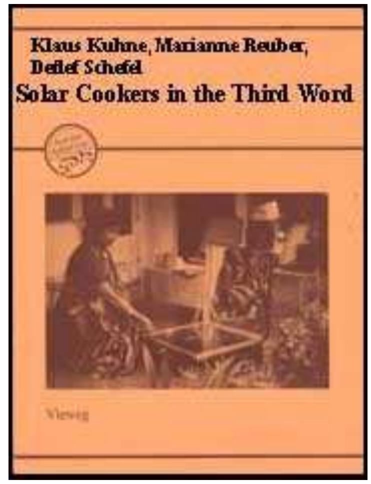
Solar Cookers in the Third World (GTZ, 1990, 228 p.)

3. Conditions of Acceptance for Solar Cookers



Ultimately, the acceptance of solar cookers in and by the Third World depends on numerous prerequisites:

- Available models: Is the solar cooker technically mature and of high quality?
- Solar radiation: Is enough solar energy available?
  Energy demand: Is the target population in a precarious energy situation?
- Social situation: Are solar cookers acceptable from the standpoint of social structure?
- Dietary patterns: Can solar cookers fit into the dietary patterns of the target groups?
- Eating habits: Do the prevailing eating habits allow the use of solar cookers?
- Cooking habits: Can the customary cooking techniques be preserved when using a solar cooker?
- Cooking facilities: In what respect do the traditional cooking facilities differ substantially from solar cooking devices?
- Technology: Which technical aspects of solar cookers are especially important in the social context?
- Economy: Are solar cookers cost-efficient?
- Side effects: What kind of overall impact, including side effects and consequential effects, do solar cookers have?
- Additional conditions for acceptance: What other prerequisites must be fulfilled to ensure acceptance?

The above questions are defined and examined here in relation to the project results discussed in the preceding chapter.
This is followed by a questionnaire designed to facilitate evaluation of some major aspects of solar-cooker acceptance.

3.1 Preliminary Notes

Solar cookers are still at the development stage. No one model has yet achieved technical perfection; most prototypes are modified time and again.

Maturity: Most solar cooker projects consist more of prototype testing programs than of dissemination programs for technically mature solar cookers. Consequently, nonacceptance of an "unfinished" prototype does not necessarily mean that the future product - in the form of a technically mature, cost-efficient, series-built solar cooker - will also encounter similar nonacceptance and consequent failure of relevant dissemination efforts.

Quality: Most solar cookers, being prototypes, have not nearly reached their ultimate potential quality with regard to thermal efficiency, craftsmanship, stability, etc. The essential aspects of microquality and macroquality are dealt with in the following chapters (3.2 through 3.12).

3.2 Solar Radiation

The first and foremost prerequisite for success in a solar cooker project is adequate insolation, with only infrequent interruptions during the day and/or the year.

Insolation: The duration and intensity of solar radiation must suffice to allow the use of a solar cooker for prolonged, worthwhile regular periods. While cooking with solar energy is possible in Central Europe on a sunny summer day, a minimum irradiation of 1500 kWh/(m²a) (corresponding to a mean daily insolation of 4 kWh/(m²d) or 15 MJ/(m²d)) should be available for any solar cooker project. Indeed, some sources speak of higher minimum insolation levels required.

But these annual data can sometimes be misleading. The essential condition for solar cooking is a reliable "summer weather", i.e. essentially predictable sequences of regular cloudless days.

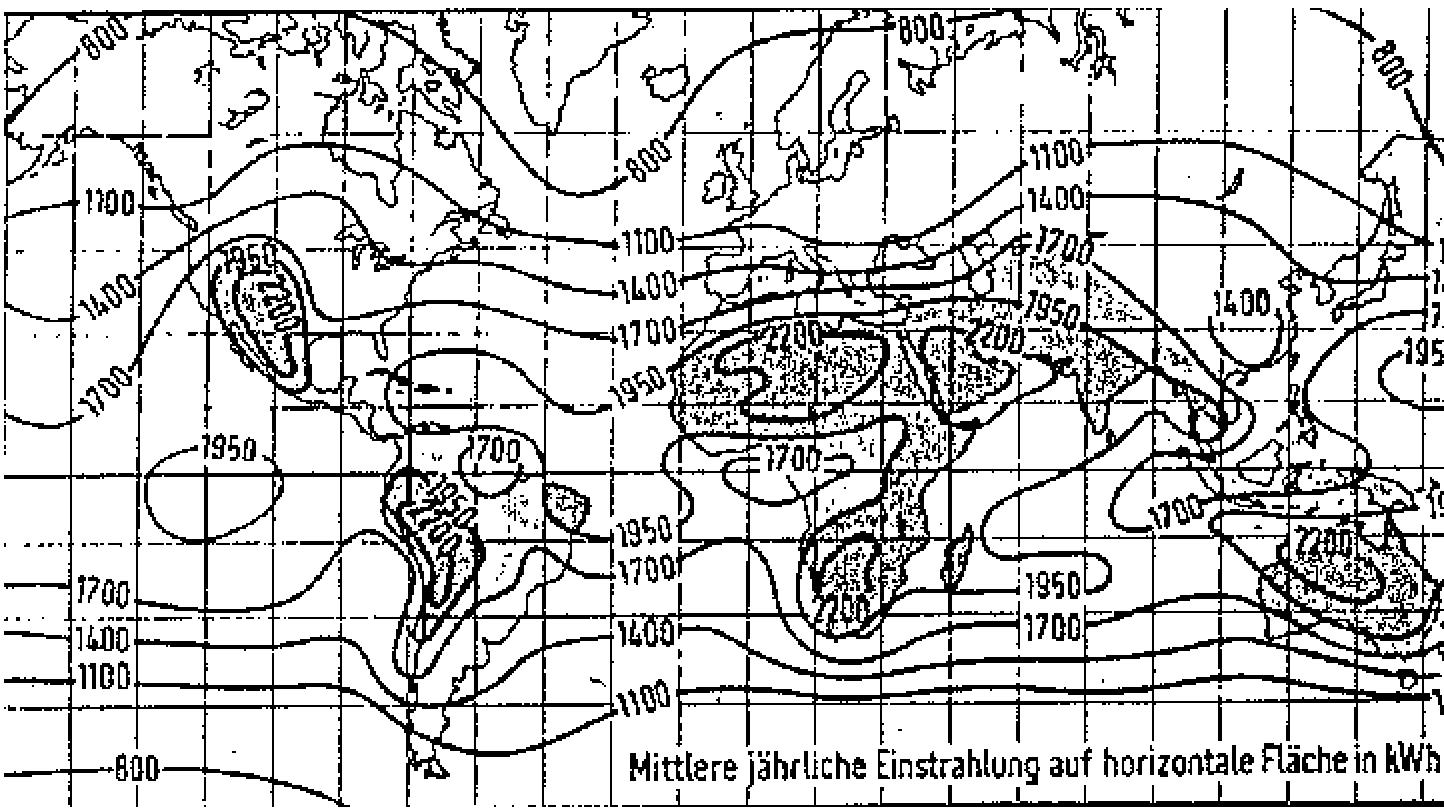


Figure 14 /189/ shows the global distribution of annual irradiation in kWh/(m²a).

Visibly, the supply of solar energy varies substantially from country to country, even within the Third World's tropical belt. Thus, local data must be referred to - and they are not always available.

Some examples:

- India: Solar radiation in most regions of India is good to very good for purposes of solar energy exploitation (see fig-. 15). The yearly averages of daily annual global radiation range from 18 to 25 MJ/(m²d), or 5 to 7 kWh/(m²d), depending on the region. In most places, the insolation reaches its minimum during the monsoon season and is nearly as weak again during the months of December and January. In Delhi and Calcutta, though, the sunshine deficit during the monsoon season is not as pronounced as the one in winter. Figure 15 shows the regional distribution of global radiation incident upon India.

- Kenya: Kenya's climate and insolation potential are conducive to the use of solar cookers (see table 3). Kenya straddles the equator and therefore has a purely tropical climate. In Nairobi, the daily irradiation alternates between 3.5 kWh/(m^2d) in July and 6.5 kWh/(m^2d) in February, but it remains practically uniform (6.0...6.5 kWh/(m^2d)) in Lodwar, as indicated in table 3. Table 3 also shows that the solar irradiation in Nairobi is adequate for cooking with solar energy nine months a year (excluding June through August). On the other hand, conventional cooking facilities must be relied on for cloudy or hazy days. In the Lodwar area, though, solar cookers can be used year-round.

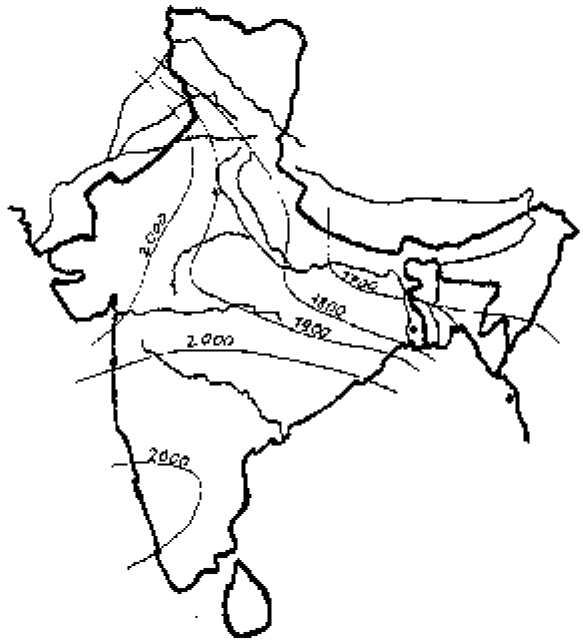
- Mali: The irradiation values vary from region to region but may be regarded as generally favorable. Irradiance increases steadily from south to north. Table 4 lists the 10-year averages of monthly sunshine duration' in hours, for 15 towns in Mali. The total annual sunshine duration comes to about 2 , 200 hours in the extreme southern parts of Mali and 3 , 500 hours and more in the country's northern reaches. An average value of about 3,000 sunshine hours per year is achieved around the 13th parallel, i.e. in the southern part of the country. The Narema and Quelessebougou areas get more precipitation and therefore have lower annual averages of sunshine duration (2,800 hours) than the rest of Mali.

- Pakistan: The solar radiation level in Pakistan decreases steadily from south to north, but remains substantially below India's average (cf. table 5). At the east-facing slopes of the mountains
(Quetta, Peshawar) radiation is generally higher then in the lower part of the country. Minimum irradiance in winter is conspicuous all over Pakistan. In many areas, there are 3 or 4 months with less than 4 kWh/(m^2d) of global irradiation (14.5 MJ/(m^2d)), which makes it very difficult, if not impossible, to use solar cookers.

- The Sudan: The Sudan gets a lot of sunshine; daily global radiation values measured horizontally range from 18.9 MJ/(m^2d) to 27.7 MJ/(m^2d) (corresponding to 5.3...7.7 kWh/(m^2d)) on an annual average.

