Electric back-up solar cooker: Fabrication and testing

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ABSTRACT

Among all renewable energy sources, solar energy comes at the top of the list due to its abundance and more evenly distribution in nature. A prudent use of solar energy by means of solar cooking can decrease the cooking fuel expense and can help to overcome the harmful effects arising from the combustion of current dirty cooking fuels in developing nations. This paper underline need of solar cookers with proper back-up and presents the fabrication details of an electric back-up solar cooker along with on-field test results.

INTRODUCTION

A number of solar cookers have been developed so far. These are : (i) box type solar cooker (ii) focusing type solar cooker and (iii) advanced or indirect type solar cooker. To increase the thermal performance and to popularize the system among its potential users various types of technical improvements in the box-type solar cookers have been done till now , yet the use of solar cooker is not very common. Solar cooker can be substantially popularized in urban as well as in those rural areas where there is no electricity supply if combined with heat storage, back up or a hybrid system that ensures reliability during cloudy and rainy days as well as in evening hours . A detail literature review reveal that a considerable work has been done to develop solar cookers but a few work has been done on solar cooker with back-up. Here, a small size solar cooker has been fabricated that is named as Solar cum Electric Cooker (SEC). An extensive experimental study has been performed with SEC. The developed small size system is an appropriate solution to mitigate the limitation of cooking during scattered cloudy, cloudy, rainy days and in night.

Fabrication of solar cum electric cooker (SEC)

Table 1: Design details of Solar cum Electric Cooker (SEC)

S. No.	Parameters	Details
1.	Casing	
	(i) Dimension	57×45.5×21.5cm^3
	(ii) Material	Fiber sheet
	(iii) Thickness	2 mm
2.	Absorber tray	
	(i) Dimension	47×35.5×8.5 cm^3
	(ii) Shape	Rectangular (Erect)
	(iii) Material	Aluminum
	(iv) Thickness	0.35 mm
	(v) Coating	Black matt paint
	(vi) Absorptivity	0.90
3.	Glaze	
	(i) No. of glaze	2
	(ii) Material	Toughened and normal Glass
	(iii) Thickness	Upper 4 mm (normal), lower 5 mm (toughened)
	(iv) Spacing between glaze	13 mm
4.	Insulation	
	(i) Material	Ceramic fiber wool
	(ii) Thickness	
	(a) Side	5 cm
	(b) Bottom	9 cm
5.	Containers	
	(i) Shape	Cylindrical
	(ii) Dimension	Diameter 20 cm, height 6 cm
	(iii) Material	Aluminum
	(iv) No. of pots	2
	(v) Coating	Black matt paint
6.	Reflector	
	(i) Number	1
	(ii) Dimension	54.6×40.5 cm^2
	(iii) Thickness	4 mm
	(iv) Material	Silicate glass
7.	Electric Back-up	
	(i) Type	Mica sandwich strip heaters
	(ii) Quantity and capacity	Two, 90 W each
	(iii) Temperature control range	50 to 200 °C

