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A Review of Direct and Indirect Solar Cookers

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Abstract The sun's free, zero-emissions energy produces no household air pollution, preserving the environment as people cook food and pasteurize drinking water. In recent years, much experience has been acquired with the solar cooking systems described. In present work a review has been made to study conducted researches in the field of solar cookers. Experimental, theoretical, numerical analyses are included to compare operation and efficiency of solar cookers. Also the article reviews and summarizes findings of conducted researches on factors influence solar cooker use rates.

Keywords: *solar cookers, Developing impacts, efficiency, exergy*

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1. Introduction

The continuous increase in the level of greenhouse gas (GHG) emissions and the increase in fuel prices are the main driving force to utilise various source of renewable energy [1]. Among the clean energy technologies, solar energy is recognized as one of the most promising choice since it is free and provides clean and environmentally friendly energy [2-8]. The Earth receives 3.85 million EJ of solar energy each year [9]. Solar energy offers a wide variety of applications in order to harness this available energy resource. Among the thermal applications of solar energy, solar cooking is considered as one of the simplest, the most viable and attractive options in terms of the utilization of solar energy [10].

Solar cookers suggest clean and free cooking which is attraction for either modern urban life as alternative free and clean energy and rural living in developing countries that are grappled with lack of the energy. Firewood is used as fuel in family cooking in rural. In India, 47% of the energy for home cooking comes from wood, and in many Africa countries, this value is higher than 75%, such as in Mali or Burkina Faso, where it reaches 95% [11]. Over 50% of the population in Nicaragua use wood as fuel for cooking, and over 53% of the country's overall energy consumption comes from wood (GHA, 2003) [12]. Similar situation has been reported in other countries, such as, Ethiopia, Peru, and Indonesia. Wood cut for cooking purposes contributes to the 16 million hectares of forest destroyed annually.

In near future, the large-scale introduction of solar energy systems, directly converting solar radiation into heat, can be looked forward to. The continuous increase in the level of greenhouse gas emissions and the increase in fuel prices are the main driving forces behind efforts to more effectively utilize various sources of renewable energy [13].

Energy consumption for cooking in developing countries is a major component of the total energy consumption, including commercial and non-commercial energy sources. Energy requirement for cooking accounts for 36% of total primary energy consumption in India. Hence, there is a critical need for the development of alternative, appropriate, affordable mode of cooking for use in developing countries [14]. Most of the thickly populated countries are blessed with abundant solar radiation with a mean daily solar radiation in the range of 5–7 kWh/m2 and have more than 275 sunny days in a year [15].

Cooking with the energy of the sun is not a new or novel idea. According to Halacy and Halacy [16] the first scientist to experiment with solar cooking was a German physicist named Tschirnhausen (1651–1708). He used a large lens to focus the sun's rays and boil water in a clay pot. His experiments were published in 1767 by a Swiss scientist Horace de Sausure who also discovered that wooden "hotboxes" he built produced enough heat to cook fruit. French Scientist Ducurla improved on the hotbox design by adding mirrors to reflect more sunlight and insulating the box. The first book on the subject "Solar Energy and its Industrial Applications" was published by August Mouchot. In 1877, Mouchot designed and built solar cookers for French soldiers in Africa and in 1878 exhibited a solar concentrator at the Parisexhibit. The first recorded solar cooker to be used on South African soil was probably by Sir John Herschel during a scientific expedition to the Cape of Good Hope in 1885. The stove was made out of mahogany, painted black, buried into sand for better insulation and covered by a double glazing to reduce heat losses [17]. Increased public interest in solar stoves emerged in the 1950s and 1960s.

Interest in renewable energy during this period was fuelled by the aftermath of the Second World War with its fuel shortages and rationing, an increased desire to use solar energy "to help people" and as a potential area of investment [18]. Independence gained by former colonial states brought a focus on development and the need to address the "underdeveloped" state of these countries. Lastly, the oil crisis of the early 1970s also contributed to efforts to become less dependent on nonrenewable sources of energy. Growing fuel wood and other energy shortages, coupled with expanding populations in China and India, encouraged governmental research on alternatives in the 1970s with China holding its first seminar on solar cooking in 1973 [19]. Activities the 1980s and 1990s built on earlier efforts at first. China began distributing subsidized cookers in 1981. The ULOG group in Switzerland, EG Solar in Germany and Solar Cookers International were all founded during the 1980s. The work of Barbara Kerr and Shery Cole resulted in a solar cooker kit that was easy to build by the user and served as foundation for the development of a solar panel cooker by Solar Cookers International, which is still used today [19].