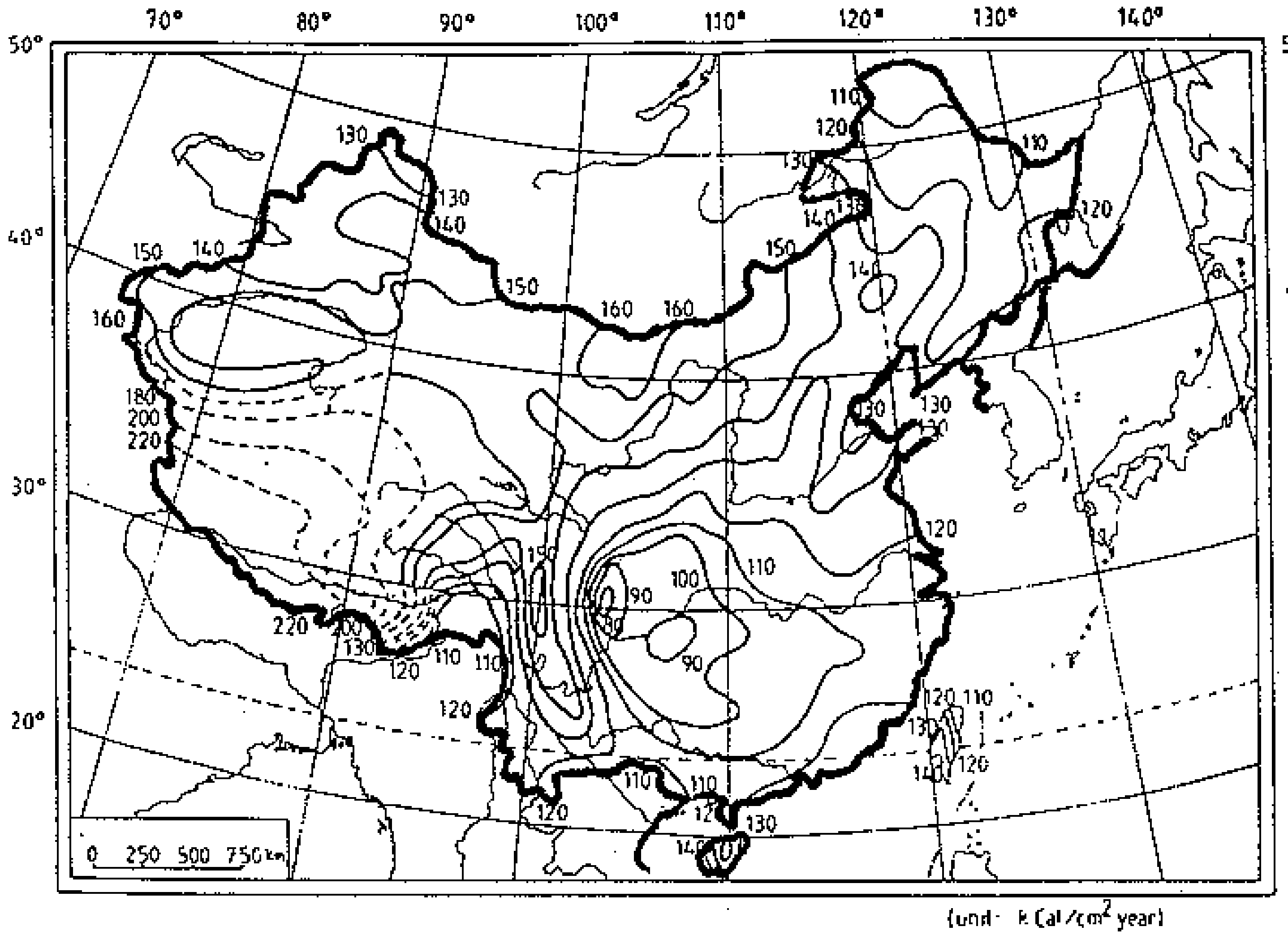
- China: The total annual global radiation in China ranges from 3350 to 8400 MJ/(m^2a), which is a daily mean global irradiation of 9.1 to 23 MJ/(m^2a) or 2.5 to 6.4 kWh/(m^2d). The areas with more than 5900 MJ/(m^2a) (16 MJ/m^2d or 4.5 kWh/m^2d), cover more than 2/3 of the country /187/ (see fig below).

- Conclusions: The above data underline the importance of various determining factors like climate, location, season of the year, etc. with regard to sunshine duration and solar intensity.



FIGURE

Figure 15: Regional distribution of average annual global radiation in India, measured in kWh/(m²a) /6/. 2000 kWh/(m²a) correspond to a mean daily insolation rate of 19.7 MJ/(m²d)



FIGURE

Figure 15a: Annual distribution of solar radiation in China in kcal/(cm²a) /187/.

100 kcal/(cm²a) = 3.2 kWh/(m²d) = 11.4 MJ/(m²d) mean daily radiation

Table 3: Monthly averages of daily global irradiation in Nairobi, Lodwar and Mombasa (Kenya), measured in kWh/(m²d) (Deutscher Wetterdienst Hamburg).

Month	Nairobi	Lodwar	Mombasa
January	6.30	6.16	5.84
February	6.55	6.16	5.97
March	6.19	6.10	6.01
April	5.25	6.03	5.24
May	4.64	6.34	4.48
June	4.19	6.10	6.02
July	3.59	5.86	4.48

August	3.93	6.30	5.01
September	5.28	6.51	5.52
October	5.61	6.30	5.49
November	5.31	6.02	5.92
December	6.13	6.29	5.76
Yearly average	5.25	6.18	5.48

Table 4: Mean monthly sunshine duration (in/month, 1961-1970) in Mali (Direction Nationale de la Meteorologie, Bamako, Mali)

Meteoro-logical station	J	F	M	A	M	J	J	A	S	O	N	D	Annual average (h/a)
Bamako	272	256	280	247	246	238	203	178	208	254	261	261	2.903
Bougouni	277	240	241	212	238	231	206	174	183	238	259	265	2.764
Gao	295	274	293	279	307	272	294	280	279	294	291	276	3.432
Hombori	285	271	290	257	271	249	254	256	259	289	289	272	3.242
Kayes	266	247	295	293	276	242	217	194	229	258	262	265	3.044
Kenieba	263	268	294	291	272	240	187	155	185	235	258	264	2.900
Kidal	291	272	304	292	319	276	310	290	282	298	293	276	3.504
Kita	277	277	289	278	260	245	209	173	182	251	269	276	2.985
Menaka	268	261	271	242	263	254	264	255	257	181	277	278	3.171
Mopti	279	267	288	256	261	243	244	230	242	277	279	275	3.140
San	286	269	296	281	271	273	252	226	247	294	283	277	3.255
Segou	292	276	292	263	274	266	254	223	242	283	287	287	3.238
Sikasso	277	240	241	212	238	231	206	174	183	238	259	265	2.764
Tessalit	293	282	299	289	298	262	279	284	268	283	281	273	3.392
Tombouctou	283	288	297	283	306	284	294	281	279	291	287	276	3.447

Table 5: Monthly averages of daily global irradiation at five stations in Pakistan, measured in kWh/(m²d)

(Deutscher Wetterdienst, Hamburg)

Month	Peshawar	Lahore	Multan	Quetta	Karachi
January	3.00	2.52	3.51	4.01	4.54
February	3.98	3.18	4.31	4.60	5.20
March	4.95	4.97	5.41	5.54	5.35
April	6.07	5.68	6.24	6.74	6.32
May	7.13	6.30	6.71	7.95	6.63
June	7.28	6.17	6.56	8.27	6.53

July	6.50	5.56	6,39	7.44	5.61
August	5.84	5.28	6.12	7.08	5.16
September	5.37	5.10	5.81	6.85	5.78
October	4.49	4.33	4.83	5.83	5.50
November	3.58	3.39	3.99	4.71	4.80
December	2.99	3.03	3.30	3.87	4.27
Yearly average	5.10	4.68	5.27	6.07	5.47

Type of radiation: Solar cooking boxes make use of global (= direct and diffuse) solar radiation, while reflector cookers exploit practically only direct radiation (see Fig. 10). The difference between global and direct radiation depends on local climate, season, weather, etc. and can be considerable.

Location: Solar irradiation levels - and, hence, the usefulness of solar cookers - can vary substantially within a country; it all depends on the location of the project area, particularly if the country in question includes distinctly different topographies, as do Kenya, India and Mali, for example.

Cloud cover: The cooking process in a reflector cooker is interrupted when the sun disappears behind a cloud, and haze, which occurs in urban areas like Nairobi, makes the reflector cooker thermal output drop off considerably - even to the point of making it hard to keep food warm. During the rainy season, which lasts anywhere from 2 to 4 months in many countries, irradiation is so low that reflector cookers are of no use at all, and the usefulness of cooking boxes is limited, e.g. to keeping cooked food warm. The same applies to any cloudy day.

Time of day: Cooking with solar energy is limited to the "better" daylight hours, unless the cooker is a heat-accumulating type. Due to atmospheric attenuation, the solar radiation received during the first hour or so after sunrise and the last hour or so before sunset is too weak to power a solar cooker. Solar tracking helps little during the marginal hours. By contrast, heat-accumulating solar cookers are useful day and night.

Season of the Year: In any area with pronounced seasonal variation in local climate and prevailing weather conditions, solar cookers can only be used in the summertime, but not during the winter or the rainy season.

Impact: Solar cooking is only possible in the presence of adequate insolation and good weather. In other words, it is decisively dependent on climate, season and momentary weather conditions.
Conventional cooking facilities must be maintained nearly everywhere - and that constitutes a serious handicap for solar cookers.

3.3 Energy Demand

The purpose of solar cookers, of course, is to save energy in the face of a double energy crisis: the poor people's energy crisis is the increasing scarcity of firewood, and the nation's energy crisis is the growing pressure on its balance of payments. Solar cooker projects should be judged with that in mind.

Energy consumption: Compared to other nations, developing countries consume very little energy. For example, India's 1982 per capita energy consumption rate, at 7325 GJ, was one of the world's lowest. But the country's energy consumption rate is increasing nearly twice as fast as its gross national product. The same is true of most developing countries. In Pakistan, 60% of all energy consumed is commercial energy, and the remaining 40% is drawn from wood (26%), dung (8%) and agricultural residue (6%). According to reports from Mali, 93% of the energy consumed there is from noncommercial or semicommercial sources. In the Sudan, private households account for more than 3/4 of total energy consumption (78%), and the rest goes for transportation (11%), industrial production (6%) and agriculture (2%); the energy vehicles are wood (45%), charcoal (29%), other biomasses (9%) and petroleum (17%). In other words, the main energy vehicles are still the traditional ones. The fact that energy lost in the conversion of wood into charcoal accounts for about 1/3 of the country's total energy consumption is revealing. Such statistics usually exclude solar energy and "manpower" and are accordingly limited in their informational content.

Household energy: Private households account for 11% and 14% of commercial energy consumption in India and Pakistan, respectively. The statistical data vary widely from region to region and depending on the local climate. In Pakistan's lowlands, for example, the average annual per capita energy consumption rate comes to 2.9 GJ, rising to 15.1 GJ in the mountains. Most household energy derives from noncommercial sources, particularly from locally available renewable sources like firewood, scrubwood, brushwood, undergrowth, broken limbs and branches, dung from animals, agricultural residue like rice stalks and cobs, and spent tea and coffee bushes in Kenya. By comparison, grass reed and straw are used in Mali, corn stalks, sugar cane and cotton waste in Egypt, and sawdust in Pakistan. Different energy vehicles can have different uses. Agricultural residue, for example, is used in India as cattle fodder, but also as roofing material and, after composting, as a fertilizer. Whenever such sources of energy are used as fuel for cooking, they are naturally no longer available for use as, say, agricultural fertilizer. In India, more dung is burned in cooking fires than chemical fertilizer is used in farming. Thus, energy conservation via solar cookers would, at least in theory, have indirect positive effects on food production. Some 75% of all fuel burned in Pakistani households is from traditional renewable sources, above all firewood; and the firewood consists of more than just dead wood - green branches from trees and whole bushes are often included. The same is true of Kenya (cf. table 6). In the Sudan, more than 98% of all household energy comes from biomass. In the country's urban areas, charcoal is the predominant household energy vehicle. In appraising a solar cooker project, it is of decisive importance to know which source of household energy predominates: firewood, charcoal, petroleum, electricity, etc. - and what the prerequisites for and consequences of their use or nonuse may be.