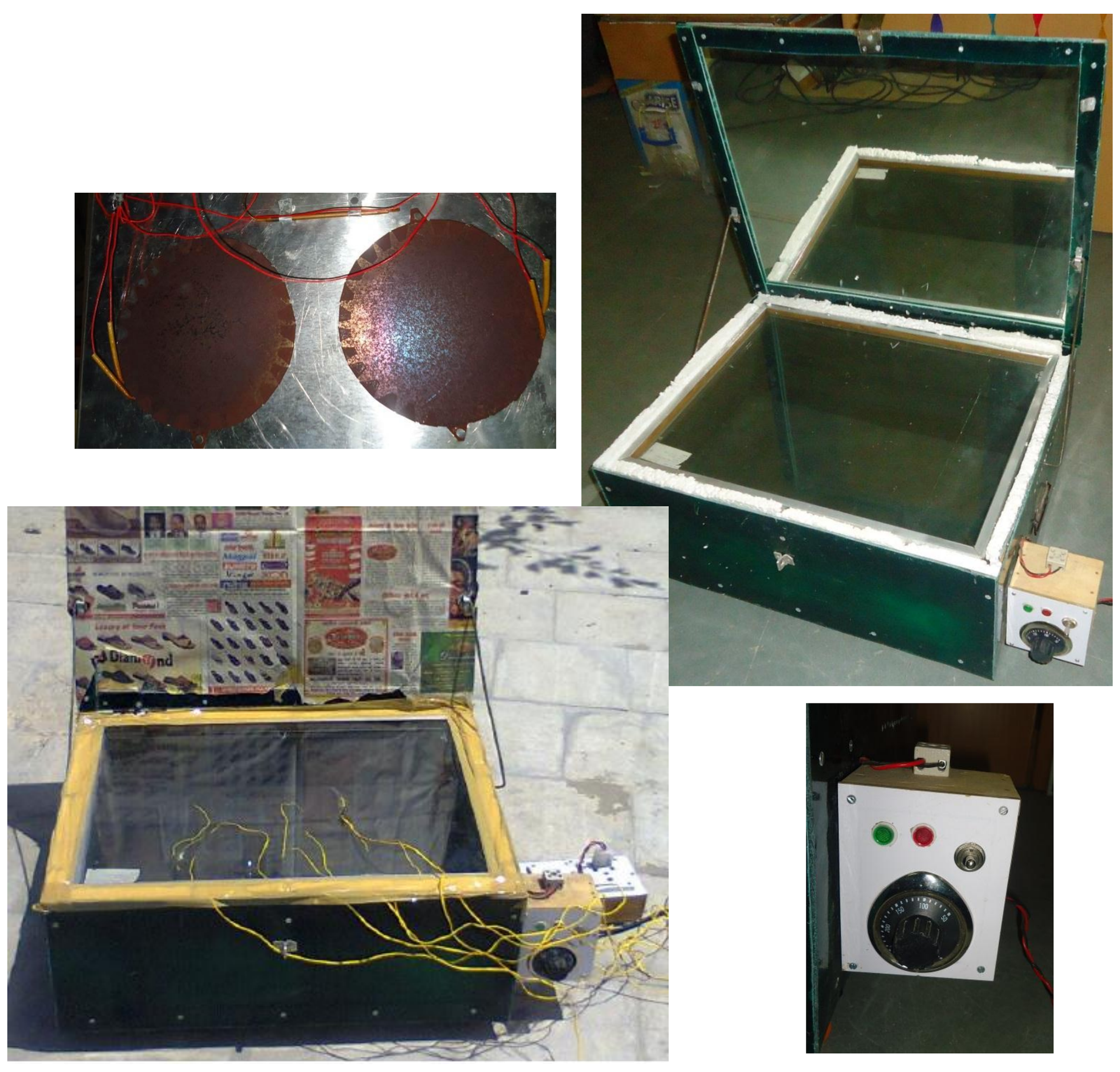

Fig. 1: Photographs of the system along with electrical back-up arrangement

EXPERIMENTAL STUDY

All the experiments were performed at the University of Rajasthan, Jaipur (26.92ºN, 75.87ºE), India as per BIS. Electricity consumption (EC) during indoor and outdoor experiments was measured by an electric meter of accuracy 0.01 unit (kWh). Meter reading was recorded in every 10 min interval in outdoor test but, for indoor test it was recorded in every 5 min. The experimental study of SEC has been carried out in the following modes: (i) indoor test with back-up (ii) outdoor test with back-up (iii) outdoor test without back-up.

