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Performance and Analysis of Thermal Energy on Solar Reflector Cooker - Application of an Alternative Source of Energy in Cyprus

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Abstract: This paper proposes a solar cooking device made of a flat array of concentric mirrors tilted to focus on a small area. The mobile array of mirrors is mounted on a stand to be movable around a ball joint and with a carrier for a cooking vessel held by a double crank at the focal area of the mirrors. Current solar cooker inventions comprise a reflector that is constructed from a plurality of reflective concentric rings arranged in a planar configuration. The term planar configuration, as used herein, is defined as a configuration in which flat rings are arranged with some part of each ring lying in a plane that includes some part of each other ring although each ring has a different tilt. This configuration is to be distinguished from a parabolic configuration. The tilt of the flat concentric rings of the cooker permits sunlight to be focused at an area, about 5 inches in diameter, obviating the need for the more expensive and difficult-to-manufacturer parabolic reflector, and is more conducive to heating a cooking vessel.

Keywords: Solar cooker, Tilt angle, Thermal radiation

Introduction

Since firewood used for cooking leads to deforestation and marketable fuels are not readily accessible to the ordinary man, the need for solar cookers becomes necessary, although waste from agriculture and dried dung from cows used for cooking is a good stimulant, and the resources used for collecting fuel can be diverted to other useful purposes. With the development of so cookers and alternative energy sources for cooking, still they are yet to be utilized as expected because they are incompatible with the normal conventional cooking practice. With the situation of things, it is only appropriate for of majority of people around the world afraid of fuel and the finance to pay for cooking with fuel. Aside from the many advantages on the health, time, and income of the users and on the environment, solar cookers can be used for boiling drinkable water, this provides access to safe water to millions of people thus preventing waterborne illnesses.

Concentration of Solar cooker, or solar oven, the use up energy through sun rays (which is the heat from the sun) to cook, fry, heat or pasteurize drinks or food. The vast majority of solar cookers presently in use are, low-technology and relatively cheap devices (Althouse et al., 1979). Because they make use of 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

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gathering firewood for cooking. Solar cooking as a form of cooking and deployed in a situation where marginal fuel uses up is important (Yazaki, 2010), or the threat of unintended fires is becoming great. They are similar to a solar oven, which uses heat from sunlight to cook food. It eliminates the need for fuel or electricity for the purpose of cooking. Solar cookers are available in several sizes and configurations, all of which have their pros and cons. Over time solar cookers have been exposed to numerous types of assessments to rate their performance. A set of solar cooker tests, measures, and equations was presented in other to assess the performance of the solar cookers especially box-type type cookers (Mullick et al., 1987). They presented an assessment and endorsement which was later embraced the d by the Bureau of Indian Standards (BIS). And in the, past the energy aspect has been totally concentrated on (Richard, 2005).

Figure 1. Solar panel cooker

Nevertheless, it was Funk in who 2000 discovered the necessity to change a Universal method for evaluating all solar cookers, and later his approvals were soon embraced by United States Agricultural Engineers as ASAE S580. However, subtests tests have been conducted on solar cookers, and their results convert that solar performance is related to percentage efficiency Mukaro and Tinarwo (2008) and Nandwani et al. (1997). Several experiments was conducted and assessments following ASAE S580 for box and sheet kind of solar cookers has all been tested (McMillan & Jones 2001; FSEC, 2002; El Sebaii & İbrahim, 2005)