Table 6: Energy consumption in Kenya according to sectors and energy vehicles (1980) /18/

	Firewood	**Charcoal**	**Residue**	**Petroleum products**	**Elektricity**	**Total**
	64%	**6%**	**3%**	**25%**	**1%**	**100%**
Urban households	2	58	--	4	19	6
Rural households	72	26	100	4	--	52
Agriculture	--	--	--	8	13	2
Industry	25	15	--	24	38	24

Trade	1	2	--	1	28	1
Transportation	--	--	--	58	2	14
	100	100	100	100	100	100

Energy consumption by the poor: The poor majority of the people in developing countries cover most of their energy requirement in a non-commercial (subsistence) way, using traditional, locally available sources of energy and their own physical labor. They simply cannot afford to buy any appreciable amounts of commercial energy. The use of firewood is often identical with poverty; depending on the country in question, the middle classes are more likely to use charcoal, while the upper classes have access to gas, electricity and kerosene (cf. table 8). Moreover, energy consumption out in the country and among the poor is characterized by lower efficiency than in town. It is interesting to note that biomass consumption in rural Pakistan does not drop off as family income increases, but instead increases (or, in towns, remains the same). The logical consequence is a relative shortage of fuel for use by the poor, whose living conditions deteriorate even more as a result. Solar cooker projects could at least try to compensate.

Procuring energy for cooking: As long as there is an ample supply of dead wood in the near vicinity, solar cookers will have little chance of acceptance, especially since the task of collecting firewood often has a social function in that it provides an opportunity for communication. Depending on the indigenous system of values, gathering firewood is seen as a job for women, e.g. in Mali, or for men, e.g. among Afghan refugees in Pakistan, or even for the older children, e.g. in Pakistan. In some Islamic societies, men are responsible for gathering wood, while in others - like in Central Sudan - 61% of the women, 57% of the children and 48% of the men participate as long as wood is available within a reasonable distance; otherwise, charcoal is given preference. In India, it is a question of caste and region as to whether women or men should gather the wood: in the lower castes, it is the women who are mostly responsible for gathering wood. Such arrangements are not without impact on the social acceptance of alternative sources of energy, e.g. solar energy, in cases where traditional fuels have become scarce, thus costing more time to collect them or more money to buy them. Another factor that should not be overlooked is that many of the poorest people gather and sell wood as their only source of income and solar cooking projects are perceived as a relevant threat.

Table 7: Energy consumption indicators for the Sudan /109/

	Eastern Sudan		**Southern Sudan**		**Gezira**
	rural	**urban**	**rural**	**urban**	**rural**
	%	**%**	**%**	**%**	**%**
Energy vehicle					
firewood	97	81	100	76	65
charcoal	73	96	11	82	92
agric. residue	43	--	--	35	86
kerosene	32	73	--	68	12
diesel	66	35	33	27	8
electricity	1	42	--	23	8
dung	15	--	--	--	47

vegetable oil	--	--	--	--	41
Procurement of wood					
buying	58	69	--	52	18
gathering	38	12	100	18	33
Energy consumption (kg/d per capita)					
wood	1,0	0,64	3,6	1,2	0,86
charcoal	0,45	0,36	0,18	0,32	0,45
Wood gatherers					
men	63	100	11	17	48
women	28	100	89	67	61
children	35	100	--	17	57
Time spent gathering wood					
short	40	100	56	67	57
less than ½ day	28	--	44	33	17
½ day	33	--	--	--	4
more than ½ day	--	--	--	--	17
Wood needed for					
cooking	77	14	100	68	78
other uses	23	86	--	32	22
Procurement of charcoal					
buying	73	96	11	82	88
producing	--	--	--	--	4
not used	27	4	89	18	8
Charcoal	needed	for			
cooking	88	100	--	98	87
brewing tea and coffee	95	100	100	96	84
ironing	79	100	100	10	91
other uses	4	12	--	17	9
Agricultural residue needed for					
cooking	13	--	--	--	64
other uses	29	--	--	35	--
not used	58	100	100	65	36
Kerosene	needed	for			
cooking	8	42	--	13	--
illumination	100	100	--	100	73
Lighting fires	58	42	--	16	27
Electricity	needed	for			
cooking	--	--	--	13	--

illumination	100	100	--	73	100
other uses	--	--	--	17	--

Table 8: Household energy consumption in Kenya for different income classes (1980) /18/

Group	Income (KSh p.a.)	Households (millions)	Firewood	Charcoal	Kerosene	Electricity
			(GJ x 10^6)			
1	0-3,100	.09	1.7	0.9	0.0	0.0
2	3,100-9,100	.16	1.3	3.2	0.9	0.0
3	9,100-18,200	.17	1.0	4.5	1.0	0.0
4	18,200-54,600	.11	0.3	2.8	0.6	0.3
5	54,600-	.05	0.0	0.7	0.5	0.6
Totals		.58	4.3	12.1	3.0	0.9

Cooking-energy quantities: The daily fuel requirement varies according to the kind of food being cooked and the number of warm meals. In the typical LLDC, each native burns one ton of firewood each year.

- In India, the average family needs somewhere between 3 and 7 kg of wood per day; in the cooler regions, the daily firewood demand varies between just under 20 kg in the winter and 14 kg in the summer.

- The nomads in northern Kenya use 70% less firewood during the rainy season, when milk is their staple food item, as compared to maximum wood consumption during the dry season, when mostly meat is eaten.

- In the southern part of Mali, the main dishes (corn, rice, millet) and the way they are prepared make for a higher level of firewood consumption than in the northern part of the country, where fish and roasted meat/fish are the staple items. The average 15-member (!) family burns about 15 kg of wood each day.

- A survey conducted in an Afghan refugee camp in Pakistan showed a daily firewood demand of 7 kg per family, but a different survey put the demand at 9...10 kg per family and day. More than half of the wood used in the average household goes for baking, and the remainder is used for cooking. Additional wood is needed for heating in the wintertime, of course.

- A family of five in the Sudan consumes roughly 2.5...3 kg of charcoal every day. According to the World Bank, the annual per capita firewood consumption rate ranges from 1.2 kg in towns to 2 kg per day in rural areas.

- Conclusions: The above examples indicate quite clearly that the required amounts of cooking energy are extremely variable; only painstaking local-scale investigations are able to pinpoint how much cooking energy can be saved by using solar cookers.

Using cooking energy: The example for Pakistan shows that differentiation should sometimes be made between fuel used for cooking - of special relevance to solar cooking - and fuel used for baking. In many places, namely, more energy is consumed for baking than for cooking. In the central region of the Sudan, 78% of all families used wood for cooking, and 87% (also) use charcoal.

Time expenditure for procuring cooking energy: The women in Mali reportedly spend about three hours every day gathering wood. Reports from Pakistan mention up to 15 hours per week, and between 10 and 20 hours per week are cited for an Afghan refugee camp in Pakistan. Rural families in India have to invest about six hours each day (1) for gathering wood. In the Sudan, the amount of time needed for gathering wood is steadily increasing, so that wood is gradually becoming something of a nondurable consumer item for poor people, too, which puts it in competition with charcoal, the latter being easier to haul. The potential time savings offered by solar cookers appear substantial.

Cost of cooking energy: Table 9 shows the retail cost of various cooking energy vehicles in certain African countries. The prices are seen to differ widely, depending on the country, the prevailing energy policy and the individual region. It is also a question of which energy vehicles are subsidized to which extent, e.g. kerosene, which enjoys a 30% subsidy in Pakistan's Orangi Project. Here, the average expenditure for fuel comes to about 25% of a family's monthly income. In Bamako, Mali, the average family spends between 15% and 20% of its earnings on fuel, i.e. wood and charcoal. In Pakistan, the cost of firewood has stayed in step with the consumer price index (c.p.i.) during the 1970s, but has pulled ahead considerably during the '80s. In the Sudan, firewood and kerosene prices stayed well below the c.p.i. between 1975 and 1984, while the cost of firewood has increased sevenfold (with wild gyrations) in the course of the past 8 years. Many families in Khartoum spend anywhere from 20% to 30% of their household income on energy. If cooking energy keeps getting more scarce and accordingly more expensive in India, the traditional noncommercial sources of energy will soon be more expensive than food. Anyone in the situation of having to buy cooking energy stands to profit solar cookers.

Table 9: Retail cost of various energy vehicles for household cooking in urban areas of several African countries /51/

	Ethiopia[1]	**Burkina Faso**[2]	**The Gambia**[3]	**Kenya**[4]	**The Niger**[5]	**Senegal**[6]	**Uganda**[7]
Wood ($/kg)	0,077	0,095	0,137	0,018	0,058	0,061	0,034
Charcoal ($/kg)	0,545	0,237	---	0,092	0,145	0,152	0,109
Kerosene ($/1)	0,564	0,488	0,544	0,348	0,401	0,424	0,400
LPG ($/k9)	0,603	1,007	1,048	0,627	0,954	0,092	0,700
Elektricity ($/kWh)	0,072	0,261	0,193	0,064	0,170	0,240	0,006

[1] UNDP/World Bank, Ethiopia; Issues and Options in the Energy Sector; May 1984
[2] Document de l'Institut Voltaique de l'Energie; 1983. Lepeleire et el.; Project CILSS - Foyers Ameliores - Elements d'Evaluation - Suggestions; 1984
[3] UNDP/World Bank; The Gambia: Issues and Options in the Energy Sector; November 1983
[4] IPC; Charcoal Production and Research Activities within the Special Energy Programme

Kenya; June 1984
[5] UNDP/World Bank; Niger: Issues and Options in the Energy Sector; May 1984
[6] UNDP/World Bank; Senegal: Issues and Options in the Energy Sector; July 1983
[7] UNDP/World Bank; Uganda: Issues and Options in the Energy Sector; July 1983

Firewood: The prime function of solar cookers is to help reduce firewood consumption, since most cooking fires are still fueled with firewood. The trouble is, firewood is usually quite inexpensive in comparison with kerosene, bottled gas or electricity (based on relative energy content).Increasing, uncontrolled felling of wood for people's own use and for selling are a main cause of deforestation, desertification, erosion, receding groundwater levels, ... - in short: it has long-term adverse effects on the ecological balance. Pakistan's meager forest heritage and rampant deforestation in Kenya show that such fears are well-founded. If denudation of the Sudan's forests continues at the present rate, they will be gone by the year 2005. As of this writing, 70% more wood than allowed was being felled. Massive diffusion of solar cookers could have positive effects.

Energy policies: National energy policies in Third World countries with little or no oil resources are usually based on the substitution of oil and/or natural gas, possibly in combination with hydropower, because expensive energy imports have a devastating effect on such countries' trade balances. The quest for ways to save energy by using it more efficiently and by developing alternative sources of energy, e.g. solar energy, or by boosting the available manpower (the main source of energy in poor societies) through more and better food, health care and education is given less priority, even if it is mentioned in some development plans, in which case the plans may be regarded as exemplary from the development-political standpoint. On the whole, solar cooker projects could, at best' contribute little toward a national energy policy. But they could make a very substantial contribution toward improving the living conditions of the poor and helping them overcome their own energy crisis - if they were accepted.

3.4 Social Situation

Decisions for or against solar cookers are predisposed by the social situation, living conditions and customs of the native populace.

Poverty: If the "poor" majority of the Third World's people is the target group, then solar cooker projects must be first and foremost to the benefit of the rural population. In India, Kenya, Mali and the Sudan, about four out of five people live in rural areas - usually with more than half of them at or below the poverty line - as farm workers, tenant farmers, subsistence farmers, craftsmen,
(itinerant) traders, often enough within the subsistence economy. More than 80% of all arable land in Mali and the Sudan is used for subsistence farming. The low, unstable - and in the Sudan even sinking purchasing power of the rural population is an important boundary condition for the introduction of solar cookers.

Population groups: The conditions for introducing solar cookers may be more advantageous for some population groups than for others. Urban middle-class families with modest savings, for example, are more likely to have an open attitude toward experiments. On the other hand, solar-cooker dissemination efforts require the aid of certain groups, e.g. women's groups, artisans' groups or other groups in influential positions, like ethnic leaders (maliks) and religious authorities (mullahs) in Pakistan. For a solar cooker project to reach its target group, it can hardly do without such intermediary target groups, who then proceed to pass the idea on to the intended users. However, it is not always easy to choose the "right" intermediary target group - consider, for example, the caste system in India, where the wrong choice could do more harm than good to a dissemination program.