2. Cooking

First, The cooking is based on heating a given of food to the boiling temperature of water and in the second part the food is kept at the boiling temperature for a certain period of time depending on the nature of the food. The obviations indicate that the mass flow rate of the gas in the first part is 2-3 times greater than the second part [20].

Lof [21] has described the principles of cooking. As per his principle, the energy requirement is at maximum during the sensible heating period. Heat required for physical and chemical changes involved in cooking is less. The energy required for a specific cooking operation is not always well defined and can vary widely with the cooking methods used. During cooking, 20% of heat is spent in bringing food to boiling temperature, 35% of heat is spent in vaporization of water and 45% of heat is spent in convection losses from cooking utensils. Insulating the sides of the vessel and keeping the vessel covered with a lid can considerably reduce the heat losses.

3. Solar Cookers

A solar cooker is a device which uses the energy of direct sun rays (which is the heat from the sun) to heat, cook or pasteurize food or drink. The vast majority of solar cookers presently in use are relatively cheap, low-tech devices. Because they use no fuel and cost nothing to operate, many nonprofit organizations are promoting their use worldwide in order to help reduce fuel costs (for low-income people) and air pollution, and to slow down the deforestation and desertification caused by gathering firewood for cooking. Solar cookers are classified into direct and indirect solar cookers depending upon the heat transfer mechanism to the cooking pot. Direct type solar cookers use solar radiation directly in the cooking process while the indirect cookers use a heat transfer fluid to transfer the heat from the collector to the cooking unit.

3.1. Direct Solar Cookers

Direct solar cookers may be considered the most common type available due to their ease of construction and low-cost material [22]. Commercially successful direct type cookers are box type and concentrating type cookers. Box type solar cooker is an insulated container with a multiple or single glass cover [23]. This kind of cooker depends on the green house effect in which the transparent glazing permits the passage of shorter wavelength solar radiation, but is opaque to most of the longer wavelength solar radiation coming from relatively low temperature heated objects [24].

The inner part of the box is painted black in order to maximize the sunlight absorption. Maximum four cooking vessels are placed inside the box [25,26]. The cover of the box usually comprises a two-pane "window" that lets solar radiation enter the box but keeps the heat from escaping. This in addition to a lid with a mirror on the inside that can be adjusted to intensify the incident radiation when it is open and improve the box's insulation when it is closed [27]. The speed of the cooking depends on the cooker design and thermal efficiency. The schematic of box type cookers with single reflectors shown in Figure 1, Figure 2.

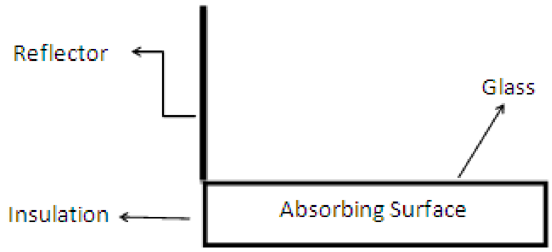

Figure 1. Schematic of box type cookers with single reflectors

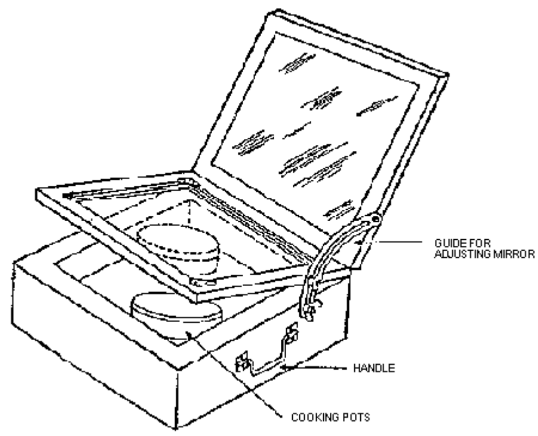

Figure 2. Schematic of box type cookers with single reflectors

Harmim et al. [28] experimentally investigated a box-type solar cooker with a finned absorber. The results indicated that solar box cooker equipped with fins was about 7% more efficient than the conventional box-type solar cooker. The time required for heating water up to the boiling temperature was reduced about 12% when a finned absorber plate was used.

