

Conversion of a Solar Geyser to Solar Cooker & Its Performance Evaluation

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Abstract— For reducing the consequences of global warming and fuel scarcity, we need to change dilemma in terms of cooking. For resolving this issue, the solar cooking offers the best alternative. There are various designs of solar cookers. Different types of solar cookers are presented by a number of researchers over the decade that includes the box type solar cookers and parabolic type solar cookers. However, these types of solar cookers have limited performance in terms of tracking and operating during night time. An evacuated tube solar geyser is converted into a solar cooker which is obsolete from tracking and cooking can also carried out during night time having a thermal storage unit (TSU). The performance of the system is observed during clear days and nights of August and September 2019 in Peshawar, Pakistan. The maximum temperature attained by the system is recorded 98.5 °C. From the observed experimented data, the results indicate that the system is faithfully performing under the required climate conditions.

Keywords— TSU Thermal storage unit, Evacuated tube solar geyser

I. INTRODUCTION

Cooking is one of the major necessities for people around the world. That accounts for one-third of the energy of the total primary energy consumptions in the developed countries of the world [1]. There are about 2.9 billion people still dependent on biomass fuels for cooking [2]. These fuels include firewood, charcoal, dung, and agricultural residues which contribute to greenhouse gases. In rural areas, biomass fuels are the only available energy source for cooking. It's been estimated that more than 2.52 billion people will still dependent on biomass fuels by the end of 2030 [2]. It is therefore highly desirable to establish complementary, appropriate and inexpensive cooking methods based on renewable sources of energy. Therefore, the solar energy is one of the efficient, environmental friendly and affordable alternative solution for cooking. In Asian countries the solar energy has very high potential. Horace de Saussure presented the first ever solar oven in 18th century after that many types of solar cookers have been emerged [3,4]. Various designs of solar cookers are in used in many parts of the world to fulfill

the domestic needs of the users. The most common type solar cookers available are the direct type box type solar cookers and the parabolic type solar cookers [5]. The direct type solar cookers have limited performance in terms of frequently tracking the sun and lack of TSU (Thermal storage unit) for preparing the food during the night time. In order to resolving the need of thermal storage unit, the solar cookers having vacuum tube collectors are the best option. Solar cookers having evacuated tube collectors have several advantages: they do not need constant supervision to track the solar rays, they can attain very high temperatures and the cooking can also be performed in the shade or inside a building (kitchen.) in order by placing the storage unit (TSU) inside the building. For considering such design that consist of having the evacuated tube collectors and the Thermal storage unit (TSU), the solar geyser is the best option. In order to fabricate such design that can perform cooking during day and night time and also the stored water can also be used for cleaning purposes. Solar geyser cooker is one of the most effective way to harness the solar energy for cooking, drinking and cleaning purposes.

This paper presents the designing of a solar geyser cooker for cooking of water base ingredients e.g beans, rice, meat, vegetables etc. Further more performance of the system has also been analyzed, such as temperature inside the cooker, ambient temperature, solar irradiance to evaluate the performance of the solar cooker. Performing such analysis the system has been installed at roof top at the Energy Center of UET, Peshawar.

II. MATERIALS AND METHODS

A. Description of the Solar Geyser Cooker

The Solar geyser has been modified and fabricated as shown in fig 8. It is composed of 3 major parts the supporting structure, the collector and the thermal storage unit. The length of the external storage unit is 94.80 cm while its height is 45.7 cm, the length of the internal tank is 64 cm while its height is 35.5 cm, between the two tanks a two inch thickness of insulator is provided for keeping the water hot for a very longer period. A head of the storage tank has been designed for placing the cooking pots inside the storage tank. The head of the storage tank is basically divided into three parts, the upper section, the

lower section and in the middle a 2 inch thick polyurethane insulator. The outer section length of the head is 25 cm and width 25 cm while the inner section of the head is 18 cm in length and 18 cm in width. The capacity of the storage tank is 100 liters. The water will be used as a sensible heating medium for cooking. The collectors of the system are evacuated tube collectos. There are total 10 number of tubes that are connected

to the storage unit in order to capture the solar energy for heating the water. Each tube is 173 cm long with a diameter of 4.2 cm. The speciality of evacuated tube collectors, they do not need tracking mechanism. They can attain very high temperatures upto 300 °C. Due to the presence of vacuum inside these tubes, the heat loss is nearly negligible.