Figure 2. 3D advance modelling and simulation of cylindrical panel solar cooker

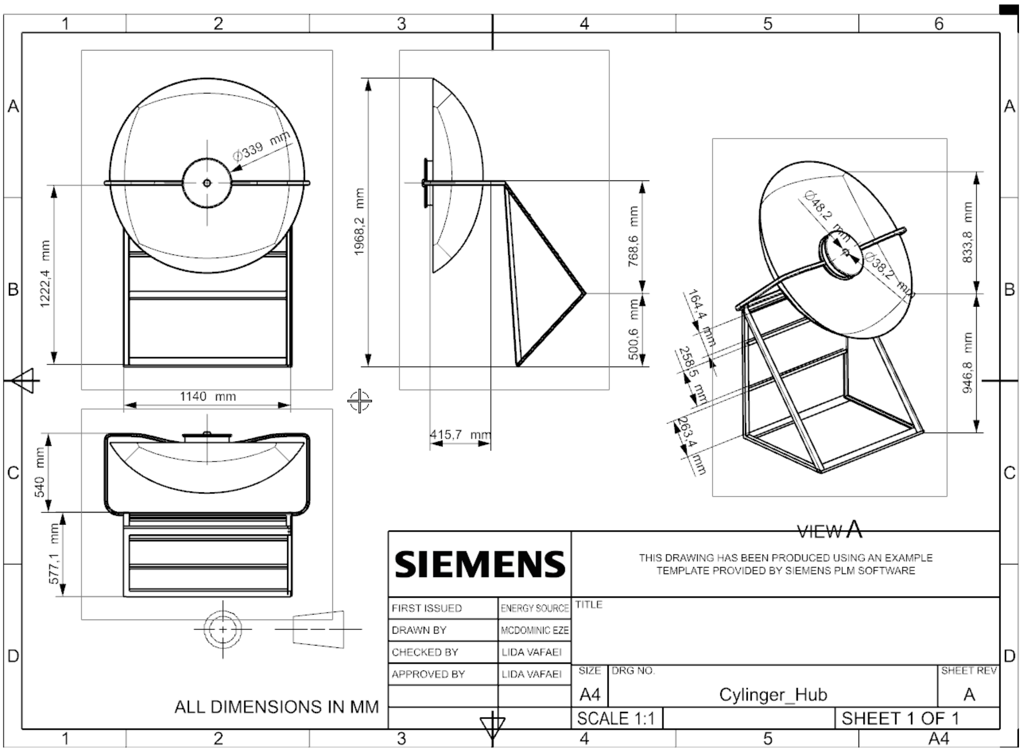


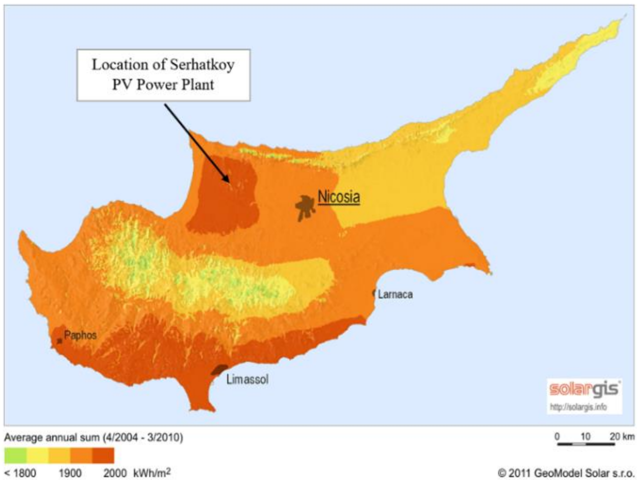
Figure 3. Geometricalional drafting of cylindrical model solar cooker

Background of the Project

European Commissioning body classified Cyprus as part of the utmost susceptible countries in the EU when it comes to reliance of energy, with regards to security of energy sources, but intensive changes are being implemented to deliver a continual swing to a supplementary energy autonomous economy, while focusing on a viable renewable means. Cyprus today has one of great prospective for solar energy of many European Union countries, but still they import record number of their electricity supplies. They presently have percentage rounding to 10 in terms of alternative energy portion, there is still an objective of increased percentage to 16 by 2020. Giving that Cyprus alternative power Roadmap, which is intended to produce within 25 - 40 percentage of required energy supply through RES in the year 2030.

The history of the solar cooker project has been a result of co-operation with one Cyprus NGO. Together the organizations, the Green Cyprus Community Project in Cyprus, and Technology for Life formed a base for the future solar cooker dissemination in Northern Cyprus. The 'Green Cyprus Community Project'(referred to later as the Green Cyprus) was originally a tree nursery in Cyprus. The Green Cyprus is a - development co-operation - program, which is a citizen's organization. The purpose of the project is to prevent complete desertification in Northern Cyprus by founding tree nurseries, planting trees and organizing environmental counselling through the approach of using solar cookers. Spearheading the drive to meet this target is an increase in using battery systems, to store excess energy and create a ‘power bank’ for the nation and sing the sun power for domestic purpose that include cooking through the use of solar cookers. Despite having massive potential in terms of both solar and wind energy, one of the problems in utilizing these energy sources, is being able to deliver them close to the point of consumption, where they are actually needed.