Experimental studies were conducted to see the effect of sand and granular carbon used as the heat absorbing material on the surface of absorber plate in solar box cooker by A. Saxena and et al [1]. An annual performance of solar cooker provided with a mixture of material spread on the absorber tray has been estimated for the different months by considering the actual values on the day of cooking trials (Table 1). The main advantages of box-type solar cookers are: They make use of both direct and diffuse solar radiation; Several vessels can be heated at once; They can double as an oven (not for crispy baked goods); They are light and portable; They are easy to handle and operate; They needn't track the sun; The moderate temperatures make stirring unnecessary; The food can be kept warm until evening; The boxes are easy to make and repair using locally or regionally available materials; They are relatively inexpensive (compared to other types of solar cookers).

Table 1. Year around performance of box type solar cooker from April 2008 to March 2009

S. No	Month	TAmbient (°C)	TSolar box cooker (°C)	Twater (°C)	Radiation (w/m2)	Wind Speed (m/s)	Time
1	April	42	145	99	950	5.38	12.00- 14.00
2	May	40	120	97	900	5.8	12.00- 14.00
3	June	38	127	98	850	5.6	12.00- 14.00
4	July	36	105	96	830	4.12	12.00- 14.00
5	August	35	100	95	800	3.97	12.00- 14.00
6	September	31	98	93	820	5.33	12.00- 14.00
7	October	31	96	89	800	5.33	12.00- 14.00
8	November	24	92	84	780	3.42	12.00- 14.00
9	December	21.5	91	82	750	2.67	12.00- 14.00
10	January	21	90	80	720	4.22	12.00- 14.00
11	February	25	94	85	750	4.01	12.00- 14.00
12	March	32	115	98	850	4.89	12.00- 14.00

Disadvantages of solar box cookers include: slow cooking process due to low temperatures Cooking must be limited to the daylight hours; The glass cover causes considerable heat losses; Such cookers cannot be used for frying or grilling [27].

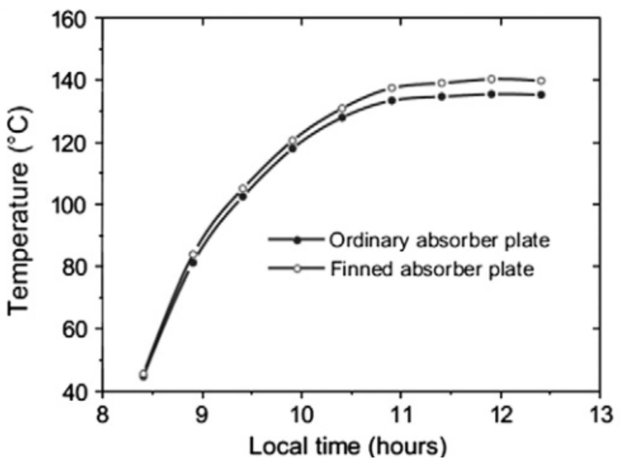

Figure 3. Finned and ordinary absorber plate temperatures

The most elementary kind of reflector cooker is one that consists of (more or less) parabolic reflectors and a holder for the cooking pot situated at the cooker's focal spot [27].

A solar parabolic cooker simply consists of a parabolic reflector with a cooking pot which is located on the focus point of the cooker and a stand to support the cooking system [29]. Concentrating type solar cooker is working on one or two axis tracking with a concentration ratio up to 50 and temperature up to 300 C, which is suitable for cooking. Cookers that concentrate light from below and cookers that concentrate light from above are the two major types of concentrating solar cookers.

Within few hours of sunshine, the cooker makes tasty meals for 4–5 persons at gentle temperatures, cooking food and preserving nutrients without burning and drying out. Figure 4 shows the commercial parabolic cooker.