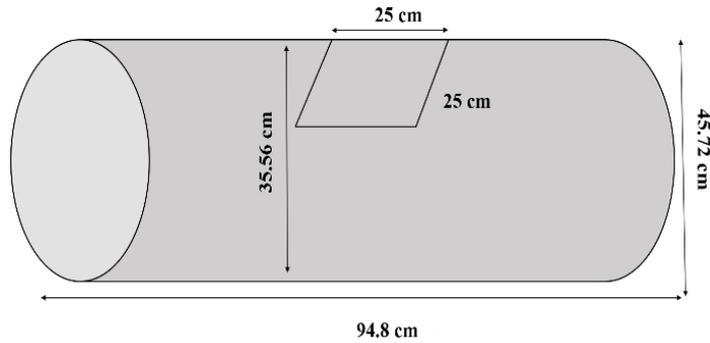


Figure 1. Model of TSU of the solar cooker

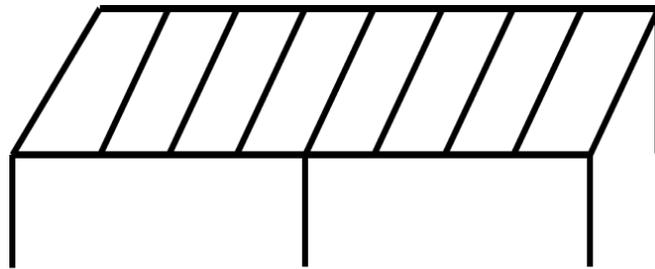


Figure 2. Supporting stand for holding cooking pots inside TSU



Figure 3. Tank of solar geyser



Figure 5. Lid of the TSU with insulation in between



Figure 4. 25 cm X 25 cm cell has been made at the top of the tank



Figure 6. TSU with closed lid



Figure 7. TSU with open lid



Figure 8. The complete solar geyser solar cooker system

B. Performance Evaluation of the Solar Cooker

Experiments were conducted on a prototype mode of solar geyser cooker during the month of August and September 2019 in Hayatabad, Peshawar with a tilt angle of the collector 34°. The following quantities were measured during testing of the performance evaluation of the system: Solar irradiance (I_0), Ambient temperature (T_A), Thermal storage unit temperature (T_S) and time (T). The data was registered by using a data logger and a pyranometer in intervals of 10 min. The temperatures were measured using NiCr-Ni thermocouples. One was attached inside the TSU (T_1) and the other one was attached outside of the TSU in order to measure the ambient temperature of the solar cooker surrounding (T_2). The inner tank of the Solar geyser is stainless steel which have a capacity of 100 liters. Water has been filled inside the inner tank of the solar geyser up to 72 liters. While the outer tank of the solar geyser is made from a Galvanized steel. Between inner tank and outer most tank of the solar geyser insulation has been provided with a material called polyurethane which is quite feasible effective and cheap. Performing the performance evaluation task, the head of the storage tank of the solar geyser cooker system has been carefully closed in order to avoid any losses during the recording of readings. Three different days of the months and nights reading have been recorded. The procedure of collecting data during day time is a bit different from data collection during night time.

1) T_A & T_S

A digital data logger (TM-947SD) was used for measuring the ambient temperature (T_A) and the the temperature of the storage unit (TS). The data logger was set with a duration of 0-600 seconds. After every 10 min the data logger automatically record the required temperatures.

2) Solar Radiation Intensity

A meteorological grid was used for taking the solar radiation intensity readings.

