	Southern Africa Development Cooperation
SCC	Solar Cooking Compendium
SCI	Solar Cookers International
SCFT	Solar Cooker Field Test
SESSA	Solar Energy Society of South Africa
TV	Television
USD	United States Dollar
ZAR	South African Rand

Equivalent of 100 ZAR

	1997	1998	1999	2000	2001	2002	2003
DEM	37.65	32.14	30.02	30.63	25.72	10.10 (Euro)	11.72 (Euro)
USD	21.17	18.07	16.36	14.42	11.62	9.51	13.22

✍ Average annual figures published by the South African Reserve Bank

Overview

Household energy needs and fuelwood

1 Access to energy can determine our future in many different ways. On the large scale, this goes for the supply of imported oil and other mega energy carriers of strategic importance, particularly for those who have access to energy. In a less visible way, it also applies to those who lack sufficient access to the most basic energy services like cooking, heating, lighting, communication, and entertainment. According to recent FAO statistics more than two billion people depend on biomass worldwide to provide energy for basic human needs while another two billion have very low access to modern energy such as electricity and thus still depend partially on traditional sources.

2 In developing countries the role of biomass, notably fuelwood, charcoal, agricultural residues, and dung is of particular significance. It amounts to approximately 33% of the total energy consumption. In Africa it rises to some 60% and can be as high as 90% in some countries. This fact is an indicator for the low rate of urbanization in Africa, where the majority of the population still lives in rural areas and will continue to do so for the foreseeable future. For most of these people there will be no economically viable and ecologically acceptable alternative to the use of biomass as fuel even in the decades to come.

3 Available biomass resources are being significantly reduced primarily by agricultural expansion, infrastructure development, unsustainable use of already scarce resources, exploitation for commercial purposes (timber), cutting for charcoal production in semi-urban areas, periodic droughts and in some countries civil strife, e.g. huge refugee camps. The major responsibility for unsustainable wood use lies not with the poor who use it for household fuel (this accounts for 10-20% of the total loss of wooded areas), but with commercial logging and clearing of wood for agricultural production, which accounts for as much as 75-80%. It has been estimated that in sub-Saharan Africa some 130 million people live in areas where the fuelwood consumption is higher than the sustainable capacity of wooded areas.

4 In the SADC region of Africa biomass amounts to nearly 80% of the total energy demand. About two thirds of it is used for household and institutional purposes, i.e. cooking, baking, lighting, heating in households and public institutions such as schools, prisons and military barracks. A substantial amount (20-30%) goes into small businesses such as brick firing, fish smoking, processing of agricultural products, beer brewing and restaurants, fencing and the building sector. Regarding fuelwood for cooking, heating and other household purposes, most of it is consumed in rural and semi-urban areas by the poorer sections of the society. A large part of the fuelwood is collected free of charge, mostly by women and children. At the same time there is an ongoing process of fuelwood becoming a commercial commodity, especially in rural towns and semi-urban areas.

5 Where biomass resources are scarce, unsustainable fuelwood use, though not the main reason for the scarcity, contributes to the negative effects at the environmental, social and economic level and compounds an already difficult living situation. When biomass is burnt carbon dioxide is set free. This fact adds to climate warming because the trees are no longer available as carbon dioxide sinks. Where fuel has to be bought, biomass-using families often are spending a substantial amount of their total income on fuelwood. Since the provision of fuelwood is primarily women's work, it is they who suffer most from the increasing shortages. Women are spending more time walking longer distances and carrying heavier loads, which affects their spine. Often they cannot manage alone, but need the help of their children, who then are kept from attending school.

6 Fuelwood will remain the main energy carrier for African households for many years to come. Because of the increasing demographic pressure the total consumption will still rise. For the continent as whole this has been estimated at 1.7% annually, for southern Africa at 1.4%. The reason for the lower increase in southern Africa is mainly due to South Africa actually expecting to reduce its consumption by approximately 3% annually, because of a very low population growth (0.6%). Since the rate of deforestation is going up, other options to satisfy the growing household energy demand have to be considered such as substitution with energy derived from fossil fuel or natural gas, renewable bio-energy carriers or other renewable energies. Solar thermal energy offers opportunities for cooking.

7 Apart from biomass, solar stoves probably have the highest potential for making a significant impact as far as energy for cooking, baking, and food processing is concerned. This applies to households as well as to small, home-based food processing businesses and street restaurants. With varying degrees southern African countries are in a favorable to excellent position to make use of solar energy. Climatic conditions, cooking traditions, the level of technical expertise and production capacities, marketing structures and access to credit facilities all favor the introduction of solar stoves in this region.

Origin and history of modern solar cooking

8 In 1774, over 200 years ago, Horace-Benedict de Saussure (1740-1799) invented and built an insulated box with multiple glazing. He called it "helio-thermometer" and used it to study the greenhouse effect on his mountaineering expeditions; he pointed out distillation and cooking as potential applications of the device which was in fact the first box-type solar stove.

9 In 1837, the British astronomer John Herschel used a solar box stove to cook meat and vegetables during an expedition to the Cape of Good Hope. The stove was made out of mahogany, painted black, buried into sand for better insulation and covered by a double glazing to reduce heat losses.

10 In 1860, the French mathematics teacher Augustin Mouchot started experimenting with solar stoves. He worked on his first solar steam engine (1866), wrote in the world's first technical solar energy book (1869) and received a gold medal for an engine producing steam with the help of a solar concentrator at the 1878 World Fair in Paris. The machine, grandparent of today's parabolic stoves, had a reflector diameter of 5 m made out of silver-plated copper which was equipped with a tracking mechanism for following the orientation of the sun and a hydraulic circuit heated by a black cylindrical absorber. In June 1878, the magazine Scientific American published an article describing how someone in Bombay, India had successfully cooked enough meat and vegetables for seven people with a solar oven.

11 In the 1950s and 1960s, most of the solar stove design variants were tried and disseminated. Many designs seem outdated today, but they were the first fully operational solar stoves and the ancestors of today's models. At this stage, the vision underlying solar stove projects was simple: the questions of acceptance and of sustainability did not enter the picture until it turned out that, in many cases, users used their stove rarely or never, and that the diffusion of solar stoves stopped when budgets ran out. But soon, in the 1980s and particularly the 1990s new developments were to take place. The user (and not an arbitrarily selected stove) was placed at center stage.

Solar cooking today

12 By now, probably more than 200 different solar stove types must have been tested and / or used worldwide. Most of them are prototypes or handcrafted small-lot products. Some proved useless in practice, but some others have undergone competent development efforts. None of them, however, has yet reached the stage of a mass-produced industrial product. Basically, each of the many varieties of solar stoves fits into one of three categories: box cookers, concentrator cooker, and collector cooker.

13 The biggest of all known solar stoves, at Mount Abu (India), consists of a field of automatically tracked parabolic concentrators producing steam which is fed directly into enormous cooking vessels, enough for 10,000 meals. The smallest solar stove measures 30 cm in diameter and uses a 500-ml jelly jar as its cooking vessel.

14 The most widely distributed solar stove models are the Indian box-type cooker and the Chinese concentrator – both claiming several hundred thousand units sold, followed by the Franco-American Cookit, distributed internationally, particularly in Kenyan refugee camps. The thermal output of solar stoves varies: 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.

15 The most important reason to use solar stoves is to save fuel. The more the stove is used, the more fuel is saved. Savings can also be in time and / or money. Furthermore, solar stoves are convenient. There is no smoke nor is there additional heat in the kitchen. Finally, most solar stoves work independently. An experienced solar cook sets the stove up, loads it, and comes to fetch the hot food ready for the hungry family.

16 There are also reasons not to use solar stoves: Solar cooking does not work every day of the year because clouds and inclement weather are often unpredictable. It needs a safe place, close to the kitchen, where the sun is not blocked by shadow from buildings or trees. Where these conditions are not found, the user has to move the stove, keeping it in the sun and in a safe place. The stove works outside, so food, pot and stove can be stolen or tampered with. It needs some degree of planning: it is not the ideal solution to provide a quick meal to an unexpected evening guest. Finally, while a solar stove pays for itself in savings, it still is expensive, particularly in an environment where *“no food”* is one reason for not cooking.

Market potential for solar stoves

17 The number of solar stoves disseminated so far worldwide is roughly 900,000 units. This figure is cumulative, i.e. stoves are counted whether they are still used or not. The overwhelming majority (90%) of the stoves were disseminated in Asia. Half of them are (Indian) boxes, the other half (Chinese) concentrators. Practically none are modern designs. Around 45,000 solar stoves have been disseminated in Africa, 70% of them in Kenya and South Africa - in both countries with more recent designs than in the Asian cases.

18 For several years now, better stoves, in terms of performance, handling, durability, looks and (sometimes) price are appearing on the market. The adaptation of these models for local and central production, as well as for all aspects of commercial distribution, is advancing. One of the remaining problems is the reluctance of established businesses to become involved in solar stove manufacturing and marketing.

19 There are two different options for the future of solar stoves. On the one hand, continue the present niche market situation where technical cooperation agencies and NGOs give away solar stoves (or sell them at heavily subsidized prices) and organize their own manufacture and marketing structures. On the other hand, adopt commercial procedures in production and distribution, with serving the mass market as the objective.