The advantages of reflector cookers include: the ability to achieve high temperatures; and accordingly short cooking times; relatively inexpensive versions are possible; some of them can also be used for baking. Disadvantages are their size, cost, the risk of fires and burns and the inconvenience to adjust the cooker as it requires frequent directional adjustment to track the sun.

Figure 4. commercial parabolic cooker

3.2. Indirect Solar cookers

In indirect type solar cookers, the pot is physically displaced from the collector and a heat-transferring medium is required to convey the heat to the cooking pot. Solar cooker with flat plate collector, evacuated tube collector and concentrating type collector are commercially available cookers under this category.

Schwarzer and Silva [30]. Developed flat-plate solar cooker which can be incorporated into the construction of kitchen as shown in Figure 5. The two basic system components are the solar collectors with reflectors and a cooking unit. Peanut or sunflower oil is used as heat transfer medium and the cooker is designed with two non-removing pots. Disadvantages of this cooker are nonremovable pots, which makes cleaning and dishing food difficult.

Figure 5. Outdoors cooker with heat storage developed by Schwarzer and Silva [30]

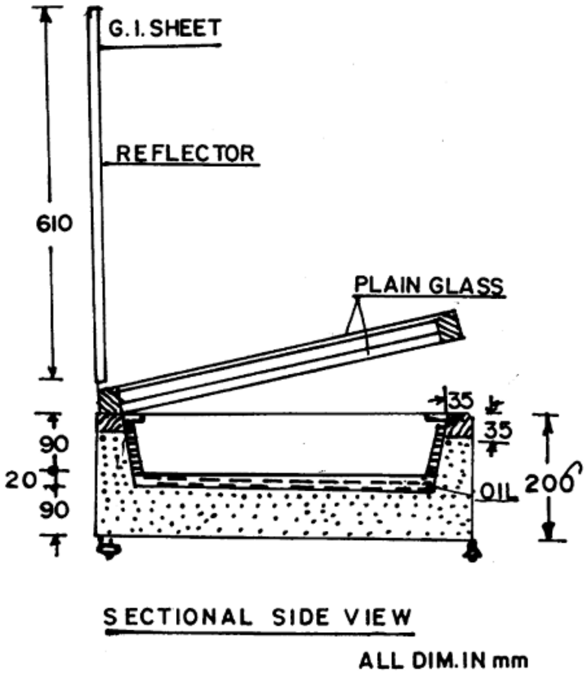

Figure 6. The schematics of a hot box storage solar cooker [15]

Balzar [31] developed vacuum tube collector-based solar cooker. It consists of a vacuum tube collector with integrated long heat pipes directly leading to the oven plate. Solar cookers using vacuum tube collectors have several advantages. They do not need tracking. They can reach high temperatures and cooking can take place in the shade or inside a building because of the spatial separation of collecting part and oven unit.

Thermal energy storage [32] is essential whenever there is a mismatch between the supply and consumption of energy. The solar cookers must contain a heat storage material to store thermal energy in order to solve the problem of cooking outdoors and impossibility of cooking food due to frequent clouds in the day or during off-sunshine hours. Thermal energy can be stored as a change in internal energy of a material as sensible heat, latent heat and thermo-chemical or combination of these. In this section, the different types of solar cookers which use sensible or latent heat storage materials are summarized.

In sensible heat storage, thermal energy is stored by raising the temperature of a solid or liquid. A hot box solar cooker with used engine oil (Figure 6) as a storage material has been designed, fabricated and tested by Nahar [15] so that cooking can be performed even in the late evening.The maximum stagnation temperature inside the cooking chambers of the hot box solar cooker with storage material was the same as that of the hot box solar cooker without storage during the day time, but it was 23°C more in the storage solar cooker from 1700 to 2400 h. The efficiency of the hot box storage solar cooker has been found to be 27.5%.

The oil is heated up in the collectors and moves by natural flow to the cooking unit, where it transfers part of its sensible energy to the double-walled cooking pots. Manually controlled valves guide the oil flow rate either to the pots or to the storage tank. The major advantages are the possibility of indoor cooking, the use of a thermal storage tank to keep the food warm for longer periods of time or night cooking and the reach of high temperatures of the working fluid in a short period of time.