3) Efficiency of the cooker

The efficiency of the solar cooker was calculated by using the following equation

$$\eta_{sc} = \frac{E_{OUT}}{E_{IN}}$$

η_{sc} ; Efficiency of Solar Cooker

E_{OUT} ; Output Energy

E_{IN} ; Input Energy

a) Input Energy (E_{IN})

$$E_{IN} = Ac * I * 600$$

Ac ; Collector Area

I ; Solar Irradiance

600 ; number of seconds of each interval

b) Output Energy (E_{OUT})

$$E_{OUT} = \Delta T * M * c_p$$

ΔT ; Temperature difference during 600 seconds ineterval

M ; Mass of fluid inside the storage tank

c_p ; Heat capacity of the fluid (for water 4186J/kg °C)

III. RESULTS AND DISCUSSIONS

There are total 11 experiments were conducted on this prototype model of solar geyser cooker. Three experiments were conducted on three different days for the collection of data during data daytime and three experiments were conducted on three different night for the collection of data during night time. Furthermore 5 different dishes were also cooked in order to evaluate the performance of the system.

A. Data Collection During Day Time

In this section, three experiments were conducted on different days of the month to observe the performance evaluation of the solar geyser cooker. For conducting day time readings and observing the maximum temperature with respect to solar irradiance and time. Fresh water has been filled early in the morning just before the sun rise in order to observe the collector performance in how much time the system can attain the maximum temperature. All the measurement instruments are connected for recording the real time readings. After filling water in the storage tank with a capacity of 72 litters by observing it very carefully and connecting all the devices the meters are now ready to start. All of these experiments are performed at the energy center of uet Peshawar. After conduction the readings and putting all the data in the excel sheet following graphs are obtained,

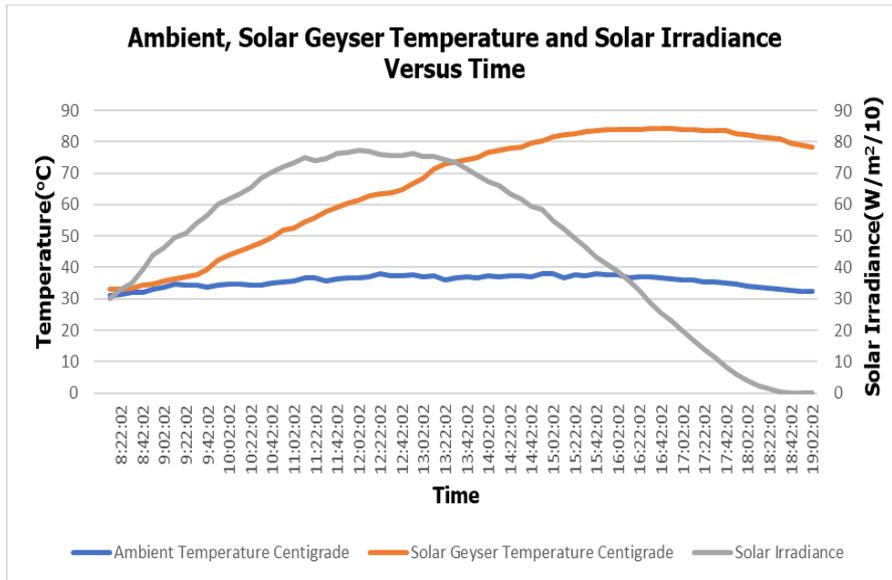


Figure 9 Variation of solar irradiance, ambient air temperature & thermal storage unit of solar geyser temperature on one-day test run with water on 8 September 2019.

The first measurement was conducted on 8th September 2019 at day time as show in the Fig 9. Four quantities have been shown on the plot, the blue line indicates the Ambient temperature of the Solar cooker surrounding (T_A), the orange line indicates the temperature inside the thermal storage unit of the solar cooker (T_S) while the silver line shows the Solar irradiance (I_o). From the graph it can observe at 8:22 am in the morning the ambient temperature was 31 °C while the solar irradiance was recorded 300 watt per square meter and the temperature inside the cooker has been recorded 33 °C due to some water that was already stored inside the tubes. In just 6

hours and 30 minutes, the solar cooker attains its peak temperature of 84 °C of that day. From the graph it can be observed as the time passes the solar irradiance also decreasing, At 7 pm of the evening the solar irradiance comes to zero while the temperature inside the storage unit is still at its peak and is quite stable. There is no fluctuation has been observed after the sunset inside the storage unit temperature. Which shows that the system can also be used for cooking during night time.