Fig. 2: Pyranometer and CI-305 thermometer

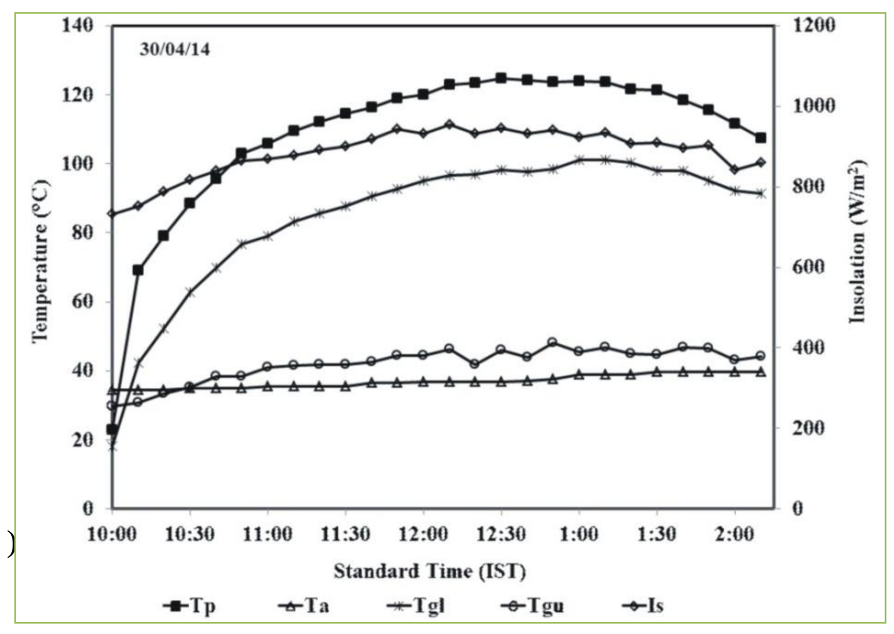

Fig. 3: Thermal profile (30 April 2014) of outdoor test without back-up without water load, without reflector (T_p, T_a, T_{gl} and T_{gu} are the plate, ambient, glaze's lower sheet and glaze's upper sheet temperatures, respectively, and I_s is the solar insolation).

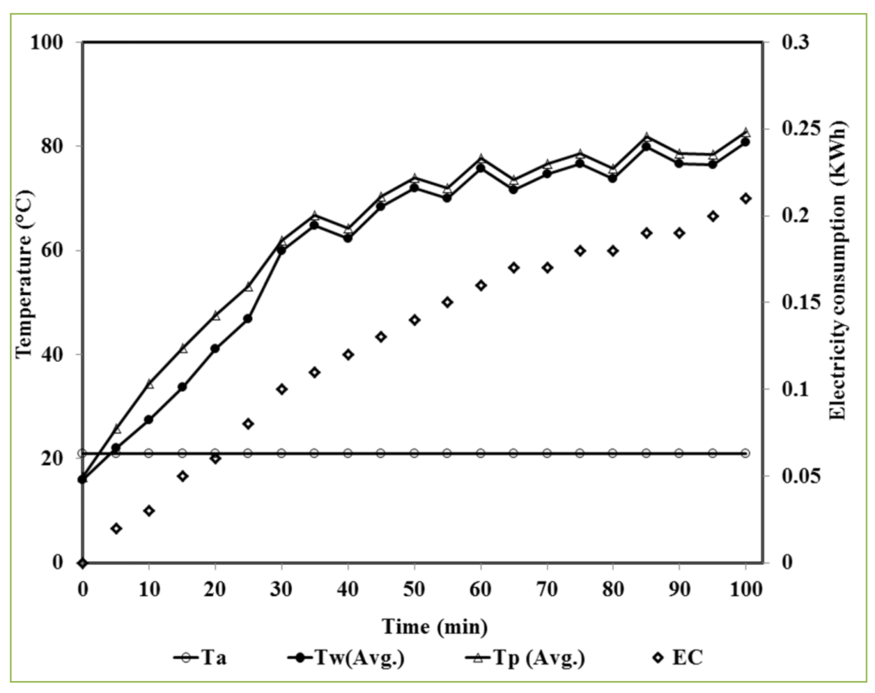

Fig. 4: Thermal profile (11 Feb. 2016) of indoor test (I) with back-up with 1.2 kg water load, maximum temperature set on 90 °C (T_w (Avg.) is average of water temperature, T_p (Avg.) is absorber plate temperature, T_a is ambient temperature and EC is electricity consumption