Latent heat storage [33,34] makes use of the energy stored when a substance changes from one phase to another. The use of PCMs for storing heat in the form of latent heat has been recognized as one of the areas to provide a compact and efficient storage system due to their high storage density and constant operating temperature. PCM (Phase Change Material) take advantage of latent heat that can be stored or released from a material over a narrow temperature range. PCM possesses the ability to change their state with a certain temperature range. These materials absorb energy during the heating process as phase change takes place and release energy to the environment in the phase change range during a reverse cooling process. Basically, there are three methods of storing thermal energy: sensible, latent and thermo-chemical heat or cold storage. Thermal energy storage in solid-to-liquid phase change employing phase change materials.

(PCMs) has attracted much interest in solar systems due to the follow advantages: (i) It involves PCMs that have high latent heat storage capacity; (ii) The PCMs melt and solidify at a nearly constant temperature; (iii) A small volume is required for a latent heat storage system, thereby the heat losses from the system maintains in a reasonable level during the charging and discharging of heat.

A solar cooker with latent heat storage for cooking food in the late evening was designed and tested [35]. In this design, the phase change material (PCM) was filled below the absorbing plate. Commercial grade stearic acid (melting point 55 8C, latent heat of fusion 161 kJ/kg) is used as a latent heat storage material. In such type of design, the rate of heat transfer from the PCM to the cooking pot during the discharging mode of the PCM is slow and more time is required for cooking food in the evening.

Hussein et al. [36] designed a novel indirect solar cooker with outdoor elliptical cross section, wickless heat pipes, flat-plate solar collector and integrated indoor PCM thermal storage and cooking unit as shown in Figure 7. They constructed and tested under actual meteorological conditions of Giza, Egypt. Two plane reflectors are used to enhance the insolation falling on the cooker's collector, while magnesium nitrate hexahydrate (T=89_C, latent heat of fusion 134 kJ/kg) is used as the PCM inside the indoor cooking unit of the cooker. It is found that the average daily enhancement in the solar radiation incident on the collector surface by the south and north facing reflectors is about 24%. Different experiments have been performed on the solar cooker without load and with different loads at different loading times to study the possibility of benefit from the virtues of the elliptical cross section wickless heat pipes and PCMs in indirect solar cookers to cook food at noon and evening and to keep food warm at night and in early morning. The results indicate that the present solar cooker can be used successfully for cooking different kinds of meals at noon, afternoon and evening times, while it can be used for heating or keeping meals hot at night and early morning.

Cross sectional views of the indirect solar cooker under investigation are shown in Figure 7, Figure 8.

The condenser section of the closed loop wickless heat pipes network was made of a copper tube of 9.5 mm nominal diameter and about 7 m length in the form of a helical coil as shown in Figure 3. The condensing helical coil (i.e. condenser section) was then flame heated, and its inner surface was cleaned and rinsed by the procedures performed on the evaporator assembly [37,38]. Then, it was incorporated into an indoor cooking unit that has an inner galvanized iron box of 0.56 m length, 0.28 m width and 0.165 m height as shown in Figure 7 and Figure 8.

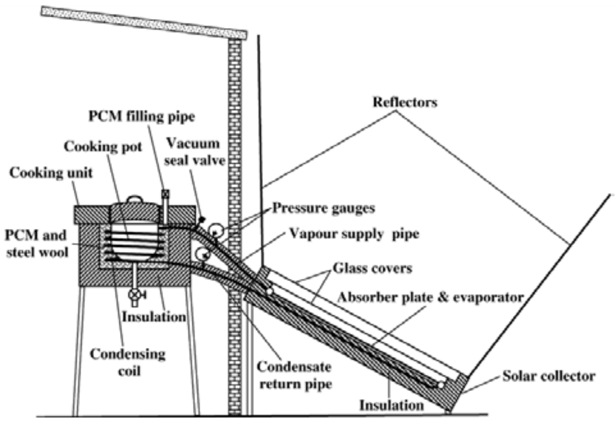

Figure 7. Cross sectional side view of the present solar cooker shows its main components