20 Solar stoves represent a sizeable global market potential: 10 billion USD for first equipment and 1 billion USD per year for replacement in a saturated market. This is a major market opportunity, albeit in a hard-to-access low-income environment.

21 Is it feasible to reach or approach these figures in reality? On an objective level, solar stoves must meet a number of obvious requirements, such as product quality, performance, handling, user support, affordability and value for money. On a subjective level, success needs confidence along the whole product chain, from manufacturer over distributor and retailer to the client or user. Solar stoves must be credible and the risk to produce, to market or to buy a "lemon", to lose money and face must be perceived as acceptable. In any case, it seems very difficult to reach a major presence on the commercial market for household appliances without the partnership of established players in this field.

Approach to test social acceptance, manufacture and marketing of solar stoves in South Africa

22 Given the variety of solar stove types, ways of use, storing them, but also the variety of potential applications and marketing, it was felt that a fixed approach (testing one stove type in one user situation, using one method) would produce information only about one particular case. Therefore, it was decided to test different solar stoves in parallel, in different user situations. The aim was get information not only on one particular solar stove but also on solar cooking in general.

23 In short, the comparative field test looked at different stove models and used in different situations as well as manufacturing and marketing environments, to identify favorable conditions for use, manufacture, and marketing. Therefore, the field test was split into two distinct phases: Phase 1 established a data base on the use of solar stoves (social acceptance test), while Phase 2 pioneered their manufacture and tested their marketing.

1 Household energy needs and fuelwood

Access to energy can determine our future in many different ways. On a large scale, this goes for the supply of imported oil and other mega-energy carriers of strategic importance – particularly for those who have access to energy. In a less visible way, it also applies to those who lack sufficient access to the most basic energy services (cooking, heating, lighting, communication and entertainment).

Will they one day have equal access to a central energy supply? Will the grid reach them? Of course, there are other, decentralized supply modes. But are they affordable, of sufficient performance, durable? Will the user accept them, buy them, maintain them and replace them once they are beyond repair? It is a matter of trust in the future: will energy come to the user? If not, the user will come to where he can find energy.

One thing is certain: Without secure energy services there can be no real social or economic development. The type of affordable energy sources available to people determines to a large degree their lifestyles. Lack of access to appropriate energy sources undoubtedly is one of the roots of poverty. In the past, the amount of energy consumed per capita has become one of the indicators of development. However, this has changed since the late 1990s. Then, it was recognized that it is not necessarily the amount of energy provided, but the quality of the energy services needed at a certain development stage and its distribution.

Worldwide fossil fuels account for 75% of total primary energy consumption. Renewable energy sources (mainly biomass and hydropower) amount to less than 19%, to which biomass alone contributes about 14%. Nuclear energy contributes around 6%.

According to recent FAO statistics more than two billion people depend on biomass worldwide to provide energy for basic human needs, while another two billion have very low access to modern energy such as electricity (one fifth of the average OECD consumers) and still depend partially on traditional sources.

1.1 Role of fuelwood to meet energy requirements

In developing countries the role of biomass (mainly fuelwood, charcoal, agricultural residues and dung) is of particular significance. It amounts to approximately 33% of the total energy consumption. In Africa it rises to some 60% and can be as high as 90% in some countries. This fact is an indicator for the low rate of urbanization in Africa, where the majority of the population still lives in rural areas and will continue to do so for the foreseeable future.

High population growth and decreasing purchasing power suggest that biomass energy use for Africa will double by the year 2020. Yet in most of these countries, fuelwood is already in short supply. This does not necessarily mean that there is an absolute shortage of fuelwood at the national level, but that there are local shortages around areas of population concentration, in semi-urban areas of urban conglomerations. In other words, there is a spatial imbalance between supply and demand. Increasingly, however, there is a biomass fuel shortage even in densely populated rural areas (**Figure 1**).

Figure 1
Typical rural areas in South Africa where people collect fuelwood

Source: SCFT

Source: SCFT

For the majority of those people, there will be no economically sound and ecologically acceptable alternative to the use of biomass as fuel, even in the decades to come. On the contrary, given rising population growth, combined with increasing urbanization, the supply situation will deteriorate further.

Despite the generally recognized vital importance of biomass energy, and the need to effectively manage biomass resources, it is barely on the radar screens of most governments and international financing agencies. All major energy investments in SADC countries are concentrated in the modern energy sectors. Less than two percent of the total energy budgets are allocated to biomass fuels. Several decades of development experience have shown that piecemeal interventions, such as design and dissemination of technically improved cook stoves, while valuable in themselves, are not adequate to address a problem of this magnitude. Biomass energy management is related to a whole range of other social, economic and environmental development concerns, and consequently can only be addressed using an integrated approach.

Strategies to tackle these issues have to focus on a triple approach: increasing the supply, using the available resources more efficiently, and employing alternative sources of energy where available and accessible.

1.2 Parameters for fuelwood supply

There are a number of factors to be considered when calculating the fuelwood needed for a sustainable supply. The main parameters are the percentage of the population using fuelwood, the rate of population growth, the degree of urbanization, the forest or woodland area available for production, the annual growth rate, the distance of wooded areas from human settlements, the efficiency of energy conversion processes, land property rights, competing land use, foreign currency shortage for import of alternative energy carriers, market price, and the fuel mix used.

Available biomass resources are being significantly reduced primarily by agricultural expansion, infrastructural development, unsustainable use of already scarce resources, exploitation for commercial purposes (timber), cutting for charcoal production in semi-urban areas and especially around large cities, periodic droughts and in some countries civil strife (with huge refugee camps). Negative impacts occur at different levels in all cases where wood is used unsustainably. It is important, however, to point out again, that the major responsibility for unsustainable wood use lie not with the poor who use it for household fuel (this accounts for 10-20% of total loss of wooded areas), but with commercial logging and clearing of wood for agricultural production, which accounts for as much as 75-80%.

In consequence, the supply of fuelwood is characterized by various degrees of scarcity causing serious social, economic and environmental hardships. With an ever-increasing population, this situation is likely to deteriorate drastically within the next decades. There are as yet insufficient data available regarding the specific causes in given circumstances, but without such information, it is difficult for national governments to develop appropriate policy options.

It has been estimated that in sub-Saharan Africa approximately 130 million people live in areas where the fuelwood consumption is higher than the regenerative capacity of wooded areas. In such cases people resort to lower grade fuels such as agricultural residues and dung, which then are lacking to maintain soil fertility (**Figure 2**).

Figure 2
People collecting fuelwood in rural South Africa

Source: SCFT

Household energy problems normally occur where there is high demographic pressure. Under these conditions there are conflicting interests. While the demand increases, the area available for increasing the supply is reduced. Energy crops may be competing with food crops. At the same time fuelwood production areas cannot be far away from the demand centers because of transport costs. On the supply side a number of strategies and mixtures of these have been practiced.

On the production level the best alternative to this handicap is the by now widely practiced agro-forestry or social forestry approach, where multi-purpose trees are inter-cropped with other food or cash crops. This can be a partial solution for rural areas, but other strategies have to be found for urban areas.

Tree planting as a cash crop might be another viable alternative, but production costs are high and the sale of fuelwood has not been sufficiently profitable to be attractive for farmers, even in cases where sufficient land might have been available. The more reliable approach has been the production of trees for multipurpose use, mainly poles for building construction, furniture production or charcoal production. In those cases fuelwood is an important by-product, which usually provides fuel for the local population.

Due to the high costs of re-planting, natural regeneration and management of resources has been a preferred and fairly successful approach. But this can only be a solution in situations where there are still abundant woodlands available. For some countries (such as Tanzania or Zambia, or some areas of Malawi and even South Africa) these natural woodlands represent a huge potential for non-wood products, such as tourism, game keeping, honey and beeswax, tannin extracts or gum arabicum. In most cases, however, the value of these non-wood products are exploited on an informal basis and do not figure in national statistics.

Regulation of fuelwood markets is another factor, which could help to increase the supply of fuelwood to the centers of consumption in those cases, where there are large distances between surplus areas and areas of deficiency. The critical factor to be considered is the difference between the market price to the production and loading costs. For the transport by road, this distance is usually between 70 to 100 km, depending on the price of the fuel and the condition of the roads.

Access to fuelwood collection areas: In a number of southern African countries fuelwood may be abundant, but because of legal ownership patterns (private and state), many people do not have access to collect fuel. Some interesting developments have been noted in recent years (in Zimbabwe, for example), where there have been agreements between private land owners and surrounding communities, for free collection of dry fuelwood. Where state forests are concerned, they are often strictly regulated; licenses can be purchased, but are either not affordable, or the forest areas can be reached only with mechanized transport.

Charcoal production: Since charcoal has double the energy content of fuelwood per kg; transport costs are reduced by half. In connection with the higher price for charcoal and the cheaper production costs in areas far from population centers, it may happen that a transport distance for charcoal might be acceptable, which is six times as high. The import of charcoal from far away surplus areas may, therefore, be an acceptable solution to reduce the pressure on forest resources. On the other hand, inefficient traditional conversion technologies (earth mounds) at present are responsible for high-energy losses. The introduction of energy-efficient kilns on a large scale could double the charcoal output.