Systems of values: When a patriarchal social order allows only men to make important decisions, or when religious norms like the observance of Ramadan call for strict fasting from dawn to dusk, this can have substantial effects on the usefulness of solar cookers. In polygamous Mali households (about 30%), each wife has her own hearth and "pantry" within the estate, even though they all take turns cooking. In Kenya, too, each wife in a polygamous household has her own separate hearth. In the Sudan, the adult women in large rural families take turns cooking. Such cultural and socio-structural aspects are of great significance in connection with the introduction of solar cookers.

The woman's role: Despite similar systems of values, the woman's role can differ decidedly from one region to another within a given country.

- Mali: About 65$ of the Mali population are Muslims; despite the Islamic influence, however, women have managed to maintain some degree of economic independence. Since men and women have separate spheres of everyday life and work, each has his/her own separate responsibilities and source of income. While the men derive most of their income from selling agricultural produce, the women are responsible for growing/procuring the family's food, with the notable exception of grain. Basically, the actual economic and social role of Mali women depends on their ethnic affiliation and main source of income, e.g. from farming or stock breeding.

- Kenya: Kenyan women also play a leading role in their country's development process - probably thanks to their gardening/farming activities and related income.

- Pakistan: Women's activities in Pakistan are confined mostly to the household. Also in the Afghan refugee camps, Islam exerts a substantial influence on everyday life and on the social order. Social life is strictly patriarchal and completely excludes women from all public activity. It would be just as impossible for them to participate in a public solar cookers demonstration or other event as it would be for them to engage in household activities outside of the courtyard area: fetching water or wood, shopping for groceries, etc.

- The Sudan: Sinking real income in the Sudan has led to closer integration of women into working life.

- Conclusions: A woman's role - especially her voice in family affairs, use of income, etc. - has a substantial effect on the introduction and use of solar cookers; consequently, the actual effects of dissemination campaigns and related educational programs cannot help but vary accordingly.

3.5 Dietary Patterns

Solar cooker projects can hardly be expected to change people's dietary patterns, but they must at least be suitable for use in cooking most of the main dishes.

Staple foods: The staple foods of a population can differ quite substantially, depending on the country, region, local traditions, crop harvests, availability, season of the years, etc. No solar cooker project should be implemented without a good working knowledge of the prevailing staple foods. Five examples:

- India: Rice and wheat are the two staple foods. Most rice is cultivated in the southern part of the country, and most of the wheat is grown in the North. Legumes, chick peas (grams) and various vegetables are also eaten. Meat plays a subordinate role. In the poorer households, millet (panic grass) is eaten in place of rice and wheat. Eggs, milk and other cereal products are eaten more in well-to-do households than among the poor.

- Kenya: The principal food in Kenya is corn (maize), followed by beans, various leafy vegetables and tubers. In some areas, goat meat and poulty, potatoes and eggs, cooking bananas and various vegetables are eaten when available. The Nomads in northern Kenya live on milk, meat, corn meal and little else. They eat mostly meat during the dry season and milk (products) during and for a while after the rainy season. Due to lack of infrastructure, corn is not always available. Corn consumption is concentrated mostly in the interseasonal months when lactation has not yet begun, but the consumption of meat already has to be reduced.

- Mali: Millet, corn and rice are the principal foods in Mali. To the extent available, and depending on their ethnic background, people also eat vegetables, meat, fish and cabbage, the latter seldom. In southern Mali, millet and rice are preferred, along with peanuts, ocra, sweet potatoes and fish. The leaves of the fiber plant hibiscus cannabis are widely used in preparing sauces. A fat traditionally extracted from the fruit of the shea butter tree is used as cooking oil. In the central area, squash, tomatoes, sweet potatoes, rice and onions are very popular. The Nomads in northern
Mali live chiefly on milk products, meat and fish.

- Pakistan: In this country, the two staple foods are rice and wheat. Lentils, beans, various vegetables, herbs, and meat are prepared together in stew fashion. While fish is an important source of nutrition for people living in Karachi and other coastal areas - particularly on the "meatless' days prescribed by the government - many people in the mountainous regions live almost exclusively on fruit, vegetables and grain. Families with above-average incomes also consume eggs, salad, fruit and wheat products. Afghan refugees in northern Pakistan have bread, vegetables, meat, and tea as their primary foods /184/.

- The Sudan: The staple food is durra (primarily sorghum plus some millet), in addition to tomatoes, broad beans, potatoes' lentils and vegetables, usually in the form of stew, which may also contain mutton and goat's meat. Due to sinking income, a bean dish called foul is gradually disappearing from poor people's menus.

- Conclusions: People have to be able to cook their staple foods in solar cookers. As long as the staple foods are rice, cereal, grain, noodles, vegetables, potatoes and mixed dishes, e.g. stews, solar cookers can serve well, though care must be taken to differentiate between the various types. A low-temperature cooking box, for example' may be just right for social groups whose main foods are rice and vegetables, but it would not be of much help when the cook needs temperatures hot enough to simmer cooking oil or to bake crispy bread. The utility value of a particular solar cooker is more or less limited by the relative importance of cooking, boiling, steaming, roasting, baking or grilling.

Meals: The most important thing is that the main dishes with the staple foods can be prepared using solar cookers. To judge this properly, one must give due consideration to the people's morning, noon and evening eating habits, i.e. to the time of day when the main meal is taken:

- Breakfast: In rural communities, breakfast may well be more important than the midday meal (lunch). In India, to the extent that breakfast is not eaten cold - and this is where solar cookers come in - it may consist of chapatis (a pancake-shaped unleavened bread, usually made of wheat flour and baked on a griddle, and which is common in northern India) milk or milk products, and sometimes tea. A typical breakfast in Mali consists of millet gruel with milk and sugar and salt. Bread (naan) left over from the day before with tea and milk is the basic breakfast in Afghan refugee camps in Pakistan. Urban families in Pakistan often have fried eggs for breakfast. Pakistanis of Indian descent often supplement their breakfast tea and chapatis with a boiled stew consisting of vegetables, potatoes and meat. In Kenya, breakfast consists of tea with milk and sugar and a thin mush cooked in milk or water. As in all other countries, there are important differences between various social groups: The Nomads of northern Kenya eat a soup of milk, corn meal and sugar (uji) and drink tea with milk. In the Sudan, a typical breakfast consists of millet gruel, vegetables or warmed-up foul, a fresh batch of which is prepared twice a week. Tea with milk is normally drunk for breakfast. Bread is sometimes eaten as a side dish. Well-to-do families add tomatoes, vegetables, eggs, cheese or liver, while poor families make do with millet, milk and an occasional piece of jerky. The useful effect of solar cookers depends a lot on the importance of fresh-baked bread at breakfast time.

- Lunch/supper: The noonday meal often differs only insignificantly from the evening meal. That being the case, the expediency of using a solar cooker when the sun is at its highest has both advantages and disadvantages. Many poor people eat little or nothing for lunch, saving what they have for supper. In Pakistan, for example, most people eat a modest lunch consisting of a vegetable stew, meat with chapatis and/or rice. Pakistani families of Indian descent often content themselves with a snack of breakfast leftovers. Some farmers and farm workers take "lunch boxes" to the fields. Frequently, though, farm hands buy their lunch from the landowner - at exorbitant prices. Mulach, a stew consisting of meat, onions, vegetables, garlic and oil, is often eaten for lunch in the Sudan; kisra, a kind of sorghum bread, is eaten with the stew. Many poor people have only tea and milk for supper, but others eat the same dishes as for lunch. Such diverse conditions naturally have an impact on the use of solar cookers.

- Main meal: Knowledge of what is required to prepare the main meal - or the "national dishes" - is of special importance, since solar cookers will be expected to have what it takes in that connection. If the dish in question is boiled, e.g. foul, a bean dish popular in the Sudan, or dal, an Indian dish based on legumes, then solar cookers are just what is needed; the same applies to kitheri, a stew consisting of beans, tomatoes, cooking bananas and squash that is popular in Kenya, and to khichadi, an India stew made up of rice and legumes. Obviously, it would be impossible to assess the acceptance of solar cookers without knowing how the staple dishes are cooked.

Cooking staple dishes: The preparation of main dishes differs according to local tradition and the type of cooking facilities used. Additionally, the cooking temperatures and manner of cooking
(boiling, roasting, baking, grilling) also differ from case to case. Some examples:

- Mali: Tot is prepared by putting a thick flummery in roughly three lifers of boiling water and stirring steadily to obtain a firm mass. The stiffness can be increased by adding powdered baobab leaves. Couscous, by comparison, is a more complicated dish to prepare: a coarse-grained, dry noodle substance made of corn or durum wheat (semulina) is put in a perforated bowl and allowed to swell and cook in the low steam heat over a pot of simmering water. Once in a while, it has to be loosened up by hand. In some places, the semulina is cooked directly in boiling water until finished. Rice is prepared like couscous or in boiling water. The sauces are made by searing vegetables and meat in hot cooking oil, quenching with water and then cooking until finished. It takes about 60 minutes to cook tot and sauce and between 80 and 90 minutes to prepare couscous. In northern Mali, meat and fish dishes are roasted, fried or smoked.

- The Sudan: The bean dish foul is easy to make, because the beans need only be cooked slowly without stirring. Mulach, by contrast, is more complicated in that the onions are first seared in hot oil, after which meat, salt and water are added and left to boil; after a while, vegetables, tomatoes or alimentary paste are added, after which frequent stirring is necessary. Aseeda, a millet pudding, also has to be stirred frequently. Sudanese "pancakes" (kisra), made of fermented millet powder, are usually cooked on a griddle-like sheet of metal.

- Kenya: Ugali is prepared by placing coarsely ground corn meal in boiling water and stirring vigorously for a few minutes. By comparison, it takes up to three hours to cook kitheri stew. The ingredients for a meal are frequently cooked in succession, with the finished ones kept warm by placing them on top of the hot pot.

- India: The unleavened bread chapati is baked on a griddle or in a skillet over a hot fire for several minutes and then roasted briefly in the open flame.

- Pakistan: The stew (vegetables + meat), as well as the rice, is stirred steadily. Indian families use a lot of fat for cooking. All ingredients (except the rice) are first fried briefly in cooking fat and then boiled in water. Baratta is prepared on a very thin sheet of metal called a tawa. The dough is baked ahead of time and then fried in lots of fat. Chapatis are either also prepared on a tawa or baked in a tandoor (a built-in adobe oven). The dough is slapped onto the inside of the very hot oven from the top and turned after a minute or two. Some families in one compound have communal tandoors in which several families can bake their chapatis together. In the larger towns, however, people often buy their chapatis in bakeries.

- China: The staple foods require boiling, steaming, roasting, etc. for preparation. This means that high temperatures and high thermal power are necessary. These requirements are easily met by reflector cookers, while in this case cooking boxes do not perform satisfactorily.

- Conclusions: The above examples clearly show how solar cookers have to "adapt" to how the main dishes are traditionally prepared. Consequently, most people tend to use a solar cooker for just a few of the more appropriate dishes. Indian ATRC cooking boxes, for example, are used mostly for cooking rice, legumes and vegetables; in the relevant Project, among the users, 20% make use of their solar cooker only for certain dishes, and 60% use it only for one meal a day.

Bread: Most solar cookers are of little use in areas where baked bread is the main staple. While solar cooking boxes will bake breed, at least in principle, they cannot produce a crispy crust.
Afghan refugees in Pakistan, for example, eat large amounts of nan (unleavened bread made of wheat flour) practically for every meal. According to a 1983 survey of 498 households, the average family consumes 20 loaves of unleavened bread per day. Half of the women interviewed said they bake twice a day, and one in five bakes a full day's supply at once. Most nan is baked in traditional tandoors. Past attempts to replace wood with other

kinds of oven fuel, e.g. briquettes or rice hulls, failed due to slight discoloration of the bread. Unleavened bread has to be baked at a very high temperature and requires heat distribution on relatively large surfaces; the cost of the technical necessities would very probably surpass the low solar-cooker price limit for poor social groups. On the other hand, some baked goods turn out especially good in solar cookers, as substantiated by reports from the Sudan.