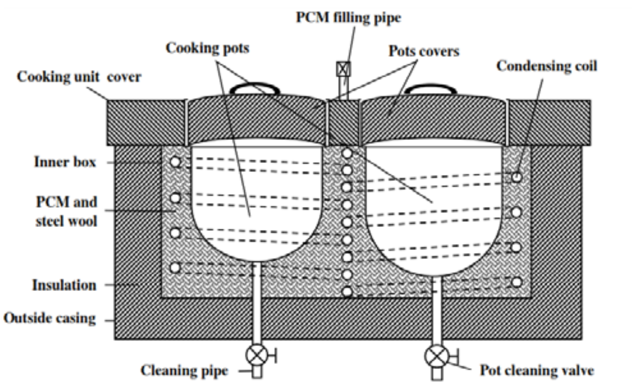

Figure 8. Cross sectional front view of the indoor PCM cooking unit shows its main components

During sunshine hours, heated water transfers its heat to the PCM and is stored in the form of latent heat through a stainless steel tubing heat exchanger. This stored heat is utilized to cook the food in the evening time or when sun intensity is not sufficient to cook the food. They concluded that system was able to cook successfully twice (noon and evening) in a single day during Japanese summer months. Noon cooking did not affect evening cooking, and the evening cooking using the heat through PCM storage unit was found to be faster than noon cooking.

4. Numerical Analysis

El-Sebaii [39] numerically analyzed a box-type solar cooker with outer-inner reflectors. Numerical calculations were carried out for different tilt angles of the outer reflector on a typical winter day (20 January) in Tanta, Egypt. The optimum tilt angle of the outer reflector was 60_. For this specific value, it was observed that the specific and characteristic boiling times were decreased by 50% and 35%, respectively, compared to the case without the outer reflector. The overall utilization efficiency of the cooker was determined to be 31%.

In another research which was conducted by Terres et al. [40], numerical simulation results were shown to determine the heating in liquids when a solar cooker box type with internal reflector is used to this end. The data evaluated correspond to temperature values from bee honey, olive oil, milk and water when they are heated in the solar cooker. The maximum simulation temperatures reached are 91.8°C, 91.6°C, 86.2°C and 85.3°C that correspond to bee honey, olive oil, milk and water respectively. A comparative between simulation and experimental results also were shown. The values presented evidence the influence of the specific heat in each fluid considered. In the numerical simulation were used solar radiation and environment temperature values for February 26, 2006 in Mexico City.

Chen et al [41] investigated theoretically on the PCMs used as the heat storage media for box-type solar cookers. The selected PCMs are magnesium nitrate hexahydrate, stearic acid, acetamide, acetanilide and erythritol. For a two dimensional simulation model based on the enthalpy approach, calculations have been made for the melt fraction with conduction only. Different material such as glass, stainless steel, tin, aluminium mixed, aluminium and copper are used as the heat exchanger container materials in the numerical calculations. It is also found that the initial temperature of PCM does not have very important effects on the melting time, while the boundary wall temperature play an important role during the melting and has a strong effect on the melt fraction. The results also show that the effect of thickness of container material on the melt fraction is insignificant.

The results obtained in this paper show that acetamide and stearic acid, should be used as storage media in a box-type solar cooker to cook and/or to keep food warm in the late evening with different heat exchanger container materials. The large value of thermal conductivity of heat exchanger container material did not make a significant contribution on the melt fraction except for at very low thermal conductivities.

5. Energy and Exergy Efficiencies

Richard Petela [42] has been presented the theoretical exergy analysis of a solar cooker and the distribution of the exergy losses in the cooker. Equations for heat transfer between the three surfaces: cooking pot, reflector and imagined surface making up the system, were derived. The model allowed for theoretical estimation of the energy and exergy losses: unabsorbed insolation, convective and radiative heat transfer to the ambient, and additionally, for the exergy losses: the radiative irreversibilities on the surfaces, and the irreversibility of the useful heat transferred to the water.

The exergy efficiency of the SPC, was found to be relatively very low (~1%), and to be about 10 times smaller than the respective energy efficiency which is in agreement with experimental data from the literature. The influence of the input parameters (geometrical configuration, emissivities of the surfaces, heat transfer coefficients and temperatures of water and ambience) was determined on the output parameters, the distribution of the energy and exergy losses and the respective efficiencies.