Increase of fuelwood supply for cash crop processing: Depending on the country concerned (e.g. Zimbabwe, Malawi, Mozambique, Botswana, Zambia) substantial amounts of fuelwood are used for cash crop processing, especially coffee, tea, and tobacco. This has denuded whole areas and has put special hardships on the local population. In isolated instances governmental regulations have forced the cash crop growers to replant annually the same number of trees as are being cut, but this has not yet been applied universally.

1.3 Parameters for fuelwood use

In the SADC region of Africa, biomass amounts to nearly 80% of the total energy demand. Approximately two thirds of this is used for household and institutional purposes (cooking, baking, lighting, heating in households and public institutions, such as schools, prisons, military barracks), but a substantial amount (20-30%) goes into small-scale businesses such as brick firing, fish smoking, processing of agricultural products, beer brewing and restaurants, fencing and the building sector. In each country and in each region within a country the situation is different.

Regarding fuelwood for cooking, heating and other household purposes, most of it is consumed in rural and semi-urban areas by the poorer sections of society. A large part of the fuelwood is still collected free of charge, mostly by women and children. Heavy loads (up to 35kg) are carried over long distances. As scarcity increases and collection distances are becoming longer, men are getting more involved as a shift to transporting fuelwood by donkey cart or pickup can be noticed (Figure 3).

Figure 3
Collected fuelwood for sale in South Africa

Source: SCFT

At the same time there is an on-going process, of fuelwood becoming a commercial commodity, especially in rural towns and semi-urban areas. Men largely control collection of fuelwood for sale. It is not unusual to find families where the women travel long distances to collect the fuel for cooking, while the men sell fuelwood at the market. Some of the important parameters for fuelwood use are:

- Amount of fuelwood used: The amount of fuelwood used per family depends to a large degree on the cooking traditions and the size of the family. In many African countries cooking traditions still favor communal cooking within the extended family. This reduces the amount of fuel needed per meal per person. The type of food cooked is another indicator for fuel use. The so-called ‘hard’ foods (maize, beans) take much longer and are more fuel-intensive. An average consumption figure for southern Africa is 1m3/person/year, or 1.4 to/family/year. However, these figures may vary widely, depending on fuelwood availability and fuel mix used (**Figure 4**).

Figure 4
Traditional fuelwood cooking in semi-urban areas

Source: SCFT

? Efficiency of technologies: The vast majority of people in sub-Saharan Africa still use the relatively inefficient three-stone fire with an average efficiency of 5-15%. Over the last twenty years efficient, affordable, and accepted technologies have been developed, that have proven efficiencies of between 15 and 30%. When introduced together with efficient kitchen management systems, they have shown regular savings in the field of between 30 and 60%, in institutional kitchens up to 70%. Unfortunately only an estimated 15-20% of households have been reached so far.

✍ Preferences of fuelwood users: It is an accepted fact, that except for specific purposes (for certain dishes the smoky flavor of fuelwood is preferred, or for the preparation of traditional medicines) most people do not use fuelwood by choice, but because they cannot afford or do not have access to higher grade fuels. However, historically, a progression of fuel use for household purposes has been noted. From the starting point of fuelwood there is a downward movement to crop residues and finally dung, and an upward progression to charcoal, kerosene, and finally gas and electricity. The type of fuel used at a certain time in general is a finely tuned measure of the economic status of a family. In particular, however, the availability of the preferred fuel is not guaranteed (although it would be affordable), so that other strategies have to be employed.

✍ Energy security and diversity of supply: What can be noted in reality, therefore, is a multiple fuel use, depending on what is available and affordable. People are reluctant to rely too much on one fuel or technology. Although higher-grade fuels may be preferred, the majority of households own different types of stoves and use two or three different fuels. This can be considered as a kind of risk management. What is important is that the meal is cooked and ready on time.

✍ Coping strategies: Where there are serious fuel shortages people have resorted to various coping strategies. Some of them, like using wood more carefully, extinguishing the fire after use, using only dry wood, and shielding the fire generally increase the efficiency of fuel use. Where fuel is bought, it is being used more judiciously. Other coping strategies, however, have negative effects on the health and well-being of the families, e.g. changing to lower grade fuels, reducing the number of meals cooked (often only one warm meal a day is cooked), changing cooking traditions (less energy-intensive, protein-rich meals are provided), and water for hygienic purposes is no longer heated.

On the average between 20-30% of fuelwood is consumed by small-scale rural industries. This fact contributes significantly to fuelwood scarcity for household purposes. In Malawi, for instance, from mere observation it becomes clear, that brick firing alone consumes a high percentage of fuelwood (15-20%). In such a case finding a substitute energy carrier for this particular major activity should be the first intervention priority, as it would relive the other sectors from immediate pressure and would allow for a more substantial planning and intervention process. Cutting of fuelwood for drying tobacco is responsible for 12% of deforestation in southern Africa. The three main producers (Zimbabwe, Malawi, and Tanzania) have a deforestation rate, which is 60% higher than that of the other countries. For these reasons, it is of utmost importance that national governments pay priority attention to this sector when developing their national biomass energy strategies.

1.4 Impact of fuelwood consumption

Where biomass resources are scarce, unsustainable fuelwood use, though not the major reason for the scarcity, contributes to the negative effects at the environmental, social and economic level and compounds an already difficult living situation. It is important, however, to not only look at the negative effects, but also focus on the positive potential that activities to improve this unsatisfactory situation can have. Research over the last two decades has indicated an array of key constraints and opportunities:

- **Environmental constraints**

When biomass is burnt carbon dioxide is set free. This fact contributes to climate warming because the trees are no longer available as carbon dioxide sinks. Higher carbon dioxide content in the air also disturbs the biological balance and encourages the growth of certain plants, which may become dominant. Forests and woodlands provide a natural protective system for the earth. They take over important functions in regard to the water reservoir, protection from erosion, climate regulation, temperature balance, the filtering of the air, and the regional distribution of humidity at the macro and microclimate level. Unsustainable cutting of trees for fuel contributes also to a loss of bio-diversity.

- **Environmental potential**

On the other hand, many research studies have shown, that development activities which focus on a sustainable and efficient use of the available biomass resources, coupled with household and community tree planting activities have proven to have positive impacts and contribute significantly to a restoration of the natural environment at the local and national level. Less dung and agricultural waste needs to be used, preserving it for organic fertilizer, trees planted for erosion control (and firewood) protect the vegetation cover and its ecological function, less wood needs to be transported, benefiting the environment by reducing traffic levels.

At the global level it is difficult in practice to estimate the potential of biomass to offset CO_2 emissions, because the different variables involved (area planted, crop productivity, energy conversion efficiencies, and substitution factors) make it a complex process. Nevertheless, such calculations have been carried out by FAO to show that the technically possible CO_2 replacement potential of sustainably produced biomass might be as high as 8-27% of the current global emissions by fossil fuels, given the necessary international pressure, instruments for such re-focusing of priorities could be through GEF funding or Clean Development Mechanism. Obviously these environmental effects concern more the national and global level, which means, that positive impacts can be expected only, if large-scale efforts are made. This can only be achieved, if national governments and donors jointly provide the necessary framework conditions.

- **Economic constraints**

Where fuel has to be bought, biomass-using families often are spending a substantial amount of their total income on fuelwood, whereby the poorer families spend the highest percentage for fuel not only in relative, but also in absolute terms. This is due to the fact that poor families can only buy in small amounts, on a daily basis, while richer families can afford to buy in bulk, often purchasing whole trees or truckloads, where a kg of wood costs only a fraction of the retail price. Money that is spent on fuelwood is lacking for other important daily needs, such as school fees for children, medicine for the sick, or better quality food.

✍ Economic potential

Activities to improve a critical energy situation, such as tree planting and the introduction of fuel-efficient technologies and fuel and kitchen management systems offer enormous potential to improve the economic situation of the poorer, biomass using section of people in rural and even urban southern African countries. There are examples from other African countries (in East and West Africa),

That employment and thus additional income for thousands of men and women can be created in the informal and formal industrial sector (depending on the scale of development programs) producing and selling appropriate and efficient household technologies. Artisans (pottery makers, tinsmiths) are trained and their skills upgraded; retailers, wholesalers, promoters find new jobs;

That through the use of efficient technologies expenditures for household energy can be significantly reduced and the savings spent on improving living conditions. With savings of between 40-60% at the individual household level this can be considered significant. With hundreds of thousands potentially produced and sold, this also has a significant impact for the national economy;

That the workload of women is markedly reduced and their time set free for other productive activities; considering that a woman spends up to 20 hours a week collecting fuelwood, this can have an enormous impact;

That operating tree nurseries and selling seedlings for planting for firewood and commercial purposes is another potentially beneficial activity in which both men and women can participate.

All these positive impacts make it apparent, that household energy programs are well suited to be considered among the primary interventions for strategies for poverty alleviation. But perhaps even more important than the economic effects are the socio-cultural and health impacts.

✍ **Social constraints**

Since the provision of fuelwood is primarily women's work, it is they who suffer most from the increasing shortages. Women are spending more time walking longer distances and carrying heavier loads, which affects their spine. Often they cannot manage alone, but need the help of their children, who then are kept from going to school.