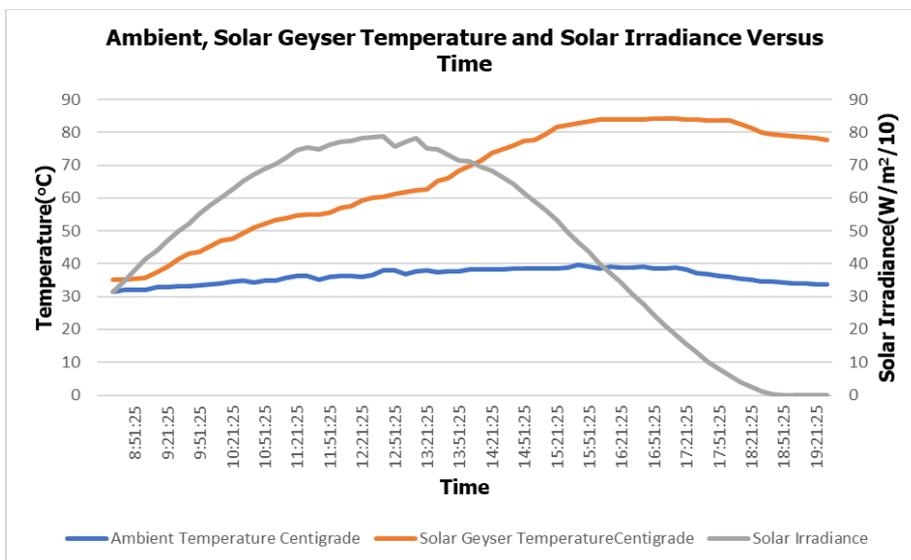


Figure 10. Variation of solar irradiance, ambient air temperature & thermal storage unit of solar geyser temperature on one-day test run with water on 9 September 2019.

The Second measurement has been performed on 9th September 2019 shown in fig 10. Same procedure has been applied as the previous experiment. The 1st reading was conducted at 8:21 am in the morning. In 6 hours and 20 minutes

the system attained its maximum temperature of 84.1 oC which is quite similar to the previous the reading.

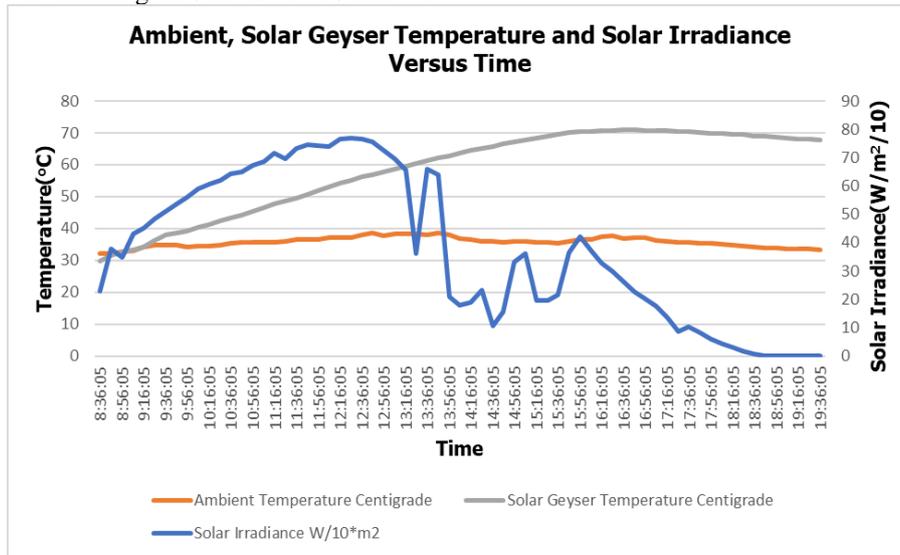


Figure 11. Variation of solar irradiance, ambient air temperature & thermal storage unit of solar geyser temperature on one-day test run with water on 24 September 2019.