The 2019 budget for this sector is set at 64.96 million euros, with 58.61 million euros committed to subsidies, of which 29.81 million euros are directly related to utilizing power from renewables. The 29.81 million euros’ figure includes 25 million euros for a new subsidies plan design, to encourage the use of renewable energy sources for houses (net metering, domestic cores and roof insulation), and promoting ‘green’ transport – such as plug-in electric or hybrid vehicles. The project brought together a wide range of specialties, from sustainable architecture, carbon accounting, energy mapping and sustainable technology. “In the case of Cyprus, one thing we have to look at is the huge climate potential of the empty rooftops which provides us the concept of initiating solar cooker in Cyprus, so we know what we can do with the abundant sun. It is not about rebuilding Nicosia, but to see what can be done with existing technology.” A look at the average solar radiation per year this tells the story better.



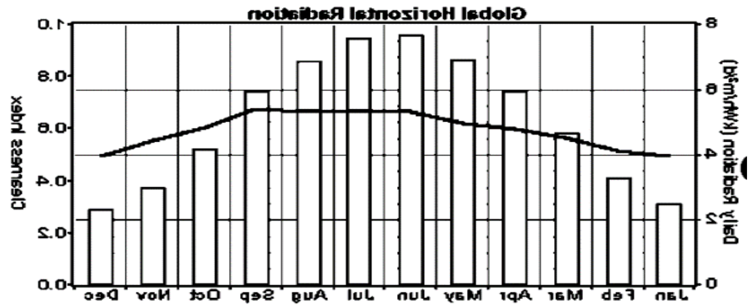


Figure 4. Daily radiation – clearness index average solar radiation in Cyprus throughout the year

Table 1. Cooking efficiency

When it is not ok	When it is ok
The sun low in the sky	The sun high in the sky
Partly cloudy	No clouds
Much wind	No wind
White or shiny—no lid	Black pots with lid
Large, heavy pot	Max 5 liter, light weight pot
Too much water	Little or no water added
Large quantity— big pieces of food	Small quantity— small pieces of food

Figure 5. Cooking type with respect the position of the sun

Solar Performance Procedures Testing with the Use of New Standard

The challenges of testing several designs of solar stove devices led to the establishment of several testing criteria for assessing thermal cookers all over the world. American Society of Agricultural Engineering (ASAE) Standard S580, the standard developed by the European Committee on Solar Cooking Research (ECSCR) Bureau of Indian Standards, based on work by Mirdha and Dhariwal (2008).

Be that as it may, the three criteria have insufficiencies, India guidelines give testing standards dependent on warm test methodology for box-type sun-powered cookers. The exhibition of the reflector-based sun-based cooker executed right now is done dependent on this adhering to guidelines, IS 13429. The standard featured two techniques for testing: a stagnation (test without load) and a heap test. Test on the cooker was done in the Month of March when the sunlight-based illumination was greatest (Mukaro &Tinarwo, 2008). The test was completed between 11.00 am and 4.00 pm for ten sequential days so as to decide the most extreme plate and water temperature in the cooker during this period.

Various tests without load were directed on the cooker to decide its temperature of stagnation and furthermore to check the increased cooker inner temperature. water was placed in a cylinder pot and covered and the absorber temperature was measured, water and ambient, as well as wind speed, were measured. The temperature of stagnation, encompassing temperature (ambient) (Ta), and safeguard plate temperature (Tp) were estimated for various times between 11:00 am and 4.00 pm during the activity of the cooker utilizing Type K, mineral protected grounded intersection, 1.6mm width thermocouple with Elix advanced thermometer (LX-6500) capable of reading temperature between -50°C and 750°C. Thermo-Anemometer (PROVA Instrument, AVM 01) was utilized to gauge wind speed (v) and sun-oriented radiation was estimated utilizing a worldwide radiation meter (GRM 100).