Side dishes: In some countries, Mali for instance, the usefulness of solar cookers seems to be restricted to the preparation of entremets and sauces/gravies, as opposed to main dishes. That is surely an impediment to their acceptance. Solar cookers really should be well-suited - or even better-suited than traditional means - for cooking at least certain kinds of food, or people won't try them in the first place.

Taste: Indian housewives contend that unleavened bread loses its typical flavor if baked in a solar cooker. Indeed, they say, other dishes also come out tasting different if they are cooked in, say, an ATRC cooker. Under such circumstances, solar cookers can hardly be expected to find acceptance. The extent to which the taste of Sudanese food is altered by cooking in a solar cooker is a point of controversy.

Beverages: At first glance, solar cookers appear to be just the thing for preparing beverages, above all tea. In some cultures, however, the men like to spend lots of time preparing and drinking tea around an open fire - in the shade. In Mali, where the practice has taken on a nearly ritual character, this has had a definite limiting effect on the use of solar cookers. The same is true in the Sudan, where the low efficiency of the most commonly used type of solar cooker makes it unsuitable for brewing tea quickly - and tea is taken with all meals as well as at dawn and dusk.

3.6 Eating Habits

In evaluating the usefulness of solar cookers, one should keep in mind that not only what people eat is important, but also how and when they eat it.

Mealtimes: Just when meals are cooked and eaten is more or less inflexibly dependent on the family's workaday routine.

- Breakfast: Since most of the rural population is accustomed to working "from sunup to sundown"", they eat breakfast at about dawn, i.e. around 6:00 or 7:00 a.m., possibly as late as 8:00 a.m. The earlier the breakfast, the less useful the solar cooker, since solar radiation is still rather weak early in the morning. This can be especially problematic during Ramadan, when breakfast has to be eaten before the sun comes up. Most families in India forego an early breakfast in favor of brunch, thus saving the midday meal. Late breakfast between 9:00 and 10:00 a.m. is also customary in the Sudan. Due attention should be paid to such particularities, which can greatly enhance the utility value of solar cookers for breakfast.

- Lunch: As a rule, lunch is eaten sometime between 1:00 and 2:00 p.m., sometimes as early as noon. Here, too, there are some major exceptions to the rule, depending on the social group in question and their daily routine. In some parts of India, people eat lunch (brunch) around 10...11 o'clock in the morning, while the Sudanese tend more toward 2...4 in the afternoon. Afghan refugees in Northern Pakistan prepare the main meal of the day between noon and 1 o'clock. But for evaluating the usefulness of solar cookers, breakfast and supper are more important than lunch with regard to timing.

- Supper: In practically all developing countries, supper-time has to wait until the workers have come home from the fields. In India, Mali and the Sudan, supper is often served as late ' as 9:00 in the evening.

- Conclusions: The traditional mealtimes cannot be altered for the sake of solar cooking, because they are firmly embedded in long-standing rhythms of living and working. It is therefore, not surprising that 60% of those participating in one Indian solar cooker project cooked only a single "solar" meal per day. If, however, the solar cooker is a heat-accumulating type that collects solar energy independently of when the heat will be needed, then it doesn't much matter when meals are eaten.

Common meals: Since different members of the family have different work to do - housework, fieldwork, paid labor, going to market, attending school, ... - supper is often the only common meal of the day. Communal meals - with or without neighbors - are only possible on weekends and holidays in some places, like in Kenya where a shortage of arable land forces many men to take jobs in town or on distant plantations, while the women stay home and tend the fields. Lunch is often warmed up for the children when they come home from school in the late afternoon. All in all, the number of dishes prepared in the course of a day can vary widely, depending on the momentary situation. In Kenya, most meals are cooked for 6 to 10 people; in Pakistan and the Sudan between l0 and 15 people eat together in rural areas, but only 6 to 8 in town; Indian women cook for anywhere from 5 to 15 people. Such guideline values can fluctuate considerably, depending on the ethnic group religion, time of day and day of week. If at all possible, a solar cooker should have enough capacity to serve a good number of people at once, not just the average family.

Eating sequence: In some strictly Islamic societies, e.g. in the Sudan, the man, as head of the family, has the privilege of eating first - served by his wives' daughters and daughters-in law; then come pregnant and nursing women and children, then the other women, and finally the adolescents. In case of famine, this can lead to undernourishment, particularly among female adolescents and women in general. In some places, the men are served by women, while in others the men will only accept male servants and the women eat somewhere else, i.e. not in the man's presence. The fact that meals often have to be cooked "in shifts" instead of for the whole family at once must be given due consideration in connection with solar cookers.

3.7 Cooking Habits

How the food is cooked, i.e.-how heat is applied via a liquid (water, fat) or air (baking or grilling), influences the appropriateness of solar cookers in the Third World. For women, who are nearly always responsible for cooking, often assisted but rarely displaced - by their eldest daughters, the value of a solar cooker depends on how well it accommodates conventional cooking habits while saving a considerable amount of work.

Accessibility: Many dishes require frequent stirring. It must be easy to add more ingredients while the food is cooking. Tasting/seasoning must also be possible, of course. With some types of solar cookers, though, it is not possible to get at the food without having it cool off too much. For example, it is usually not possible to stir food in a box-type solar cooker - the pot has to be taken out of the cooker for stirring. That naturally has an adverse effect on acceptance, despite the time-saving advantage of cooking boxes, namely that the food can be left to cook by itself with no stirring necessary. In fact, those advantages are not always realized. According to reports from Pakistan, it was very difficult to convince women of the fact that the food in a solar cooking box need not be stirred continuously. The women involved in Pakistan's Orangi Project criticized the fact that the food cannot be taken out of the box until it is finished - mainly because the customary main dishes, if prepared according to conventional methods, require several successive cooking operations.

Cooking time: It takes up to three hours to prepare dishes like kitheri and mulach (staple foods in Kenya and the Sudan, respectively). When different members of the family eat at different times, the stove may be in service anywhere from 6 to 8 hours a day. In the event of delays due to moderate temperatures caused by low thermal output, high heat losses, or low irradiance
(glass cover, dusty reflectors, cloudy day), cooking can take much longer than usual. That naturally retards acceptance, e.g. in the case of the Sudanese solar cooking box. In other words, fast cooking is a very important acceptance criterion.

Interruptions: Some solar cookers make it very difficult, if not impossible, to interrupt cooking in the course of complicated meals, because it is hard to get the pots out of the cooker, or thermal losses would be too high. That, too, has a bearing on acceptance.

Attendance: With some types of equipment, e.g. solar cooking boxes, the cook cannot tell when the food is finished. Opening the box would waste a lot of heat - and time. But when clouds, haze and shadows retard the cooking process more or less erratically, this can be a real problem. On the other hand, solar cooking boxes do not require attendance. The advantage is that the cook can go do something else like work the fields, tend the garden, prepare other kinds of food, wash the dishes, nurse a baby, ... But that only comes to bear when women are actually able to take advantage of it, i.e. when cooking the meal does not involve too many intermeshed processes.

Cooking processes: Overlapping cooking processes are necessary for many staple dishes. In Pakistan and the Sudan, some kinds of food are first fried and then cooked under constant stirring. When using a solar cooking box, this is impossible, but it works with a reflector cooker. Conversely, of course, food that can be cooked in a single step e.g. without having to be fried first, can easily be prepared in cooking boxes. Meals that are cooked in several pots at once instead of in succession are also good in that sense.

Size of morsels: For the acceptance of solar cookers, food that has been cut up into small pieces is better than food that is cooked in large chunks.

Warming: Some dishes have to be kept warm for a certain length of time, either until the other dishes are ready (a cooking box will do the job) or until evening (in which case a heat-accumulating solar cooker or a non-solar insulated "hot box" may be necessary). Reflector cookers can do neither.

Burning: One of the foremost advantages of some solar cookers, especially of box-type solar cookers, is that they won't overcook or burn the food. On the other hand, that advantage is gained at the cost of lower temperatures and longer cooking times.

Baking: Some devices, like the Tube Solar Oven, are equally well suited for cooking and baking. Depending on the prevailing dietary patterns, that can be of special advantage as long as solar baking has no adverse effect on taste and when the customary food preparation processes involve both cooking and baking. In solar cooking boxes, baking is possible, too. But the low temperatures don't allow the generation of a crispy crust.

3.8 Use of Stoves, Fireplaces and Hearths

Over the centuries, stoves have become accommodated to the eating and cooking habits of their users - and vice versa. For solar cookers, there is no getting around a comparison with traditional stoves.

Types of stoves: The most common type of "stove" is an open fire, sometimes supplemented by other cooking facilites. Some examples:

- Kenya: Kenyan stoves are appropriate to the climatic, economic and cultural situation. Most women do their cooking over a three-stone fire like the one shown in figure 16. Those who can afford one use a little round wood/charcoalfueled sheetmetal stove called a jiko. Some Nomads build little baked-clay (adobe) walls around an open fire, and others cook in a kind of adobe pit. For Nomads and for market women, mobility is a prime criterion for a hearth/stove. In areas with pronounced seasonal changes in temperature, mobile stoves are also prefered, since they enable cooking indoors or outdoors, as desired. In cool weather, the hearth also serves as a heater. Many families also use it as a source of light, making it the centerpoint of social life.

- Pakistan: The cooking facilities used by Pakistani families also differ according to region and family income. Most rural housewives cook their meals on one or more chimneyless adobe stoves. In families with adequate income, the women cook on a gas- or kerosene-fueled metal stove. Practically every rural Pakistani family has its own oven for baking, in contrast to Indian families, who frequently bake their bread on top of the adobe stove. The oven also serves to keep the food or tea water warm for extended periods. At higher elevations and in other relatively cool areas, the hearth also serves as a source of heat, but rarely as a source of light or as a family meeting place. Afghan refugees in Pakistan cook on an open three-stone hearth (indoors in winter and outdoors in summer) or on a self-constructed horseshoe-shaped adobe stove. Some families also have a metal stove or kerosene cooker. Most refugees are given a free kerosene cooker. Unfortunately, the cookers in question are of poor quality, smoky and bad for the taste of the food. Consequently, some families hardly use their cooker at all, or even buy a better one at the market. Women use the cookers mainly for boiling water for tea and for preparing light dishes, e.g. vegetables.

- India: A small chimneyless earthen or brick stove called a chulha is the customary cooking device among Indian women. A given family can have either several earthen stoves for one pot each or one big chulha for several pots at once. Small, charcoal-fueled metal stoves that double as space heaters are also used in cooler regions.

- Mali: Most Malian women cook on three-stone hearths. Additionally, there are various types of earthen stoves for one or more pots, plus various metal/cast-iron cookers. The women often use several cookers at once if necessary. Nearly all Malian hearths are portable and can therefore be used indoors or outdoors, depending on the weather and lighting conditions. In hot areas, the women prefer to cook indoors to avoid the high outdoor temperatures. In cooler areas, the hearth also serves as a space heater. In the evening hours, the open fire becomes an important source of light and a meeting place for family members and neighbours.

- The Sudan: Three-stone hearths are customary in rural areas. They are often accompanied by tin stoves for charcoal. Also customary are baking tins over a wood fire (cf. Fig. 17). As a rule, a family has several different lightweight hearths.

Side effects: The main lesson to be drawn from the above examples is that traditional hearths can be quite versatile and have some positive side effects, e.g.:

- versatility: traditional hearths are more than just means of cooking food; they also provide heat and light;
- side effects: preservation of food by smoke from an open fire increases storability and, hence, makes for a safer supply of food; the smoke also drives away insects;
- communication center: in many societies, hearths have an important social function in that they serve as centers of communication, especially in the evening;
- conclusions: solar cookers have to compete with those merits. The extent to which they can or cannot compete depends on criteria like the following:

Size of hearth: Sometimes, setting up and operating a solar cooker takes a considerable amount of (extra) space that is not always available, especially in densely populated urban quarters. Some solar cookers - especially reflector cookers are quite voluminous and require an accordingly large area.