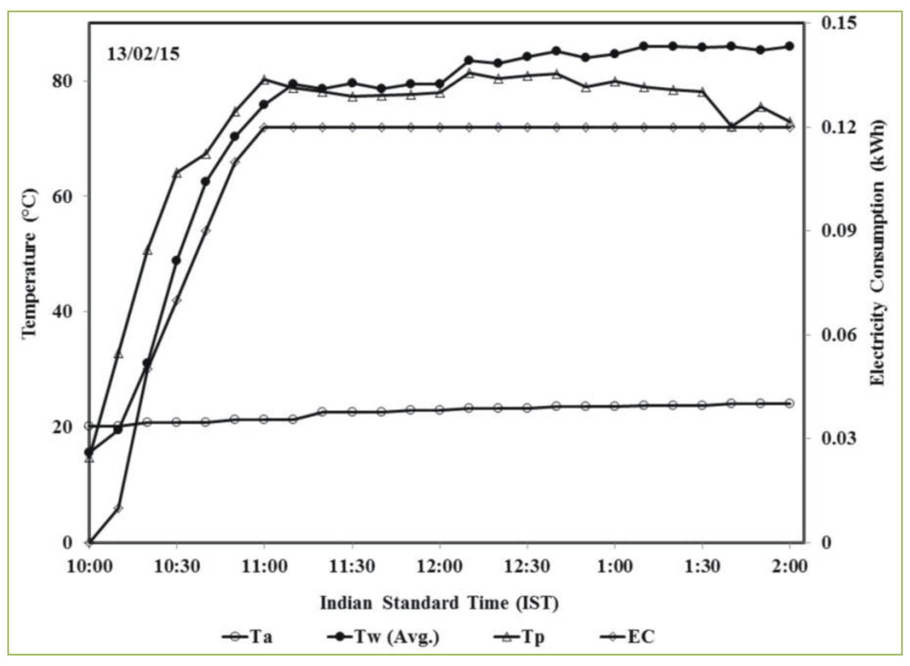

Fig. 5: Thermal profile of outdoor test (I) with back-up with 1.2 kg water load without reflector, maximum temperature set on 90 °C (T_w (Avg.) is average of water temperature, T_p is absorber plate temperature, T_a is ambient temperature and EC is electricity consumption)

RESULTS AND DISCUSSIONS

- The temperature profile under stagnation test is shown in Fig. 3. It shows that the temperature of absorber plate increases with the time of day until it attains the maximum value 124.6°C at 12:30 pm (945 W/m², ambient temperature 36.9 °C). The value of first figure of merit (F_1) is found to be 0.093 °Cm²/W. Optical efficiency of the system is 67%. This temperature profile also shows that on clear sunny day system is capable to cook boiling type food.
- From Fig. 4. (max. temp. 90 °C), the average water temperature (T_w(Avg)) reaches near 80 °C in 75 min and it is sustained further. For cooking time period (**Δt_s**) 105 min about 0.23 unit electricity (P_{rb} = 131 W) is consumed. This cooking time is considered as per Ref. [11].
- For the same temperature values (90 °C) outdoor tests are also performed on a partial cloudy day test results are plotted in Fig. 5 (outdoor test-I). Form Fig. 5 (max. temp. 110 °C), T_w(Avg) attains 80 °C in 70 min and for the cooking in 100 min about 0.12 unit of electricity (P_{rb} = 72 W) is consumed. The average insolation is 614 W/m^2 for the cooking period.
- Experimental results show that with very less consumption of electricity system is capable for cooking in all modes.

Table 2: Experimental and calculated values of electric back-up

Electric back-up power (W)	Indoor test-I Δt_s = 105 min	Outdoor test-I Δt_s = 100 min
P_{rb} (Exp.)	131	72

CONCLUSION

An electric back-up solar cooker provides superior cooking results as compared to conventional solar cooker. It is a better solution of one major drawback of solar cookers that is inability of cooking during rainy and cloudy days. The developed system performs in three modes: (i) outdoor without back-up (ii) indoor with back-up (iii) outdoor with back-up. All these new features may promote solar cooking in urban as well as in rural areas.

ACKNOWLEDGEMENT

Authors are grateful to the University Grant Commission (UGC), New Delhi, India for the research grant.

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6th SCI World Conference, Muni Seva Ashram Goraj, Vadodara, Gujarat, India, 16-22 January 2017.