The 3rd and final reading of the day time was conducted on 24th September 2019 which was quite hazy day as we can observe it from the plot fig 11. From the figure the blue line indicate the solar irradiance while the orange and silver line indicate the ambient temperature and the solar geyser cooker temperature. Having a cloudy day still the performance of the system is not affected and the cooking can also be carried out. The maximum temperature attained by the system in 6 hours and 50 minutes which was recorded 80 oC.

B. Data Collection During Night Time

In order to evaluate the performance of the system during night time 3 experiments have been performed for the collection of data during night time. From that data we can concluded that whether the system is stable for cooking during night time or not stable. Regarding collection of data during night time, three parameters have been observed the T_A and the T_S with respect to time. After the collection of data following graphs are obtained,

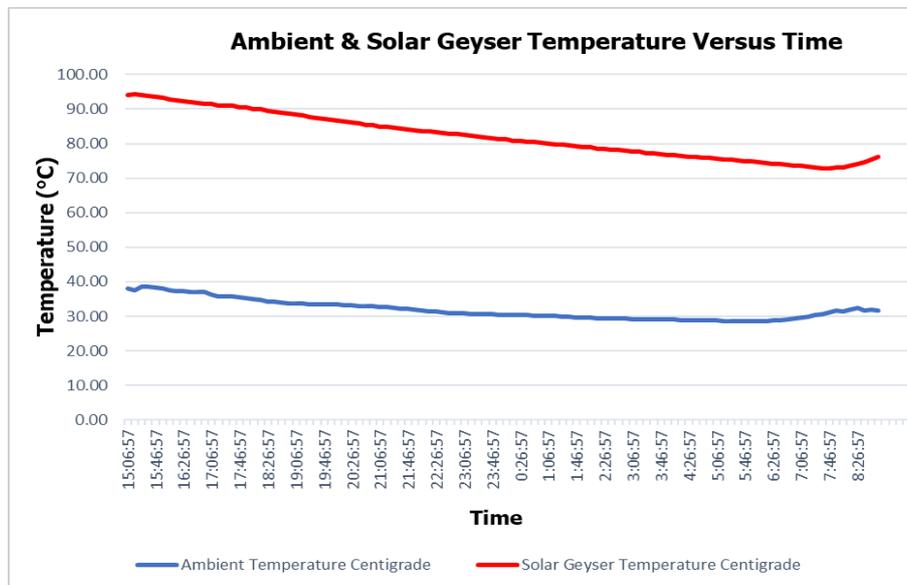


Figure 12. Variation of ambient air temperature & thermal storage unit of solar geyser temperature on one-day test run with water on night of September 10, 2019.