Perhaps the most serious negative impact of biomass use is felt at the level of family health. Even when fuelwood was still abundant, its use for household energy purposes has been a health risk for women and children. Incomplete combustion is responsible for the release of a number of health-damaging pollutants. Indoor air pollution (**Figure 5**) has been identified as a major cause for a number of serious illnesses, which affect the whole family, mostly women and children. Among them are chronic respiratory ailments, eye infections, lung cancer, ARI among children, low birth weight of infants. All this is aggravated by the use of lower grade fuels (especially dung) in cases of wood scarcity. Another health concern is the frequent burns, which children suffer when they fall into unprotected fires. However, in southern Africa (especially in the sprawling townships of South Africa) fire caused by the spilling of kerosene is an even greater health risk.

Figure 5
In-door air pollution from traditional fuelwood cooking

Source: SCFT

✍ Social potential

More efficient and ergonomic conversion technologies (improved stoves) lead to a better combustion, resulting in less wood being needed and less pollutants being emitted as well as greater safety from burns. This reduces the workload of women, diminishes their anxiety in regard to the safety of their children, and provides them with more time to care for their families. If less wood needs to be collected, more children can attend school or do their homework.

Medical studies at the University of Nairobi have shown that in households with improved stoves CO concentrations were reduced by 2.5 times, which coincided with the incidence of ARI being reduced by 2.5 times. At the same time chronic respiratory ailments and pulmonary diseases were significantly reduced. Similar studies have been carried out in other developing countries.

In recent years this has become especially important in regard to the pandemic HIV/AIDS issue in southern Africa and in other African countries. The care of AIDS patients brings a greater need for extra hygiene, preparation of special foods and better food, emotional care and so on. At the same time AIDS leads to labor shortages and causes a decline in family food production and cash income, which is critical for the purchase of agricultural inputs, foodstuffs, medical and educational expenses. The use of energy efficient stoves cannot solve this problem, but it certainly can contribute to women managing better in critical times.

But there are other development concerns connected with gender and household energy issues, which have hardly been studied and are often underrated. This has to do with the strengthening of the innovative and organizational capacity of women when they become involved in the planning and management of household energy programs. There are a number of examples from Africa and elsewhere, which show that women develop self-initiative and self-confidence beyond their normal social surroundings. They get public recognition and their voices are heard in community meetings.

Likewise the progressive role women play in creating environmental awareness can be considered under this category. Because women are implicated much more than men, they have a greater interest in bringing about social change through a more secure access to sustainable energy services. On a different, though similar level the role of schools and other educational institutions can be considered. As custodians of the future, it is absolutely vital for a society to sensitize the young generations to the need to protect and conserve their environment and to the possibilities that secure and reliable energy services can play in that goal. Convincing examples of this are available in SADC countries.

1.5 Other options to meet household energy requirements

Fuelwood will remain the main energy carrier for African households for the next decades. Because of the increasing demographic pressure the total consumption will still rise. For the whole of Africa this has been estimated at 1.7% annually, for southern Africa at 1.4%. The reason for the lower increase in southern Africa is mainly due to South Africa actually expecting to reduce its consumption by approximately 3% annually, because of a very low population increase (0,6%), while Malawi and Zambia show low rates of increase. Since the rate of deforestation is also increasing, other options to satisfy the growing household energy demand have to be considered.

✍ **Substitution with energy derived from fossil fuel or natural gas**

It is generally agreed, that despite enormous efforts and high expenditures in some countries (such as South Africa, Namibia) SADC countries will not be able to provide electricity derived from fossil energy or gas to satisfy the growing energy needs of its growing populations. While it can be observed, that the chances for urban households are improving, this does not hold for poor rural and semi-urban households and the informal industrial sector. Therefore other options have to be considered.

Theoretical calculations have shown that in countries with an already relatively high consumption of oil products for transport and industry, a change from wood to kerosene would require only approximately 10% higher foreign exchange expenditures. For poorer countries, which do not have own resources of fossil energy, this is an insurmountable obstacle, especially in view of the fact, that those are also the countries with an underdeveloped infrastructure to guarantee a decentralized supply system.

✍ **Substitution with renewable bio-energy carriers**

Among the most promising are other forms of bio-energy and renewable energies. One of the most interesting developments of the last few years has been the upstart of the so-called gel fuel. With financial support from RPTES, several sugar producing southern African countries (Zimbabwe, Mozambique, South Africa and others) have produced this methanol-based fuel. Substantial field tests have proven the acceptance of this fuel for household purposes, provided it can compete with kerosene in terms of cost and the appropriate technical devices are available. It has other qualities (does not burn when spilled), which people prefer to kerosene for greater safety. Gel fuel is an interesting potential for the future, as long as it does not compete with agricultural production.

FAO has been doing research and documentation on other bio-energy potentials worldwide. Electricity can be produced from such plant material as sugarcane, sorghum, cottonwood, alfalfa, elephant grass, and many others. Some of these could be planted on degraded lands and could at the same time serve to rehabilitate such lands. The potential is there, but what will be realized will depend to a large degree on the financial resources available and the competing development issues.

Biogas is another untapped potential household energy source that could substitute fuelwood, but because of the high costs involved (approximately 500 USD for a family biogas plant), it is affordable only for large farms. For southern Africa, however, where large-scale farming plays an important role, this technology needs to be further exploited.

So far, the potential for bio-energy has hardly been tapped in southern Africa. There is no doubt, however, that bio-energy programs together with agro-forestry and integrated farming have the potential to improve both the energy and food security. As in other parts of the world, it opens up new opportunities for decentralized commercial activities in the energy/agriculture sector and helps to develop rural areas.

✍ **Substitution with other renewable energies**

Other renewable energies, such as wind, hydro, geothermal, and ocean energy, while of considerable importance for some areas in some countries, will, mainly because of high investment costs, not be available for substituting for fossil energy on a large scale. An exception to this is solar energy in the form of photovoltaic for lighting purposes and in the form of solar thermal for cooking, baking and crop drying (**Figure 6 and Figure 7**).

Figure 6
Fuelwood and solar cooking, complementary energy sources in rural South Africa

Source: SCFT

Figure 7
Solar cooking in rural South Africa

Source: SCFT

1.6 Opportunities for solar stoves

Apart from biomass, solar stoves probably have the highest potential for making a significant impact as far as energy for cooking, baking and food processing is concerned. This applies to households as well as to small, home-based food processing businesses and street restaurants. With varying degrees southern African countries are in a favorable to excellent position to make use of solar energy. Climatic conditions, cooking traditions, the level of technical expertise and production capacities, marketing structures and access to credit facilities all favor the introduction of solar stoves in this region.

On the technical side, there has been tremendous progress during the last five years in improving the quality of solar stoves in respect to efficiency, durability and user friendliness of the product. Although there is general agreement that solar stoves are not a stand-alone product, there is no doubt that in combination with other fuel-efficient technologies it can make a significant contribution to the energy security of households and small businesses alike.

All the aspects regarding the positive impacts of using efficient household technologies apply in the same or even a higher measure for solar cooking, since whenever solar energy is being used, biomass energy is substituted completely. Linkages with other development projects that address the same target groups should be sought, so that synergy effects can be achieved and the chances for a break-through for solar stoves improved (**Figure 8**).

Figure 8
Solar cooking, a new and innovative cooking option in South Africa

Source: SCFT

In a wider sense a statement made in a recent FAO publication, that “the energy challenge now faced by countries around the world is to provide energy services that allow all people to achieve a decent standard of living consistent with sustainable human development. This link between energy and development remains a key factor in development policy. It will be shaped by current trends of globalization, markets and popular participation in decision-making processes, the changing roles of government and energy utilities, and the mix of sources of national and external funding”, applies also to the spread of solar stoves. They have an important role to play in fulfilling this challenge

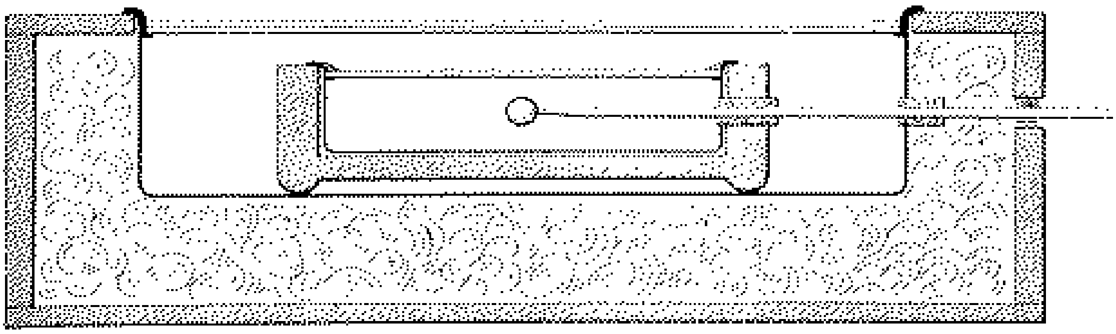
2 Origin and history of modern solar cooking

More than 2 000 years before US plans to establish a missile defense shield, Archimedes had the idea to burn ships at distance with the help of concentrating solar reflectors (an idea that could not have been put into practice at the time). Even at these early times, the power of the sun was well known to have potential for technical applications. It must have been used, at one obscure moment or another, to heat or cook food.