Setting up: While some solar cookers are installed for stationary operation, others have to be set up anew every morning. Many Indian families that own an ATRC cooker, for example, complain that it is too heavy to be carried in and out of the house every time it is needed for cooking. The solar cooker project that was carried out among Afghan refugees showed that many would simply use their traditional hearths if no one was around to help carry out the box in the morning. Many devices are just plain too heavy for women. Others, like the one used in the North Horr, Kenya Project - are too bulky for easy transportation. Mobility is particularly important for some socia1 groups: polygamous women, market women, field workers. Accordingly, solar cookers must satisfy quite stringent demands with regard to mobility.

Stability: Sometimes, mobility conflicts with the stability that is needed for, say, stirring the food, keeping the cooker from being knocked over by children or domestic animals, etc.

Cooking height: Coming home from a long, hard day out in the fields, women in the Third World prefer to sit down or squat for cooking. Some solar cookers, however, can only be operated standing up; in some cookers, the pot is suspended at shoulder level. That, too, impairs their social acceptance.

Location: Women customarily do their indoors cooking in a walled-off cooking area or in a separate room or hut. For some Nomads in northern Kenya, it is strictly taboo to cook or eat outdoors. According to one adage, "only hyenas eat outdoors". But it lies in the nature of (most) solar cookers that they be used outdoors, no matter how disdainful that may be in Kenya. It is also frowned upon in India, not only because a stove standing outside is easier to steal, but also because proper weather protection is hard to come by: the stationary IGDP-type cooker (Dhauladhar solar cooker) in India has to be covered with a tarpaulin and carefully serviced during the rainy season. Very few solar cookers, e.g. the cooking part of the Solar Hot Plate Cooker, can be used indoors.

Cooking in the shade: As a rule, the solar cooker has to stand out in the sunshine, while the woman doing the cooking normally would prefer to be either indoors or at least outside in the shade of a tree, where there is also room for chatting with other women and the children. A reflector cooker, however, is merciless: the woman is forced to stand out in the sun, because the cooker has to be kept properly adjusted, and the food has to be stirred periodically. Only few solar-cooking devices will allow the work in the shade, e.g. the heat-accumulating ISE solar cooker, the Solar Hot Plate Cooker, the Convective Solar Cooker, etc.

Cooking capacity: The question of how well the amount of food that can be cooked at once in a solar cooker, will meet the requirements of an average target-group family is an important criterion for acceptance. The aforementioned eating habits play an important role with respect to individual family members and social groups. Solar cookers in North Horr, Kenya, are too small for most rural families, because their cooking capacity is limited to three kilograms. Large families in India have the same problem with ATRC cookers. In many projects, the capacity of the cooker seems to be oriented more along the lines of a four-member urban family than for a typically large (10-15 people) rural family.

Loading capacity: Several vessels may have to be used at once, depending on the complexity of the individual dishes and how many steps of cooking are necessary to complete the meal. Using more than one big pot at a time is practically impossible with a reflector cooker. Considering the variety of dietary patterns, heating and eating and cooking habits and the number of people who may wish to eat together it is no wonder that solar cookers are widely regarded as too small. A good solar cooker should have adequate loading capacity in addition to some extra "holding space'' for pots, pans and dishes.

Type of vessel: Kenyan and Malian women use different sized pots made of clay or aluminum. Aluminum pots are also the rule in Pakistan. If solar cookers will accommodate the customary vessels - instead of only pots with particularly flat bottoms (as they are necessary for the Stoy/Pohlmann cooker), they will find a higher degree of acceptance.

Cleaning: Some solar cookers seem to be difficult to keep clean, e.g. after a pot has boiled over or spilled. For example, the Sobako cooker used in Kenya had to be partially dismantled for cleaning. Conversely, solar cookers that can be kept clean by wiping with a moist cloth are naturally more acceptable. Cleaning always comprises the danger of damaging the reflecting/absorbing surfaces. Here, too, solar cookers have to compete with conventional devices that are either easy to keep clean or rarely require cleaning.

Versatility: Box-type solar cookers and solar steam cookers are unsuitable for roasting and grilling and only conditionally suitable for baking. In fact, genuine versatility in the sense of being suitable for cooking, roasting, baking, frying, etc. is displayed by very few solar cookers - meaning that they are only capable of assuming certain limited functions in connection with the preparation of food.

Useful time: With the notable exception of the usually quite expensive and complicated heat-accumulating devices, solar cookers are only useful during certain hours of the day and seasons of the year, in addition to needing good weather.

Substitution of traditional cooking facilities: Many of the above considerations document the fact that solar cookers can rarely do more than supplement the existing cooking options, i.e. they cannot replace the traditional cooking facilities. Such was the case in India's solar cooker project in Gujarat. Traditional and solar-powered stoves/cookers are almost invariably used simultaneously, e.g. with the solar cooker serving to heat the food up, and the wood fire doing the rest of the cooking. As long as the traditional cooking facilities are also regarded as a source of heat an light, solar cookers can only be a supplement, never a substitute.

3.9 Solar Cooker Technology

Some of the more technical aspects of solar cookers constitute barriers to social acceptance. Some related problems that have occurred in past solar cooker projects are dealt with below.

Thermal output: The thermal output of a solar cooker includes all of the following:

- Efficiency: This is the ratio between the available heat and the incident energy, with the available heat being determined by heating a certain amount of water from a certain initial temperature up to the boiling point, and the incident energy being the measured global radiation times the aperture of the cooker for the same period of time (cf. section 2.2). In the case of heat-accumulating solar cookers, only the partial efficiency of the energy-accumulating components (collector and heat store without the cooking vessel) can be directly measured and therefore treated as a known quantity. There is an extensive lack of valid, comparable data on solar-cooker efficiency from methodically indubitable investigations. Consequently, the criteria applied here are more of a ''social" nature: a solar cooker should, within a reasonable length of time, cook the staple foods of the target group,

- Temperatures: Solar cooking boxes and solar steam cookers achieve only moderate temperatures and take accordingly long to cook meals. On the other hand/ the advanced-type reflector cooker for Mali reportedly develops excessively high temperatures;

- Temperature control: Most devices have no means of heat adjustment/control, though some - like most box cookers have an indirect temperature-control option by way of the box and reflector alignment relativ to the sun's position.

- Starting power: Reflector cookers and the Solar Hot Plate Cooker have good starting power, but most others count as fairly weak;
- Temperature profile: Uniform heating of the pot is not always possible, depending on focus position, thermal contact, etc. The temperatures measured in various parts of a Sudanese cooking box, for example, showed considerable variance. When one or more of the above aspects is given too little consideration at the design stage, the effect on acceptance can be devastating.

Durability: Solar cookers must be robust, sturdy and able to indefinitely withstand improper, if not to say grossly negligent, handling by the user and members of the family. The service life of a solar cooker must be much longer than its payback period.

Robustness: When one or the other part of a solar cooker has to be repaired due to minor damage, the whole cooker remains out of service until the part has been fixed. Usually, it is a broken mirror or pane of glass that impairs the cooker's serviceability. The fact that children, domestic animals and improper handling are quick to cause damage must be accounted for at the design stage.

Handling: Solar cookers that concentrate direct radiation at a focal spot require practice, a good grasp of the working principle/ and constant close attention to the job at hand namely handling and cooking. Some of the work involved consists of unaccustomed - sometimes even uncomfortable - manual exercises. Correct focusing of the incident radiation, continuous tracking of the sun, and working in and around the focal spot are among the "necessary evils". A solar cooker should not be evaluated on the basis of careful handling by trained personnel, but rather of somewhat careless handling by someone with less technical interest in the outcome. To put it more justly: by very busy people who have a lot of other things to worry about at the same time. Awkward, unaccustomed handling procedures - like extracting a hot, heavy pot - are an impediment to mass diffusion. In other words, ease of handling and convenient operation can decide whether or not an existing solar cooker will still be in use next month or next year.

Solar tracking: The need for solar tracking is one of the more tedious drawbacks of reflector cookers. Adjusting a Sobako 1 every 10 minutes is practically a full-time job all by itself. Depending on the situation, this necessity can be acceptable or unacceptable. The Sudanese solar cooking box has to be readjusted every hour or so. The rectangular shape of the ATRC, Serve, or Dhauladhar cookers makes solar tracking practically unnecessary. The need for constant, more or less complicated solar tracking is a major handicap for most reflector-type solar cookers.

Glare: Most people are irritated by the reflected sunlight in a reflector-type solar cooker. The Falco S/C scope of supply includes a pair of sunglasses. When stirring food or manipulating the cooking pot in the cooker's focal spot, one is exposed to blinding glare and possible injury by burning. That, too, is a substantial drawback of some reflector units. Some others, like the VIAX cooker, offer the possibility of easily turning the mirror out of focus for stirring and handling.

Danger of injury: Some solar cookers are still so primitive and inherently faulty constructed and/or finished (e.g. the Sudanese RERI Cooker), that they pose a real hazard to children who may be playing in the near vicinity.

Breakdowns: Some solar cookers, e.g. the Orangi Cooking Box, still require constant maintenance & repair work. That, of course, is not only detrimental in the long run, but also puts an unacceptable strain on the household budget of the average target-group family.

Manufacturing materials: If industrial components are used (panes of glass, aluminum foil, mirrors, special paints, plywood, ...) they will be hard to repair or replace with locally available materials. In India's Dhauladhar project, though, the brick & clay stoves were installed once and for all in the near vicinity of the user's house. The use of familiar materials like clay, which is also used for building houses, facilitates production of the cookers - at the cost of mobility. The more local materials used, the greater the probability of long-term acceptance. Traditional hearths and stoves are practically always made of exclusively local materials.

Design: Add to the above a simple design and a well-worded, uncomplicated set of building instructions, and solar cookers can be built at low cost by native craftsmen and in small workshops or factories; repairs can be taken care of quickly and inexpensively. The simple design of the cooker used in North Horr, Kenya, for example, has earned much applause. The same is true of the mechanics of the Falco S/C Cooker. Obviously, the easier it is for people to build their own solar cookers, the more likely they will be to accept them. Good craftsmanship is necessary, though. Traditional-type hearths and stoves are often made by unskilled workers wielding a knife and hammer. Solar cookers, even the most simple cooking boxes, can hardly compete with that.

Defects: Perfect functioning of solar cookers is a main prerequisite for successful introduction. Technical deficiencies and faulty designs detract from the devices' utility value and make the target group lose interest before the project ever gets out of the trial phase.

- Take, for example, the (extremely inappropriate) Sobako cooker in Kenya, where the technical problems consisted mainly of:

· inadequately secured heat-insulating panes around the oven
· the matching vessels' tendency to rust
· an oven that was 1 cm too short
· swelling and distortion of various components under the effects of heat and humidity
· uneven heating of the oven, and so on.

- A survey of 1572 households using ATRC cookers in Gujarat, India, revealed that the heat-absorbent paint used to coat the inside of the casing and the cooking vessels peeled off in 96 % of all cases. Additionally, 44 % of the users complained about steam collecting between the inner and outercovers. The safety spacer between the outer cover and the reflector came loose on 41 % of the cookers. About 23 % of the cookers had broken or cracked covers. An equal share of households criticized the faulty seal and resultant air permeability between the box and the cover. The mirror was broken or damaged in 13 % of the cookers. Indeed, only 1 % of the cookers were found to be in perfect working order.

- The cooker used in Mali proved to have a major defect in the form of untimely formation of bubbles between the polyethylene foil and the reflector, which reduced the cooker's heat output. While it was no problem to get rid of the bubbles by punching holes in them and pressing the foil down against the background, the users nonetheless considered this to be a substantial disadvantage.