The principles of radiative heat transfer applied in the present paper are presented e.g. by Holman[43]. Szargut and Petela [44] as well as Szargut et al. [45], present the concept of exergy and its application to the analysis of processes. Extensive review of the problems of radiation exergy is provided by bejan [46]. Some clarifications regarding exergy of thermal radiation are discussed by Petela [47].

The main reason of low efficiency of devices driven by solar radiation lies in the impossibility of full absorption of the insolation.

In relation to the exergy efficiency there is an additional reason which makes this efficiency significantly lower than the energy efficiency. A low exergy performance efficiency of SPC, and of other devices driven by solar radiation, is caused by the significant degradation of energy. The relatively high temperature (~6000 K) of solar radiation is degraded to the relatively low temperature e.g. to the temperature Tw of heated water, which is not much larger than the ambient temperature T_0.

The influence of the geometric configuration of the cooker on its performance was outlined. By applying the variation only of the "openness" (x2) and "depth" (y2) of the considered SPC it was shown that the energy efficiency of above 18%, and exergy efficiency of above 1.6%, could be reached. It can be confirmed by calculation that the determined optimal surface profile of the considered SPC can be scaled up, at the unchanged optimal efficiencies, to the SPC with the all dimensions changed proportionally. The scheme for calculations of the radiation shape factors illustrated in Figure 9.

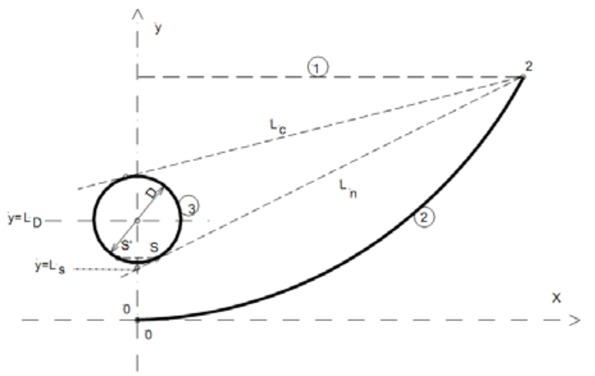

Figure 9. The scheme for calculations of the radiation shape factors

Shukla and Gupta [48] presented an energy and exergy analysis of a concentrating solar cooker. The cooker was devised for community cooking and integrated with a linear parabolic concentrator which concentration ratio is 20. The experiments were carried out in both summer and winter conditions. Through the experimental results, the average efficiency of the solar cooker was determined to be 14%. Heat losses caused low efficiency were classified as optical losses (16%), geometrical losses (30%) and thermal losses (35%). The rest of the losses were due to edge losses, etc. The maximum temperature that the water in the cooker reached was 98°C during the tests.

In another research N. L. Panwar and et al. [49] presented an energy and exergy analysis of a domestic size parabolic solar cooker in actual use. The experimental time period was from 10:00 to 13:30 solar time. During the experiment, it was found that the maximum temperature of water was 368 K. The energy out of the cooker varied between 46.67 and 653.33 W, whereas its exergy output was in the range, 7.37-46.46 W. Over the time, both efficiencies were decreased because of the optical and thermal losses from the reflector and pot. By using properly insulated cooking pot, the considerable amount of conventional energy can be saved.

It is clear from Figure 10 that the ambient temperature was in the range of 301 K to 309 K. It was minimum at 10:00 h (301 K) and reached the maximum at 13:30 h (309 K).

It is clear from Figure 11 that energy and exergy efficiencies of cooker reduce with corresponding solar time. The maximum energy efficiency was evaluated 32.97% and it was observed at 10:30 h, whereas it was minimum at 13:30 h. As far as maximum exergy efficiency is concerned, it was evaluated 2.18% and it reduces as increasing solar time. Apart from increasing solar radiation, both energy and exergy efficiencies were decreased drastically and this may be due to high loss from pot as it is not insulated.

Ozturk [50,52,53] conducted several experimental researches on solar parabolic cookers and analyzed the performance parameters in terms of thermodynamic laws. Ozturk experimentally examined energy and exergy efficiencies of a simple design and the low cost parabolic cooker under the climatic conditions of Adana which is located in Southern Turkey (at 37_N, 35_E). The energy output of the parabolic cooker was determined to be 20.9–78.1 W, whereas its exergy output was in the range of 2.9–6.6 W. The results showed that the energy and exergy efficiencies of the parabolic cooker were calculated between 2.8–15.7% and 0.4–1.25%, respectively [52].