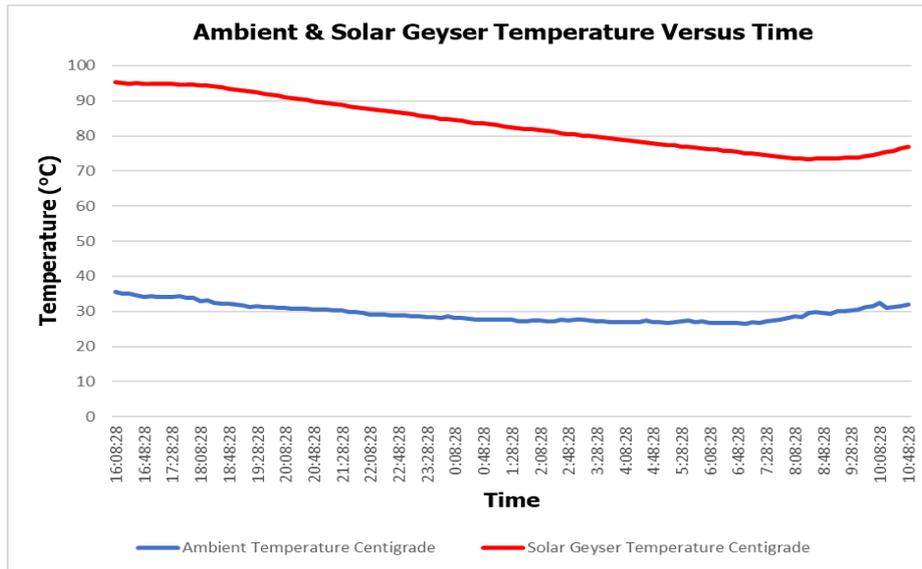


Figure 13. Variation of ambient air temperature & thermal storage unit of solar geyser temperature on one-day test run with water on night of September 15, 2019

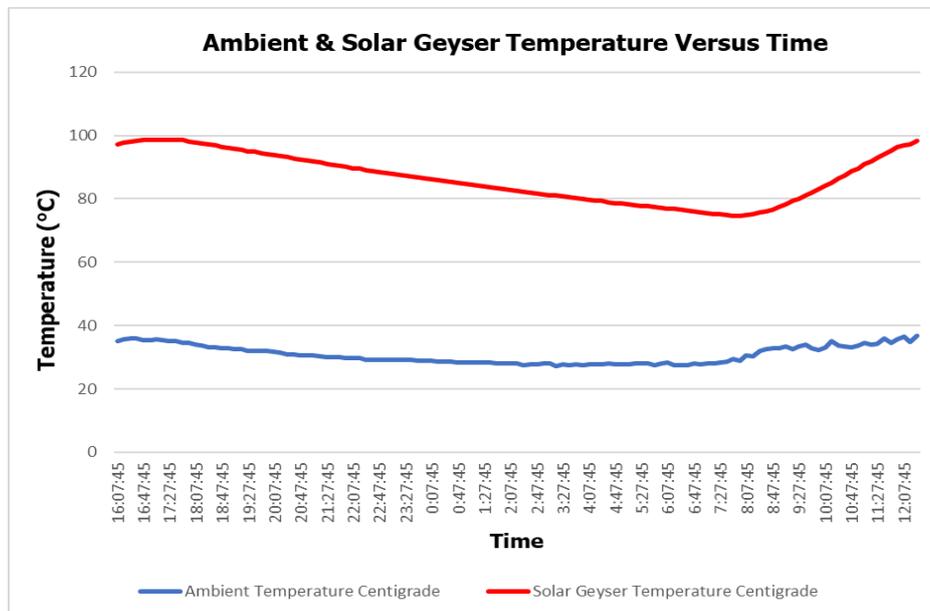


Figure 14. Variation of ambient air temperature & thermal storage unit of solar geyser temperature on one-day test run with water on night of September 17, 2019

TABLE I. PERFORMANCE DURING NIGHT TIME

S. no	Average Temperature Each Night		
	Day/Month/Year	Starting Time of Reading	Average Temperature
1	September 10, 2019	7:00 pm to 9:00am	82 °C
2	September 15, 2019	7:00 pm to 10:00 am	83.3 °C
3	September 17, 2019	7:00 pm to 9:30 am	86.5 °C

C. Efficiency of the System

From the recorded data during day time, the efficiency of the system of each day are plotted,