2.1 Solar Stoves in the 18th and 19th century

In 1774, over 200 years ago, Horace-Benedict de Saussure (1740-1799) invented and built an insulated box with multiple glazing (**Figure 9**). He called it a “helio-thermometer” and used it to study the greenhouse effect on his mountaineering expeditions – and to boil fruit; he pointed out distillation and cooking as potential applications of the device which was in fact the first box-type solar cooker.

Figure 9
Measuring air temperature in one of de Saussure's "hot boxes"

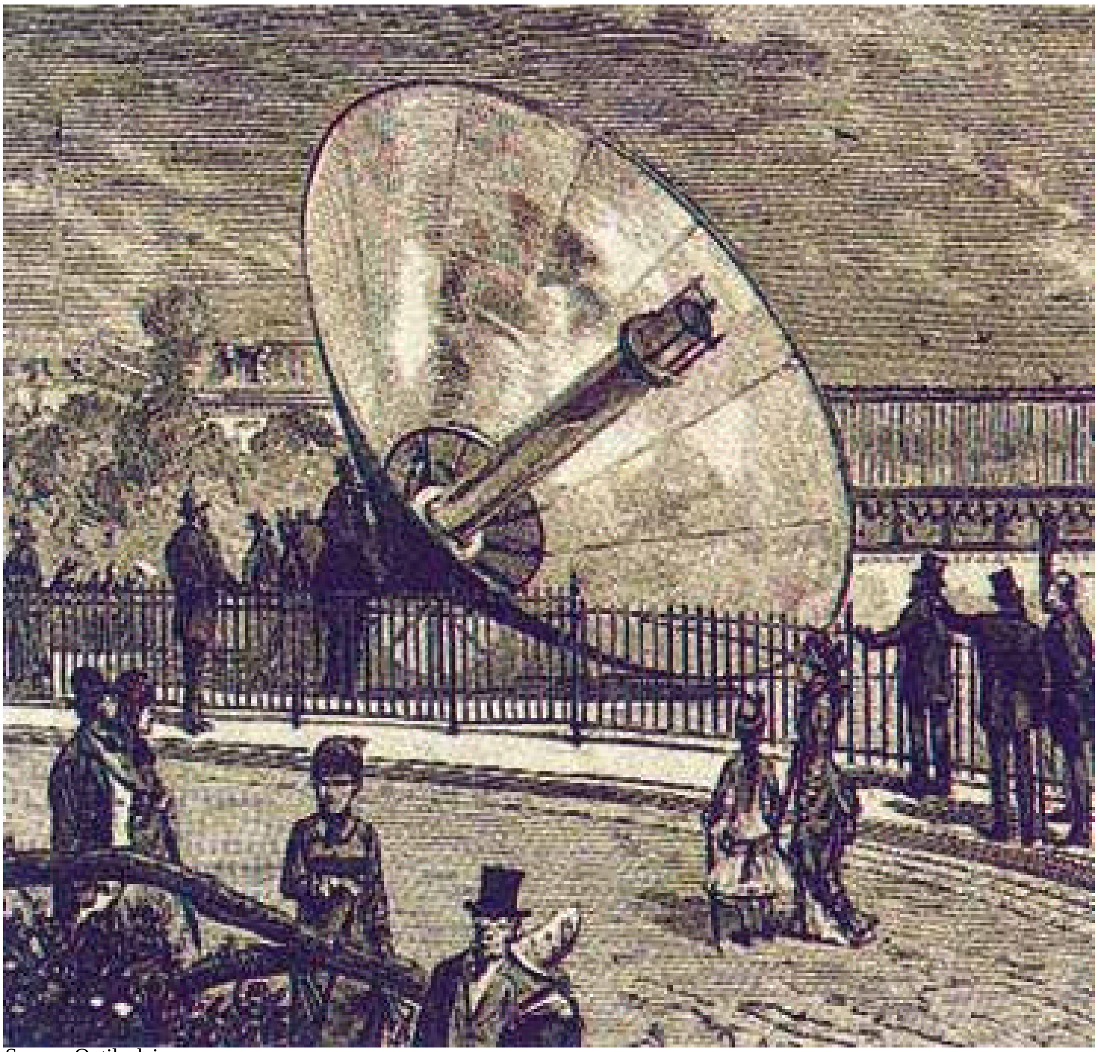


Source: Outilsolaires

In 1837, the British astronomer John Herschel used a solar box stove to cook meat and vegetables during an expedition to the Cape of Good Hope. The stove was made out of mahogany, painted black, buried in sand for better insulation and covered by a double glazing to reduce heat losses.

In 1860, the French mathematics teacher Augustin Mouchot wrote: “Possibly there will be no more coal in Europe…what will the industry do?” His answer was to harness solar energy. He started experiments with solar stoves, worked on his first solar steam engine (1866), wrote the world’s first technical solar energy book (1869) and received a gold medal for an engine producing steam with help of a solar concentrator at the 1878 World Fair in Paris (**Figure 10**). The machine, grand-parent of today’s’ parabolic stoves, had a reflector diameter of 5 m made out of silver-plated copper which was equipped with a tracking mechanism for following the orientation of the sun and a hydraulic circuit heated by a black cylindrical absorber. It produced enough steam to get a motor of half a horsepower going and was used to demonstrate a printing machine during the fair.

Figure 10
Mouchot's concentrator



Source: Outilsolaires

Mouchot was clearly aware of the practical and economic boundary conditions of solar energy use: “In hot and arid climates, the potential applications depend on the availability of fuels and on cost and difficulties in transport of the solar devices”.

Another early report on actual solar cooking appeared in June 1878, when the magazine Scientific American published an article describing how someone in Bombay, India had successfully cooked enough meat and vegetables for seven people with a solar oven.

2.2 Solar stove revivals in the 1950s and 1960s

Widespread public interest in solar stoves started in the 1950s and 1960s where most of the basic design variants were tried and disseminated. They include the following examples:

- The classic Indian box cooker (fiber reinforced plastic or sheet metal outer casing, aluminum interior casing, double tempered glazing, single glass mirror reflector lid) was developed and tested in many variations, including the use of a light bulb as back-up heat source (**Figure 11**).

- Maria Telkes invented the "Telkes cooker"- a box featuring an array of four external reflectors.

- Harry Tabor invented a parabolic concentrator using an array of shaving mirrors.

Most of these designs seem outdated today, but they were the first fully operational solar stoves and the ancestors of today's models. It should be noted that many other designs tried during these years were abandoned (re-surfacing at regular intervals).

Figure 11
Classical Indian box cooker

Source: MNES

At this stage, the vision underlying solar stove projects was simple:

- Many families had limited access to fuel for cooking
- Solar stoves could be made available to cook without fuel

The questions of acceptance and of sustainability did not enter the picture until it turned out that, in many cases, the stoves were barely used, and that the diffusion of stoves stopped when budgets ran out.

Also, solar cooking with its long-term development approach lost priority when compared to immediate concerns amongst such burning issues as wars and famine.

2.3 Advancement of solar cooking in the 1980s and 1990s

The difficulty of doing anything about these dramatic issues shifted the spotlight again to the long term and triggered the solar stove revival of the 1980s and 1990s, building on earlier efforts at first. Soon, new developments took place:

- In two studies (GTZ 1990, GTZ 1991), a neutral analysis of solar stove acceptance conditions and technical prospects was presented.
- A number of new stove types were developed, i.e. more efficient boxes, more user-friendly concentrators, and different large capacity models.
- An increasing number of stove developers realized that solar stoves had to be the answer to the user's needs - and not the other way around.

Two examples of organizations that have been part of this shift in priorities are Solar Cookers International (SCI) and the European Committee for Solar Cooking Research (ECSCR). For details see **Box 1** & **Box 2.**

2.4 Experiences with Solar Cooking to Date

It has been said many times,

- Sometimes gently: "The driving force behind most projects in solar cooking is not a pressing demand, but a pressing and outspoken supply"
- Sometimes bluntly: "Solar cooking is a solution looking for a problem"

Box 1
Solar Cookers International

SCI's roots are traced to the Arizona women Barbara Kerr and Sherry Cole back in 1976, when they developed a solar box cooker, made of cardboard, aluminum foil, and a piece of glass.

It was established in 1987 (called Solar Box Cookers International at that time), when Bev Blum of Stockton led the effort to establish a non-profit organization, which would share this with the world.

In 1994, SCI volunteers developed the world's simplest solar cooker; the Cookit, on the basis of a design by Roger Bernard, for use in emergency situations such as was occurring in Rwanda. Cookit is a foil covered cardboard panel, which directs sunshine onto a dark covered pot which inside an oven roasting bag. The clear bag lest sunlight in, and traps the heat. Two to three hours' sunshine is sufficient to cook food. SCI has provided solar cooking resources and training to refugee women and their families in East

SCI has demonstrated that the Cookit can also pasteurize contaminated water by placing a dark or pot in the Cookit for several hours, without the need of a roasting bag.