- Of 13 test families in the Sudan, 11 filled out and returned the survey questionnaire. Seven of them criticized the cooker's slowness, 6 its lack of heat control, 5 the need to cook outdoors, 3 the lack of accessibility, 2 the awkward cooking procedure and 1 the danger of eye injury posed by the reflector. Just for good measure, there were also jammed covers, warped boards, projecting screws, and generally inferior workmanship. Consequently, major improvements are envisioned: modified reflector, improved cotton insulation, more appropriate sizing, simpler construction, properly closing cover, etc. Once the causes of complaint have been eliminated, another technical test phase will have to be gone through before market studies can be conducted.

- Conclusions: Poor people cannot be expected to accept so many serious defects. Solar cookers must be technically mature before they are used in a field test.

Miscellaneous: Numerous other criteria are also of determining importance for acceptance, depending on the unit involved and the amount of experience gained: swelling of parts, defective insulation, heat losses, insulation modalities, etc. Only painstaking evaluation of individual solar cookers will show just how important such factors can be with regard to social acceptance.
User-household surveys are a suitable starting point.

3.10 Economic Efficiency

The economic efficiency of a solar cooker is reflected by the time it takes to recoup the initial outlay and day-to-day maintenance costs by reducing commercial fuel consumption. Of course, the equipment must also remain serviceable substantially beyond its payback time. Oh the other hand, a purely monetary approach to the question of economic efficiency presents problems when applied to low-income households in which most of the fuel used is of noncommercial origin, e.g. cow pats, wood, scrub brush, etc. or to subsistence farming families with little or no involvement in the money economy. In the world's poorer countries, such families are often in the majority. The following aspects are of special importance.

Cost of production: For most solar cookers, little data is available on the actual cost of production. Since most of those in question are prototypes that do not yet display the technical maturity needed for series production, pertinent information is of low indicative value. Due to the chronic shortage of foreign currency in the Third World, preference should be given to cookers that can be made locally using indigenous materials. Whenever production costs are mentioned in connection with a solar cooker project, e.g. the Sobako project or the Sudan's Special Energy Program, they tend to go beyond the means of the target group. In relatively successful projects (Gujarat, SERVE), the sales price of the cookers is subsidized.

Purchase price: Practically any amount of money, however small, would still be too expensive for most rural households as long as firewood can be gathered for free (like in Mali) and the farmers earn very little money. A US$ 100 price tag would be utterly unacceptable. A family with a lower middle-class income (craftsman or laborer) in a town in Mali would have to pay between two and three months' earnings for a solar cooker. Even if the payback period were only 1 1/2 years (in towns), such a purchase would still amount to a major investment that only few could aford.

Indeed, some 80% of all urban families are unable to buy enough firewood for several days at once. In Pakistan, a single cooker of limited serviceability costs 2 months' pay. In Kenya, too, the in principle low cost of US$ 25 was still too high for most families, considering the meager income of the average rural household, coupled with the act that higher priority has to be attached to other expenditures. Experience gained in other projects aimed at disseminating firewood-saving stoves in Kenya shows that a new stove should not cost more than US$ 10. Due to the extremely low purchasing power of the "needy poor", most solar cookers are bought by the comparatively "well-to-do poor". In India, the solar cookers proved too expensive for most people, even though the price was subsidized by 50 %. While the payback period of 2 to 3 months (for those who buy fuel) is really very short, the price of a solar cooker amounts to an enormous outlay for a low-income family. Consequently, most solar cookers are owned by people with medium-to-high incomes. But some such families still would have been willing to buy the cooker at the normal, unsubsidized selling price. Subsidized or not, solar cookers almost always prove to be too expensive for the target group. Additionally, due to their particular time preference, the needy always compare solar cooker prices with those of other kinds of stoves and cookers. As long as a traditional stove in the Sudan costs about 2 % as much as a solar cooker, the latter's competitive power will remain practically negligible among very poor social groups. To make matters worse, the cost of a solar cooker in the Sudan included a profit margin of as much as 600 %I While the envisioned market price for a Sudanese solar cooker stands at US$ 80, the average Sudanese peasant is willing to pay US$ 2...4 for an improved cookstove.

Cost of maintenance: In general, solar cookers have a reputation for needing little maintenance. By contrast, though, the aforementioned complaints about defective solar cookers indicate that the cost of maintenance can sometimes be substantial. Realistic repair-cost estimates have only been drawn up for a few models.

Savings: Assuming low maintenance costs, the economic efficiency of a solar cooker can be roughly estimated by subtracting the cost of procurement and maintenance from the cumulative savings on fuel. Since solar cookers can only be used at certain times of the day in certain seasons of the year, they can never replace a traditional hearth. Reports from Mali peg fuel savings at up to 50 %, and the users of India's ATRC cooker claim it reduces energy consumption by 1/3 to 2/3 and firewood consumption by 30...60 %. According to information from the Sudan, solar cookers used together with traditional hearths cut charcoal consumption by about 25 %. All things considered, just how much money actually can be saved by reducing fuel consumption depends on a number of factors: - the kind of fuel being replaced - the local and seasonal fuel price structure - the number and nature of meals/dishes being prepared - how many days a year a solar cooker can be used. In general, solar cookers can be expected to reduce fuel consumption by 30...60 % in tropical and subtropical areas.

According to one Indian study, 32 % of all families that use their solar cooker every day claim to be saving no fuel at all, probably because the simultaneous use of other cooking fires continues undiminished. Some 68 % of the daily users confirm that they are spending less on commercial fuel: 50 % save between US$ 1 to US$ 1.50 per month; more than 7 % say they save between US$ 80 and US$ 1, and more than 42 % report savings of less than US 70. Compared to the stated monthly income of the respondents (US$ 90...300) such savings are regarded as very modest. Table 10 lists some details. No opportunity costs have been calculated for time saved, but rural
- underemployed or unemployed - laborers would probably attach a rather low value to it.

To the extent that the widespread use of solar cookers could appreciably retard the extraction of natural biomass for use as fuel, the ecological benefits would be quite substantial, though it would be hard to attach a monetary value to the conservation effect. On a global scale, however, progressive deforestation is due less to people's gathering firewood than to homesteading, the expansion of agricultural acreage, the lumber industry and industrial consumption.

Table 10: Achievable savings stated for the use of a solar cooker, Gujarat, India

Monthly savings	**Urban and fringe areas**	**Rural areas**	**Total**
less than US$ 0.7	37.00%	63.41%	42.64%
US$ 0.8...1	53.80%	28.05%	7.01%
US$ 1...1.5	9.20%	8.54%	50.45%

Payback time: Table 11 shows how long a solar cooker would probably take to pay for itself at a purchase price of US$ 5...150, assuming roughly 45 % savings on fuel, with the original cost of fuel running at US$ 2.5...5 per family. Any cooker that will pay for itself in less than a year stands a good chance of acceptance in the sense of economic viability. Assuming that the 45 % reduction in fuel consumption is spread evenly over the entire year, and that there will be about 3 months worth of cloudy days per year, then the cutback in fuel consumption amounts to about 60 % during the 9 months of sunshine. That shortens the payback periods of less than 1 year (calculated on a year's-average basis) to about 3/4 of their listed duration (assuming that the entire payback period begins and ends in a single sunny season, because the average monthly savings during the dry season come to 60 % instead of the 45 % calculated for the full year). In such cases, then, the payback periods listed in table 11 can be multiplied by a factor of 0.75. Figure 12 lists the corrected payback periods for the cases in which amortization in a single dry season is possible. obviously, this approach cannot be applied to tropical regions with two rainy seasons each year - with the possible exception of extremely favorable cases involving payback periods of 3 months or less.

Table 11: Payback period (in months) for a solar cooker, as a function of the purchase price and original monthly cost of fuel

Monthly expenditure for fuel	**Purchase price of solar cooker**						
	$ 5	**$ 10**	**$ 25**	**$ 50**	**$ 75**	**$ 100**	**$ 150**
$ 2.50	4.4	8.9	22	44	67	89	133
$ 5.00	2.2	4.4	11	22	33	45	67
$ 10.00	1.1	2.2	5.6	11	17	22	33
$ 15.00	0.7	1.5	3.7	7.4	11	15	22
$ 20.00	0.6	1.1	2.8	5.6	8.3	11	17
$ 25.00	0.4	0.9	2.2	4.4	6.7	8.9	13

Table 12: Payback period (in months) for a solar cooker during one single dry season, as a function of the purchase price and original monthly cost of fuel

Monthly expenditure for fuel	**Purchase price of solar cooker**						
	$ 5	**$ 10**	**$ 25**	**$ 50**	**$ 75**	**$ 100**	**$ 150**
$ 2.50	3.3	6.7					
$ 5.00	1.7	3.3	8.3				
$ 10.00	0.8	1.7	4.3	8.3			
$ 15.00	0.5	1.1	2.8	5.6	8.3		
$ 20.00	0.4	0.8	2.1	4.2	6.2	8.3	
$ 25.00	0.3	0.7	1.7	3.3	5.0	6.7	10.0

Payback periods amounting to more than 1 year for solar cookers as "objects of investment" are not regarded as negotiable, much less motivating, for the average household. This need not necessarily apply to large units intended for use in communal kitchens, in which case somewhat longer payback periods may appear acceptable. In general, though, only relatively short payback periods have a chance of being accepted, because the vast majority of people belonging to the social groups for which the procurement of fuel is a major cost factor, have very limited capital resources.

Additionally, in contrast to other kinds of renewable energy equipment with longer payback periods, such quick redemption of the capital outlay helps keep the interest burden (if any) at a minimum. In practice, no case is known of in which solar cookers were disseminated via interest-bearing,loans. At the same time, families with low-to-medium incomes in developing countries hardly need fear any substantial loss of interest as a result of investing in a solar cooker. The tabular comparison of solar cookers (cf. appendix 1) does not include the payback period, because it is heavily dependent on local and seasonal fuel prices, and they, in turn are usually unknown. In addition, the payback period has no effect on how useful a particular type of solar cooker would or would not be in some other region.

Lifetime energy price: The lifetime energy price, PEL, is the purchase price of the solar cooker, P, plus expenditures for repairs/maintenance, R, multiplied by the useful life, L, of the unit, then devided by the useful energy produced by the cooker. The latter derives from the useful life, 270 days of service per year (9 months), the aperture (A, collector area) of the cooker, the cooking time, t, the mean global irradiance, G (at the time of cooking), the cooker's efficiency, n, and the number of meals cooked per day, n:

$$PEL = \frac{P + R \cdot L}{L \cdot 270 \cdot A \cdot t \cdot g \cdot \eta \cdot n} \quad \text{in US\$ / kWh} \quad (11)$$

The term "efficiency'' is something of a problem for solar cookers, which also complicates calculation of the lifetime price of energy. For lack of any more accurate data, the efficiency values used here have been taken from the appended tabular comparison (calculated from the heatup power stated in the questionnaires (cf. section 2.2)). The average global irradiance, g, at the time of cooking was assumed to be 750 W/m². The same value was chosen for reflector cookers. The drawback of reflector cookers, namely that they only exploit direct radiation, is partially compensated for by their specific advantage, namely that they can be made to accurately track the sun during the cooking process. The cooking time is defined as 1.5 h for reflector cookers and 3 h for solar cooking boxes. As to the number of meals per day, n, it was postulated that between 1 and 2 meals are cooked in a solar cooking box, and a full two meals per day in a reflector cooker, which has substantially shorter cooking times. Thus, n = 1.5 for a box-type solar cooker, and n = 2 for a reflector cooker.