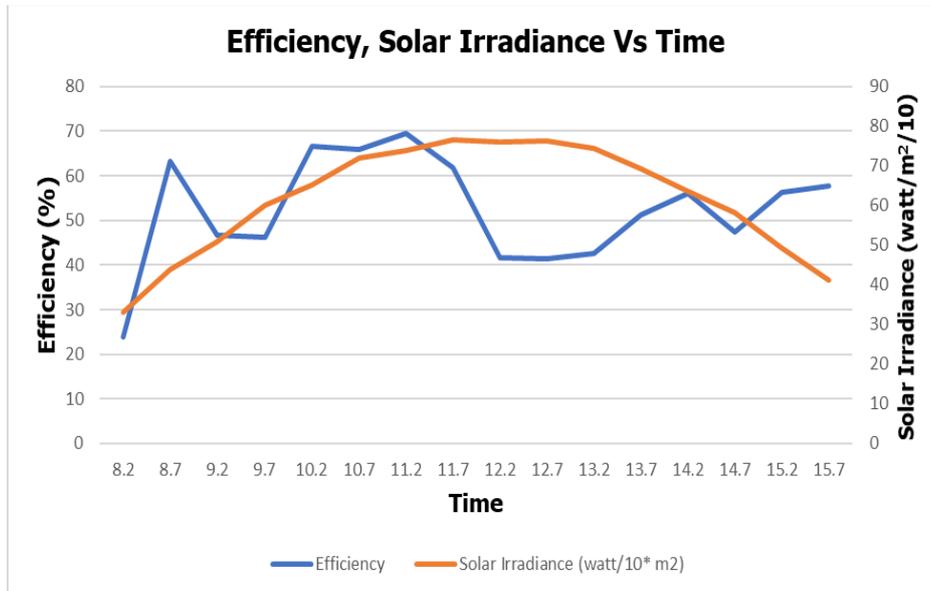


Figure 15. Variation of efficiency & solar Irradiance with respect to time of thermal storage unit on one-day test run with water on September 8, 2019

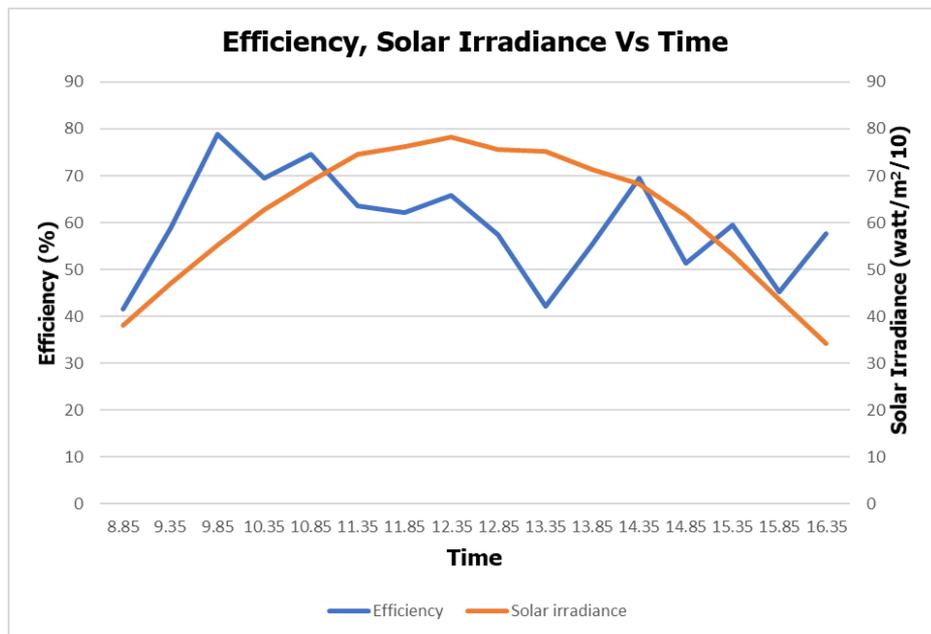


Figure 16. Variation of efficiency & solar Irradiance with respect to time of thermal storage unit on one-day test run with water on September 9, 2019.