SCI has created an impressive mailing list of solar cooking advocates and experts. They publish periodical (paper and online) with solar cooking information from all over the world.

Source: SCI

Box 2
European Committee for Solar Cooking Research (ECSCR)

The European Committee for Solar Cooking Research (ECSCR), founded in 1991, is an ad-hoc committee of (mostly European) experts in all fields of solar cooking.

Its philosophy is to join forces between users on one side, and individuals and institutions active in solar cooking research and development (R&D) on the other side; to put solar cooking efforts on a more objective and less solution-oriented basis; to advance in a parallel procedure of development of better cookers and better understanding of the user situation.

Activities of the Committee:

- Organising workshops to pool the know-how of the members in order to arrive at better cooker concepts.
- Proposition, in 1993, of the project SOLAR COOKING IN THE YEAR 2000 in which, based on an analysis of needs in the field, optimised solar cookers were to be developed by a parallel
- procedure of field tests and consumer-type product testing.
- Elaborating a comparative solar cooker test method, comprising user aspects (ergonomics, safety, quality, etc.) as well as thermal performance.
- Comparative tests of 8 (respectively 25) solar cookers of different types at the Plataforma Solar de Almería (PSA).
- Participation in the DME/GTZ Solar Cooker Field Test in South Africa.

Source: ECSCR

To a certain extent, this seems unjust. No new product on the market emerges just because customers want it. There is always a product that requires public awareness before market pull can set in.

On the other hand, solar stoves often seem more attractive to solar energy proponents than to the stoves' prospective users. Ex-users probably outnumber users. One reason might be that solar stoves are only kitchen appliances. They have many advantages, but not much excitement value: just imagine a truck full of filter cigarettes, soft drinks and solar stoves left unattended. What would go first?

How important these non-technical, non-economic, subjective aspects are can be shown by the experience of the hay-box, very popular during World War 2. The hay box is used as follows: Food is heated to boiling point as usual and the pot is then placed in the hay-box. Cooking is completed without further heat input and the food stays hot for hours. But history is against this cheap, practical, fuel-saving appliance. It was utterly discarded once the energy shortage was over!

Some solar stove developers have started to take these aspects into account and some solar stoves are starting to look like attractive products (**Figure 12**).

Figure 12
Modern box cooker from Portugal

Source: Collares-Pereira

3 Solar cooking today

3.1 The particular charm of solar cooking

Solar stoves are not products like any other products. They have a magnificent logic to them: clean energy, environment, health, help for women and children forced to gather wood under the scorching sun and in places where every tree counts - a lasting emergency where help is needed and where help can be extended at affordable cost. Moreover, it is a simple and understandable technology. Most who have approached a solar stove in action have gone from disbelief to the urge to re-invent or at least improve solar stoves.

On the other hand, solar stove projects, in the past, have had a low success rate. This explains why a number of development experts are still allergic to solar cooking and can become quite vocal when facing solar stove proponents. Solar stove proponents are, in turn, often allergic to proponents of other solar stoves.

Solar cooking has advanced, in spite of all errors and mishaps, to a point in development, production and marketing where the active implication of professionals is important for further progress. Unfortunately, the market for solar stoves is not easy, it concerns a widely unknown, innovative product in a low-density, low-income environment.

3.2 Three basic types of solar stoves

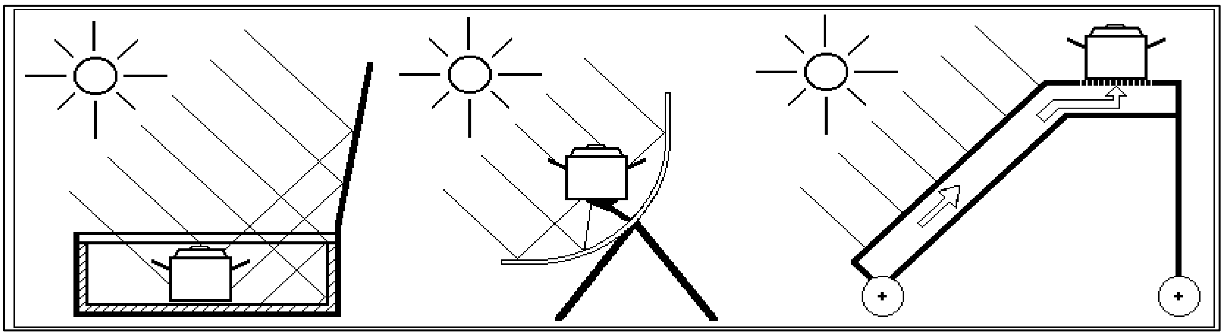
Basically, each of the many varieties of solar stoves fits into one of the following three categories (**Figure 13**).

3.3 More than 200 models of solar stoves

Within the scope of three studies (GTZ, 1990, GTZ 1991 and an internal study, 1998) a total of 168 different solar stoves were catalogued, the most frequent type (95 out of 168) being variations of the box cooker, followed by 51 concentrator, and 22 collector cookers. Despite the global scale of the studies, one can be sure that some models were overlooked and not counted. Probably, by now, more than 200 different solar stove types must have been developed, tested and / or used worldwide. Most of them are prototypes or handcrafted small-lot products. Some of them proved useless in practice, but some others have undergone competent development efforts. None of them, however, has yet reached the stage of a mass-produced industrial product.

The biggest of all known cookers, at Mount Abu (India), consists of a field of automatically tracked parabolic Scheffler concentrators with adjustable focal length producing steam which is fed directly into enormous cooking vessels, enough for 10,000 helpings. The smallest, measuring 30 cm in diameter and using a 500-ml jelly jar as its cooking vessel, was presented in 1998 by Enrique Martinez at the "3rd Encuentro Solar" in Benicarló, Spain (**Figure 14**).

Figure 13
The basic types of solar stoves



1 Box stoves	2 Concentrator stoves	3 Collector stoves
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.	concentrate direct solar radiation on a cooking pot. They are quite efficient but require the user's attention to keep them aligned with the sun, maintaining good performance.	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.

Source: SFCT

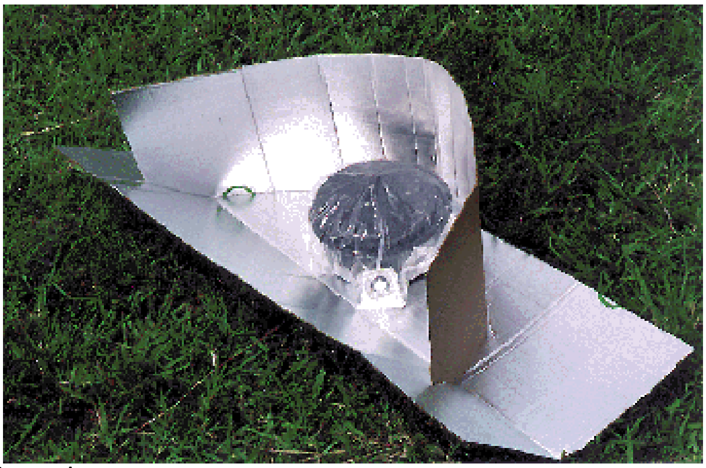
Figure 14
The largest and the smallest solar stove

Source: Brahmakumaris

Source: Synopsis

Among the most widely distributed models are the Indian box-type cooker and the Chinese concentrator (**Figure 15** and **Box 3**) – both claiming several hundred thousand units sold, followed by the Franco-American Cookit, distributed internationally, particularly in Kenyan refugee camps.

Figure 15
The CookIt and Chinese concentrator



Source: Accessone

Source: Beijing Newline United Corporation Ltd

Among a number of low-cost stoves there are some claims to the quasi / no-cost stove, the most radical designs being a dug-in box model of SunSeed and a box with used off-set printing plates for inner and outer casing – and even for pots and pot lids. It was presented in 1999 by Richard Wareham at the World Solar Cooking and Food Processing Conference in Varese, Italy (**Figure 16**).

Figure 16
The SunSeed dug-in box model

Source: ECSCR

Box 3
Case study: Solar stove test use Mongolia

In late summer 2001, a field trial concerning the use of solar stoves in Mongolia was organised by GTZ. Six families participated. The test stove was a Chinese concentrator, a long focus model with high concentration ratio.

The evaluation results are shown in the following Table:

User	Start test period	End test period	Number use cycles	Total water boiled litres	Average cycle time (minutes)
Amird	09/08/00	18/10/00	210	589	60
Tsermas	18/09/00	30/10/00	67	208	32
Jigmedsenge	01/08/00	07/09/00	96	290	35
Gankhuyag	01/08/00	21/09/00	112	240	40
Bold	09/08/00	15/09/00	20	104	53
Darkhanbat	08/08/00	-	42	150	35

The differences in cycle times are striking and are certainly caused by different tracking intervals (this type of stove is extremely sensitive to tracking frequency); the data indicate that users, the more they use the stove, the more they stretch tracking intervals – they would probably prefer stove models with lower peak power and longer tracking intervals (see below). Further information and average values are given in the next Table:

Number of user households	6
Monitored use days	237
Relative use rate	77%
Average use cycle time (minutes)	43
Average daily use cycles	2
Average water load (litres)	3.3
Average output power (W)	492

When asked for desirable improvements, users mentioned the need for an adjustable potholder or a special solar pot, preferably with thermal insulation.