In the case of heat-accumulating solar cookers, the device's overall efficiency cannot be determined on the basis of how long it takes to boil a certain amount of water. They gather energy all day long and release it to the food at high power within a relatively short length of time when needed. This different situation is accounted for by an alternative definition of the lifetime cost of energy, PEL, for heat-accumulating solar cookers:

$$PEL = \frac{P + R \cdot L}{L \cdot 270 \cdot A \cdot t \cdot g \cdot \eta' \cdot n} \quad \text{in US\$ / kWh} \quad (11)$$

This time, η' is the efficiency of the energy-collecting components (collector and storage), with no regard for heat transmission to or losses by the food. Presumably, the average total efficiency amounts to roughly 2/3 of the efficiency η' of the energy-collecting components, measured during a period of good insulation - thus the factor 0.67. We are fully aware of the fact that not only the calculation of efficiencies, but financial calculations in general, involve a substantial degree of uncertainty - no matter how intimidatingly precise the formulae may look. For example, few empirical data are available with regard to useful lifetimes and the cost of repairs/maintenance. Additionally, the efficiency data were not determined by neutral parties, and the test conditions were not uniform. Lastly, solar radiation data and their time histories differ widely from region to region.

Cost of cooking: The cost of cooking (CC), which is the specific cost of energy for cooking food during the first year, is relatively unencumbered with such uncertainties. While one could also relate the specific cost of energy to the entire service life of the cooker, the first year is the financially decisive year with regard to motivation in connection with the dissemination of inexpensive solar cookers in developing countries. The cost of cooking during the first year iB calculated according to the formula:

$$CC = \frac{P}{270 \cdot m \cdot n} \quad (13)$$

with m as the mass (weight in kg) of the food that can be cooked at once. Based on the first year of service, the economic-efficiency criterion CC clearly favors inexpensive appliances with a payback period of less than one year. Box-type solar cookers are the best bet in that sense. Reflector cookers with a PEL that shows they are no more expensive to operate than a solar cooking box are not as good at exploiting the incident energy. They do catch more energy than a cooking box, but they can't cook more food with it.

The lower energy yield, coupled with a higher purchase price, makes the CC of a reflector cooker significantly higher than that of a solar cooking box. Consequently, reflector cookers are financially unattractive for most families in developing countries. Heat-accumulating solar cookers with a high purchase price have an economically unjustifiable CC. Their purchase price entails at least medium-term financial planning - and that can hardly be expected of most families in developing countries. Consequently, in the case of heat-accumulating solar cookers, the cost of cooking CC has been replaced by the cost of cooking with respect to lifetime CCL, i.e. the price of energy per kg of food cooked over the entire useful lifetime of the cooker:

$$CCL = \frac{P + L \cdot R}{270 \cdot m \cdot n} \quad (14)$$

This has important consequences for the dissemination of heat-accumulating solar cookers: In practice, long-term financing and amortization mean that such devices are much more suitable for use by institutions like schools, hospitals, etc. than by private families, and then only if their capacity is large enough to justify the high purchase price.

Summary: In considering the economic efficiency of solar cookers, one must proceed on the basis of the very low real, average income of the majority of the population and take into account their fundamentally different time preferences. Otherwise, any conclusions drawn will tend to be false.

3.11 Direct and Indirect Impacts

Essentially indirect impacts, effects, side effects, aftereffects and consequential effects are sometimes accentuated in an attempt to justify solar cooker projects.

Saving of time: Solar cooking dispenses with a major share of the tedious, time-consuming work of gathering firewood, thus taking some of the load off the shoulders of the responsible women, men or children. In a box-type solar cooker, the food will not burn, needs no stirring, and therefore does not have to be watched. That, too, saves considerable amounts of time and energy. In Chinese reflector cookers, some dishes need shorter cooking time than on a conventional fire. In rural communities, time saved can be worth more than money saved. Ultimately, the social appreciation of saved time will depend on the woman's role and whether or not the time is saved at the cost of conversation. The macroeconomic importance of any time saved depends on its opportunity costs. Time savings should be evaluated on a socioeconomic - not economic - basis.

Less smoke: Solar cooking keeps smoke out of huts and is therefore seen as an especially clean way of cooking. Here, too, one must examine such arguments from a socioeconomic standpoint. While smoke from a cooking fire does have unhealthy effects, it also helps preserve food (which is intentionally stored in the same room). At the same time, it strengthens thatched roofs and makes them more water-repellent. Additionally, smoke keeps insects away and the fire serves as a source of light and heat at night. A solar cooker offers no such advantages.

Health effects: Solar cookers have multiple health effects: - air quality: The absence of smoke at the place of cooking means better air quality for women who used to cook over a wood or charcoal fire. In densely populated areas, that advantage is enjoyed by the population in general; - burns: Reflector cookers pose the danger of burning/blinding. On the other hand, conventional hearths and stoves are much more dangerous for children; - circulatory stress: Reflector cookers force the cook to stand out in the hot sun. In Mali, especially the pregnant and nursing mothers complained of frequent headaches and dizziness. Here, too, the pros and cons have to be carefully balanced on a case-by-case basis, i.e. generalizing is uncalled-for.

Nutritional effects: Solar cooking boxes cook food gently, thus preserving many nutrients and flavor substances that would normally be lost by cooking over a fire. On the other hand, it has not yet been - but should be - clarified to which extent slow cooking - particularly in box-type solar cookers, where the food is held at relatively low temperatures for considerable long time - could lead to decomposition with possibly toxic consequences, specially in aluminum vessels. Applied nutritional-physiological research would be appropriate in that connection.

Effects on balance of payments: Solar cooking saves fossil fuels like petroleum and bottled gas. For countries with a lack of foreign exchange and no indigenous oil or natural gee' that translates into less dependence on imported energy and resultant disburdening of the balance of payments. However, since solar cookers are still so sparsely disseminated, with only few poor target groups actually using them, it would hardly be worthwhile to even attempt to calculate such indirect consequential effects.

Ecological impact: The same applies to the consequential effects of reducing firewood consumption, namely a more sparing use of natural resources, preservation of the eco-system, less deforestation, desertification and soil erosion, groundwater protection, preservation of climate, avoidance of drought. The relative contribution of solar cookers to any of these is too minor to warrant any serious attempt at quantification. Contributions by other projects, programs and policies are of much greater significance, especially projects dealing with reforestation, massive dissemination of efficient wood-burning stoves in limited areas, control of lumber harvesting, and promoting efficient energy consumption in transportation and industry.

3.12 General Conditions of Acceptance

The decision to buy and use a solar cooker rests in part on considerations of a more general nature. A good many of the arguments discussed above can have a positive or negative bearing on the final decision.

Decision to procure: Asked why they bought a solar cooker, 1572 users in Gujarat, India, named the following motives /139/:

- savings on fuel (61 % of those interviewed)
- wish to try something new (21 %)
- time savings (8 %)
- subsidized purchase price (8 %)
- no more burned food (2 %)

In well over half of the households, the decision to buy a solar cooker was made by the male head of the family. Only one in six solar cookers was purchased on the basis of a common decision by husband and wife. In the Sudan, though, it is customary for the women to purchase household items with their husband's money; they have a say in decisions concerning innovation.

Utilization motives: In each different social group and for each different type of solar cooker, the entire network structure of acceptance conditions presents itself anew - and differently. The aforementioned survey of 1572 households in Gujarat, India, drew attention to the following problems concerning acceptance of the Indian Solar Cooking Box /139/: - cooker too heavy (criticized by 37 % of those questioned)

- cooking takes too long (30 %)
- cooking time runs counter to the family's workaday routine (30 %)
- no suitable place to put the solar cooker (9 %)
- rejection of aluminum cookware (7 %)
- altered taste of food (4 %)
- complicated handling (4 %)

As a result of such problems, many families have stopped using their cookers. Indeed, of the 2204 families surveyed, approx. l/3 (818) said that they still used their solar cooker, while 1006 said they still have their solar cooker but no longer use it. Some 226 families had either sold their solar cooker or given it away. A different survey of 490 households came to the conclusion that about 12 % of the cookers were in disuse /116/. More than 22 % of the families use them to cook one or two meals a week, and 66 % use them daily. The situation in Afghan refugee camps in Pakistan is similar: only 2 families out of 10 actually used their solar cooker for preparing meals; the other 8 families said they use their cooker rarely or not at all - for the following reasons:

- broken glass cover
- damaged mirror
- cooker too small for a large family
- cooking takes too long
- cooking on a solar cooker only possible during the summer months
- aversion to preparing/cooking meals in the sun
- unaccustomed to operating the cooker one woman claimed to have no food to cook.

Awareness: The main prerequisite for buying and using a solar cooker is a subjective need, as opposed to objective necessity, for energy-saving devices. The real motivation is determined by the urgency and existential importance of the need in question as compared to other basic necessities. But motivation can also stem in part from a desire to decorate and furnish one's living quarters. Whether or not problem-consciousness exists, or is even possible, can only be ascertained by way of an exact situation analysis of the target group. The Sudanese Energy Development Plan, for example, calls attention to the fact that the people themselves are not yet aware that firewood is a problem, though the situation in the northern part of the country is much more serious than in the south. In India, where practically every family is affected by the increasing scarcity of fuel, awareness of the problem is still estimated as being very low. For example, cooking fires are often not promptly extinguished; in some families, they are left to burn for hours on end. Of course, a large share of rural families still gather their wood for free and therefore cannot be expected to attach existential importance to having a solar cooker. Many women say they would like to have a solar cooking device, but their other problems are more urgent: getting the day's food, worrying about the family's health, etc. As long as the target group is not personally affected, they will see little reason to buy and use solar cookers. Besides, one can always adopt an 'alternative strategy" like eating fewer hot meals in favor of more bread, etc.

User structure: In hardly a solar cooker project are the actual users of the solar cookers identical with the needy target group envisioned by the project-executing organization. All solar cookers produced to date in connection with the ATDO project in Pakistan are in the possession of Karachi residents. These people bought cookers because they wanted to try something new, not because they were suffering from a shortage of fuel. Since the families in question belong to the middle and upper-middle classes, they were able to buy their devices at unsubsidized prices. Though India's official program aspires to achieve widespread use of solar cookers among low-income groups, the dissemination measures are aimed primarily at the more well-to-do social strata. Since the strategy is to give solar cookers a status-symbol image in the hope that poor families will try to emulate the rich by buying and using one, the result could be to awake artificial needs instead of engeneering an appreciation of the need to conserve energy. Indeed, how much of a percolating effect may or may not occur still remains to be seen. One thing is for sure, though, namely that the users rarely belong to the target group - who continue to use wood to meet their energy demands.

Willingness to accept chance: At times, reference is made to the need for a willingness to accept change (as opposed to the ability to accept change). If a solar cooker is economic and fits neatly into people's dietary, eating and cooking habits, it will find acceptance. Poor people nearly always show more purposeful, shrewder behavior than other people do. Consequently, one should avoid the use of "traditional" and ''conservative" (read: prejudiced) thought patterns, so as not to seem incapable of understanding the target group's everyday rationalities. On the contrary, they should be carefully investigated as the basis of a technology impact assessment for innovations like solar cookers.

3.13 Summary

The above observations, reflections and comments show that, while some good, serviceable solar cookers have been developed, no appreciable degree of acceptance by target groups has been achieved. The reasons behind the mediocre success of solar cooking are less or a technical nature than of a sociocultural, socioeconomic and psychosocial nature. Despite continuous technical improvement, it has not been possible to adequately adapt the devices to the real wants and needs of the users.

While solar cooking boxes are widely regarded as the most practical approach to solar cooking, experience shows that no attempt to achieve mass dissemination has yet been successful. Field studies conducted in Gujarat, India, revealed that even families who own a solar cooker do not always use it. While solar cookers do have their advantages, they do not fully accommodate the wants and needs of the general population. Reflector cookers have experienced substantial acceptance - if any - only in China so far.

The possibility of cooking with solar energy is nobody's secret. But most people still fail to realize that, in some areas, solar cooking may soon constitute one of the few remaining options for preparing a hot meal. On the other hand, test projects in India and China have shown that the dissemination of solar cookers actually is possible. The extent to which future projects will contribute to the further dissemination of solar cookers, will extensively depend on howmuch attention is paid to the socioeconomic, sociocultural and psychosocial criteria dealt with on these pages.