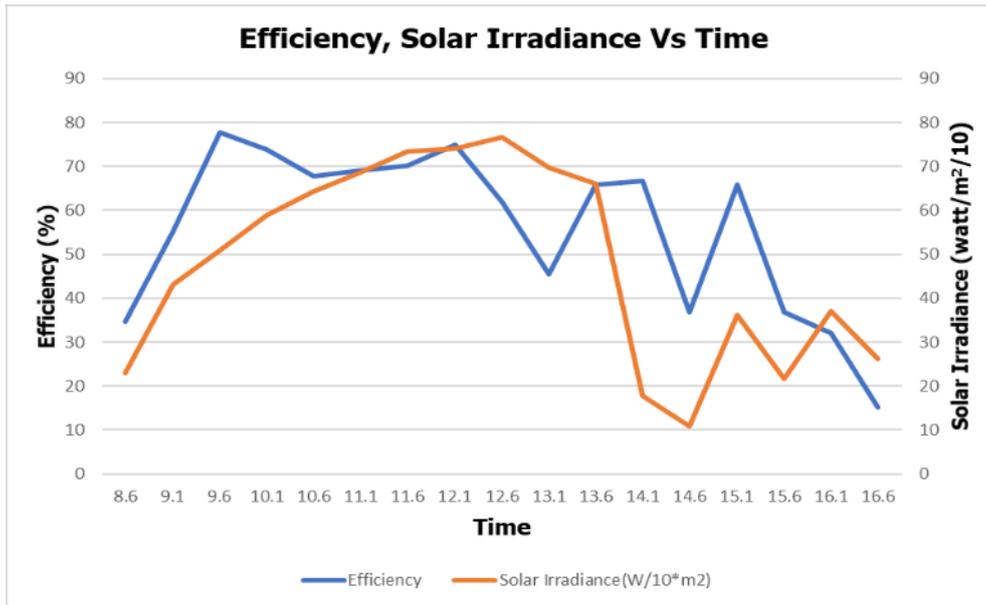


Figure 17. Variation of efficiency & solar Irradiance with respect to time of thermal storage unit on one-day test run with water on September 24, 2019.

The preceding experimentally calculated plots indicate the η_e of the solar geyser turned solar cooker. As sunrays fall on the tubes the solar geyser starts functioning and the temperature rises. From the results, it is indicated that the rise in temperature greatly depends on the capacity of water inside the geyser. In this project, the capacity of the tank was 100 liters and we provided 72 liters of water to the solar geyser to prevent the complete dipping of the cooking pot. The minimum efficiency recorded during the starting time was recorded 11 %, while the maximum efficiency was 77.8%. The average efficiency in each case is given in table 2.

TABLE II. EFFICIENCY OF THE SYSTEM

S. no	Average Efficiency	
	Day/Month/Year	Average Efficiency
1	September 8, 2019	52%
2	September 9, 2019	57%
3	September 24, 2019	56%

D. Experimented Cooked Food by Solar Cooker

There are total five dishes has been prepared using this prototype. At first experiment three dishes has been prepared during day time which are red beans, white beans and black beans. In second and third experiment which are performed during night, the foods that has been cooked on the solar cooker during night time are the goat feets, and the nihari. The timings of each dish are mentioned in the table which is given below.

TABLE III. COOKED FOOD

ITEMS	Cooked Food		
	Time Required	Date	Time
Red Beans	3 hours	Sep, 11 2019	11:00 to 14:01

ITEMS	Cooked Food		
	Time Required	Date	Time
White Beans	3 hours	Sep, 11 2019	11:00 to 14:01
Black Beans	3 hours	Sep, 11 2019	11:00 to 14:01
Goat Feets	5 hours and 45 min	Sep, 21 2019	10:30 to 16:15
Nihari	Cooked at night time	Sep, 27 2019	17:00 to 8:30

CONCUSLION

A solar geyser has been converted into a solar cooker that can be either used for cooking during day and night time and also the stored water inside the storage tank of the system can also be used for cleaning dishes, washing even for bathing. The maximum temperature attained inside the TSU was recorded 98.5 °C while the minimum temperature attained by the system was recorded 74.3 °C. Using of evacuated tubes collectos the performance parameters of the solar geyser converted solar cooker evaluated under tracking free conditions are satisfactory.

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