The use rate of 77% (based on 100% = 3 cycles per day) is very high, but varies strongly between the households, as does the highly tracking-sensitive output power. The acceptance is excellent, but not unconditional: stove use stops in winter, users criticise the high, but uneven power output, don't like to use the stove for non-liquid food (risk of burning), and are aware of the safety risk caused by strongly concentrated sunlight in an accessible spot.

The test results would have been more specific and easier to obtain using the SCFT method, e.g. by the establishment of cooking profiles and by the test use of more than one stove type.

Source: GTZ

The thermal output of solar stoves also varies widely (**Table 1**). 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 over two hours.

Table 1
Performance data of various solar stoves

	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

Source: ECSCR

3.4 Assets and constraints of solar cooking

There are a number of inherent assets in solar cooking. The most important reason to use solar stoves is saving fuel: the more the stove is used, the more fuel is saved. The saving is made by fuel (sunshine) that nobody has to cut or pay for, dry, store safely, light and tend. It requires no worry about ash and is safe. The savings made can also include time, effort and / or money. Furthermore, solar cooking is convenient. It produces no smoke and no additional heat is generated in the kitchen. Finally, a solar stove works independently. An experienced solar cook sets the stove up, loads it, and comes to fetch the hot food once the family is hungry.

However, there are also a number of constraints to solar cooking. It does not work every day of the year. Clouds and inclement weather prevent solar stove use. Solar cooking needs a safe place close to the kitchen and where the sun is not blocked by shadow from buildings or trees. Users may have to move the stove, keeping it in the sun and in a safe location. The stove works best outside, exposing it to theft and unwanted meddling. A solar stove can also attract (hungry) visitors. In addition, solar cooking needs planning: it is not the ideal solution when an unexpected hungry guest appears in the evening. Finally, while a solar stove pays for itself in savings, it still is expensive to buy at first.

4 Market potential for solar stoves

4.1 Dissemination of solar stoves worldwide

The number of solar stoves disseminated so far worldwide is roughly 900,000 units (**Table 2** and **Figure 17**). This is based on estimates from experts involved in various programs and/or projects that usually lead to rather generous guesses. On the other hand, not all projects in all countries could be contacted resulting in lower figures. The quantitative results presented are therefore probably not very reliable, but they do give an idea. In addition, it must be noted that these figures are cumulative, i.e. stoves are counted whether they are still used or not.

Table 2
Estimated number of solar stoves disseminated worldwide

Continent	Country	Number of solar stoves
Africa	RSA	10,000
	Kenya	22,000
	Others	18,000
Asia	Afghanistan	5,000
	China	150,000
	India	430,000
	Tibet	220,000
Others		45,000
Total		900,000

Source SCFT

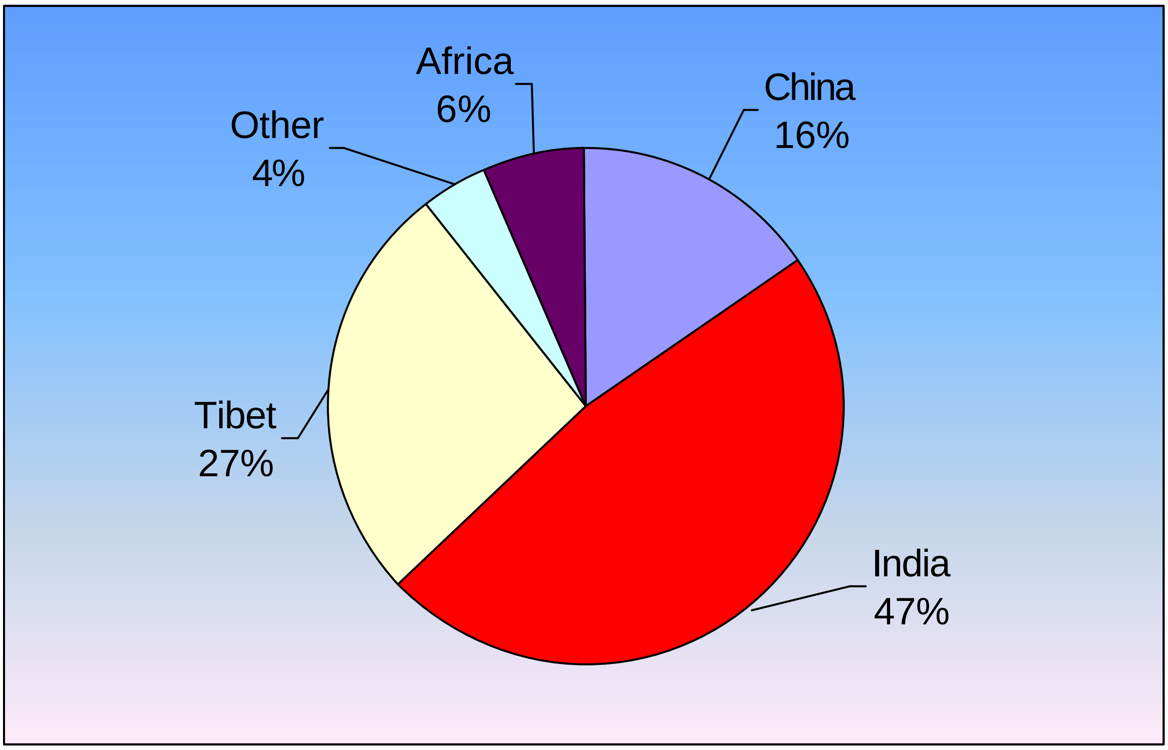
These figures indicate that the overwhelming majority (90%) of solar stoves were disseminated in Asia and that half of these stoves are (Indian) boxes, half (Chinese) concentrators. Practically none are modern designs.

It should be borne in mind that the majority of these solar stoves might not be in use anymore. Only few of them have been disseminated without (public or private) subsidies / incentives.

4.2 Dissemination of solar stoves in Africa

Table 3 and **Figure 18** show that about 50,000 solar stoves have been disseminated in Africa, mostly in Kenya and South Africa, i.e. about 70%. The solar stoves disseminated in these two countries are of a more recent design then those in China, India and other Asian countries. African countries without number entries denote cases where solar stove programs have taken place but no quantitative data are available.