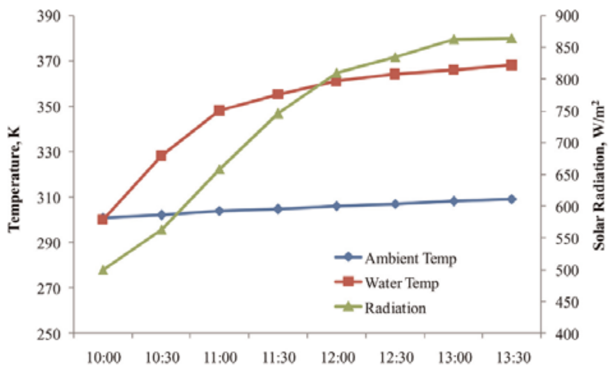

Figure 10. Temperature variation and solar radiation with time

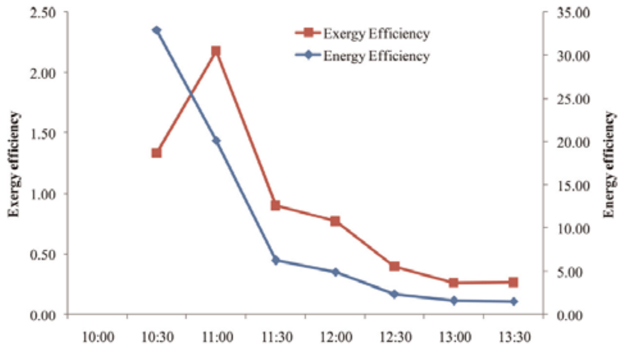

Figure 11. Energy and energy efficiencies with time

6. The Development Impact of Solar Cookers

Solar cooking has regularly been viewed as a solution looking for a problem, or a technological solution developed without sensitivity to user needs.[54]. Specific reference is made here to the activities of the DME/GTZ solar cooker field test executed in South Africa from 1996 which concluded, ‘‘Many advancements have been made in the technical advancement of solar cookers, but unfortunately, very little attention has been paid to the social context, as defined by the needs of the potential users.” [54].

Different studies investigated solar cooker use rates since 1996 in South Africa. Based on[55-60] Solar cooker use rates can be accepted to be between 31% and 25%. Many factors influence solar cooker use rates and a change in use rates including: external conditions (weather conditions), change in interest and cooking patterns, solar stove characteristics (slow cooking), fuel saving, time saving and etc.

Since it is mainly women who do the cooking in the household, it is mainly their time that is being saved by using a solar cooker. Although most solar stoves cook slower than other stoves, they require very little attention once the food is in the stove [56].

Table 2 provides the results for the corresponding total average (over all users and all fuel types), during the first phase of the solar cooker field test, stating that the overall fuel savings were 38% [61].

Table 2. Average savings for all fuels by households

	Savings (%)	Weight
Parafin	33	0.28
Gas	57	0.16
Wood	36	0.56
Unweighted total average	42	-
Weighted total average	38.4	-

The ex-post purchase study [55] did not investigate savings specifically, but when asked why respondents had bought a solar cooker (independent of the model); the most cited reasons were monetary savings in fuel expenses and convenience (time savings, unattended cooking and having an additional “fuel” source) (Table 3) [55].

Table 3 Reseans for solar cooker acquisition

Resean	Entries
Savings	44
Convenience	29
Other	13

The investigation conducted by Market Research Africa also did not record specific savings (energy, monetary or time) although it was reported that users were motivated by cost savings/energy to cost purchase their solar cookers. Free energy, cost savings and no fuel costs were the most important perceived advantages of solar cookers [62].

7. Conclusion

Solar energy is free, environmentally clean, and therefore is recognized as one of the most promising alternative energy recourses options. In supplying the needed energy, solar cookers can fully or partially replace the use of firewood for cooking in many developing regions. In this paper, a review of the available literature on solar cookers is presented. The review covers a historic overview, classification, operation and thermodynamic analysis of different solar cookers as well as the reasons of why the solar cooking technology has never been able to gain any real extent of popularity.

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