Figure 17
Solar stoves disseminated worldwide



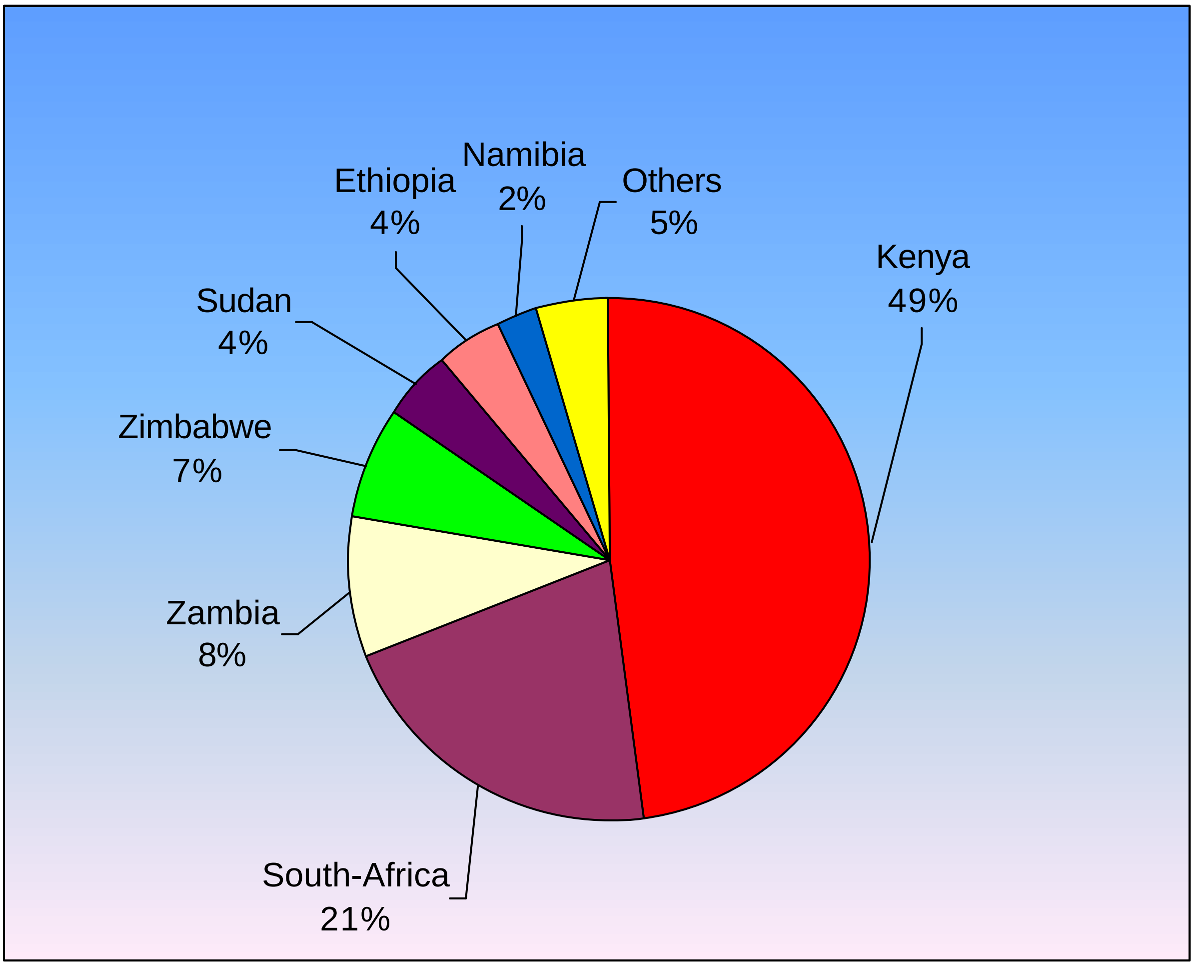
Source: SCFT

Table 3
Estimated number of solar stoves disseminated in Africa

Country	Number of stoves	Country	Number of stoves
Botswana	< 100	Mozambique	300
Burkina	550	Namibia	1 100
Cameroon	?	Niger	< 100
Chad	< 100	Rwanda	< 100
Egypt	?	Senegal	100
Ethiopia	2 000	Somalia	< 100
Gambia	?	South-Africa	10 000
Ghana	200	Sudan	2 100
Guinea	250	Tanzania	200
Kenya	22 500	Uganda	?
Madagascar	220	Zambia	4 000
Mali	150	Zimbabwe	3 300
Mauritania	?	Total	50 000

Source: SCFT

Figure 18
Solar stoves disseminated in Africa



Source: SCFT

4.3 Present and future market potential

With a few exceptions, solar stove dissemination results have remained confidential. There are reasons to believe that this might change:

- For several years now, better stoves, in terms of performance, handling, durability, looks and price have appeared on the market.
- The adaptation of these models for local and central production, as well as for all aspects of commercial distribution, is advancing.
- The proponents of solar cooking are becoming more cooperative and professional.

One of the remaining issues is the reluctance of established business to become involved in solar stove manufacturing and marketing. Thus, two different options exist:

- Continue the present niche-market situation where technical cooperation agencies and NGOs give away stoves (or sell them at heavily subsidized prices) and organize their own manufacturing and marketing structures. It must be noted that niche markets are not necessarily small, as the Indian example shows. But they are in danger when subsidies end.

- Adopt commercial procedures in production and distribution, with achieving the mass market as the objective. It is increasingly possible that "commercial" might include additional income generated via avoided costs for environmental damage and other externalities.

How big is the potential market for solar stoves? It is interesting to compare it with the market potential for other durable goods, such as cars, TV sets and PCs. This comparison is depicted in **Table 4**. The target group is the estimated 2 billion people dependent on firewood and subject to a difficult energy supply.

Table 4
Estimated market data for solar stoves and other durable goods

	Solar stoves	Cars	TV	PC
Potential market penetration	50%	50%	50%	30%
Family or user unit size	5	1	1	1
Market volume (million units)	200	1,000	1, 000	600
Unit Price (USD)	50	10, 000	100	1, 000
Market value (billion USD)	10	10, 000	100	600
Useful life (years)	10	10	10	4
Units/y (millions)	20	100	100	150
Turnover (billion USD/year)	1	1, 000	10	150

Source: SCFT

This table confirms that solar stoves, worldwide, represent a sizeable market potential: 10 billion USD for the first units and 1 billion USD per year for replacement units in a saturated market. This is a major market opportunity, albeit in a hard-to-access low-income environment. However, it is way below the potential of the other products.

So much for market potential in general. But is it feasible to reach or approach these figures in reality? This is one of the central questions motivating the field test. At this point, it is possible to formulate a number of necessary conditions for solar stove market success:

- On an objective level, it is evident that the stoves must meet a number of obvious requirements, such as product quality, performance, handling, user support, affordability and value for money. In terms of the SCFT this was clear from the start, and important efforts were aimed in this direction.

On a subjective level, success needs confidence along the whole product chain, from the manufacturer, the distributor and retailer right down to the client or user. Stoves must be credible and the risk to produce, to market or to buy a “lemon”, to lose money and face must be perceived as acceptable. The approach of taking over some of the risk of commercial failure might point the wrong way. For successful commercial partners, the financial risk might be less important than the loss of face by a product failure on the market.

In any case, it seems difficult to reach a major presence on the commercial market for household appliances without the partnership of established players in this field.

5 Approach to test social acceptance, manufacture, and marketing of solar stoves in South Africa

The two basic goals of the SCFT were to find out whether solar stoves find user acceptance and whether they can be produced and marketed commercially.

5.1 Basic rationale - "open" versus classical approach

Given not only the variety of solar stove models, ways of use, storing them, but also the variety of potential applications, of marketing, etc., it was felt that a fixed approach (testing *one* stove type in *one* user situation, using *one* method) would produce information only about a particular case. The reasons for success or failure would be hard to identify (Was it the stove, or the target group, or the marketing approach?). Therefore, it was decided to test different stoves in parallel, in different user situations, using different marketing techniques, to get information, not only on particular solar stoves, but also on solar cooking in general.
The same argument was applied to other issues:

- ✍ In general, important questions were studied using several different methods, often run by external experts or companies

- ✍ In particular, acceptance was studied by different enquiries in families who would use five different stove models; double-checks were run. A non-user control group was included.

- ✍ As a rule, it was tried to work with qualified and established local partners, instead of taking over activities that would later have to go local anyway. This intention was not always successful.

The differences between the "classic" and the "open" approach (flagged in italics) have been summarized in **Table 5**.

In short, the comparative field test looked at different stove models and used in different situations and environments, to identify favorable conditions for use and commercialization of solar stoves.

Table 5
Comparing the "classic" and the "open" approach

Issue	Classic Approach	"Open" Approach
Pre-test situation	Study the local situation	Study the local situation
Hardware (e.g. stoves) to be tested	Bring in hardware	Bring in different hardware options
Confront users with hardware	Test use	Test use: organize hardware comparison by users, e.g. by "round-robin" procedure
Monitor user reaction	Monitor and evaluate acceptance and technical aspects	Monitor and evaluate acceptance, user preference and technical aspects, compare different options
Project implication vs. local partners in production, commercial dissemination, user support	Identify local partners for production, commercial dissemination, and user support. If no immediate positive response, project takes over the activity or creates parallel structures to ensure all necessary functions in all sectors (technical, user support, production, commercial…)	Identify and implicate local partners for production, commercial dissemination, user support; no creation of parallel structures, except in emergencies.
Adaptation to project experience	Improve hardware and procedure	Improve hardware and procedure

Source: SCFT

5.2 Method of the social acceptance test (Phase 1)

The methods actually applied, presents **Table 6** issue-by-issue, in examining the acceptance of solar stoves: in the left column, the activities and issues to be studied are listed. In the three columns on the right, the different methods are presented. It can be seen that different actors, for all major issues, have used different, complementary methodological approaches.

Table 6
Acceptance study method (Phase 1)

Target issue	Main method	Control method	Double-check method
Pre-test situation	Baseline study		
Area selection	Cooking profiles	Visits	
Stove selection	ECSCR test and recommendations	Compilation of recent stove models	
Set-up of M&E system	Design of five-stage questionnaire system	Dummy interviews	
Monitor qualification	SESSA workshop	Dummy interviews	Supervisor visits
Monitoring	Monitor-run questionnaire enquiry	User-run questionnaire enquiry	Supervisor visits
Stove qualification	SESSA cooking test	ECSCR recommendations	Technical audit
User training	Monitor visits	Instruction booklet	Recipe booklet
Use rate and user satisfaction	2 independent questionnaires	Monitor visits	Supervisor visits
User preference	Enquiry Round Robin	Used stove sales	External market study
Fuel savings	Fuel consumption study	Questionnaire enquiry	Supervisor visits
Evaluation	Data base analysis	De-briefing monitors	De-briefing supervisors
Stove adaptation	Technical audit	Developer input	Technology transfer
Test stove repair	After sales service	Supervisor visits	

Source: SCFT

5.3 Method of the manufacture and test marketing (Phase 2)

For the manufacture and test marketing of solar stoves, **Table 7** provides the same type of information.

Table 7
Manufacture and test marketing study method (Phase 2)

Target issue	Main method	Control method	Double-check method
Phase 2 stove selection	Phase 1 evaluation	Low-price potential	ECSCR recommendation
Public awareness	Demonstrations	Hotline	Flyers
PR	Targeted Media	Flyers	Interviews with solar stoves users
Selection of outlets	Visits	Training of sales staff	
Manufacturer selection	Manufacturer workshop (RSA)	Tender process	Shop floor visits
Technology transfer	Plans and product information	Manufacturer workshop (D)	Informal cooperation
Stove adaptation to local conditions	Production profiles	Developer / manufacturer cooperation	Tests
Quality and performance control	Project	Developer	Tests
Stove procurement	Order of batches	Quality control on the basis of SABS	
Estimation of mass production potential prices	Value- and cost analysis	Direct estimates based on material and labor cost	Price evolution analysis by analogy with other products
Price elasticity	Special sales	Conjoint analysis	

Source: SCFT