Measurement of Performance Analysis

Solar Cooker Performance Factor

$$F_p = \frac{\text{Energy reflected by the reflectors fall on the glass cover}}{\text{Energy falling on the cover due to direct radiation}} \qquad (1)$$

The concentration of the cooker will be (F_p +1).

Rate of Heating Q/min = SPH x Mass x ΔTemperature/min (units = Joules/min)

Solar Cooker Efficiency

$$F_p = \frac{T_{wf,\max} - \overline{T}}{\overline{G}} \qquad (2)$$

$T_{wf,\max}$ is the maximum absorber surface temperature, $\overline{T}$ is the average ambient temperature, and $\overline{G}$ is the average solar intensity in the equation above. F_1 Was calculated to be 0.08 m^{2}K/W. A value of 0.10 m^{2}K/W is frequently used. The following is the thermal efficiency of solar cylindrical cookers (η):

$$\eta = \frac{\text{Energy output}}{\text{Energy input}} = \frac{\left| m_c c_{pw}(T_{wf} - T_{wi} \right| / \Delta t}{I_t A_{sc}} \qquad (3)$$

Where E_o is the energy output of the solar cooker in W; m_w is the mass of the water in kg; c_{pw} is the specific heat of the water in J/kg K; T_{wi} and T_{wf} are initial and final temperatures of the water in K; and t is the time in s.

$$\eta = \frac{mc_{pw} \, {}^{\Delta T}\!/_{t}}{GA} x100 \qquad (4)$$

From the Equation, thee water in the cooking pot is designated by m. The specific heat capacity of water is Cpw, the temperature differential of water is T, the time interval is t, the incoming solar intensity is G, and the area of aperture glazing is A. As shown in the diagram, the efficiency of a solar egg shape cooker ranges from 6.89 to 5.02 percent. The efficiency values may be considered lower when compared to similar designs without heat storage in the literature. Although the effectiveness of a propolis-based latent heat storage media is reduced slightly, the thermal energy content of oven air is preserved until late hours.

Then, if you calculate the weight of mass lost over a specific time period (e.g. 10 mins). But the beaker must be boiling first. i.e. initial mass (@100^{o}C)= 200g; and final mass (10 mins later after continuous boiling) = 175g
ThereforeΔm = 25g (mass$_{final}$ –mass$_{initial}$)
$Q_{to\ boil}$ = Q/min x time
Eg. Let's say that Q= 2516 and the time that we boiled was for 10mins, therefore:
= 2516 x10
= 25160 Joules of energy in 10 mins
Latent heat = Q_{used} / Δmass = J/g

This test was directed after the estimation of Standard Cooking Power and Standard Sensible Heating Time and is expected to quantify to what extent the cooker can keep up a high temperature without being effectively followed to follow the sun. The cooker is left stationary and the temperature of the pot substance (water) estimated, as with earlier tests. This proceeds until the pot substance had diminished in temperature by 20^{0}C from beginning temperatures (for example the last temperature toward the finish of the Standard Cooking Power test). By and by, this time estimation is standardized to 700 W/m^{2}

Result and Discussion

This research brings about deciding the best cooking time when using the solar cooking method, it shows the morning and night hours when the sun points are low, have low sun based radiation force and henceforth, unsatisfactory for sun based cooking. Between about 11.00 a.m. to 4.00 p.m., the sun powered force is high, running from around 650 to W/m^{2}, speaking to a reasonable range for sun powered cooking.

As the sun oriented radiation shifts all around and with the season, the best cooking time may go amiss in view of the impact of overcast spread. The maximum insulation resting at 480W/m^{2} at exactly 2:30 pm and the minimum falls through at 50 W/m^{2} at 11:00 am was noted. The ambient temperature and average solar radiation are respectively 45°C and 400 W/m^{2}. Usually food is fully cooked at a comparative range of 60-70 °C , water reached an amazing amount of about 59- 68°C upon testing at an insulation value of 320 – 485 W/m^{2}

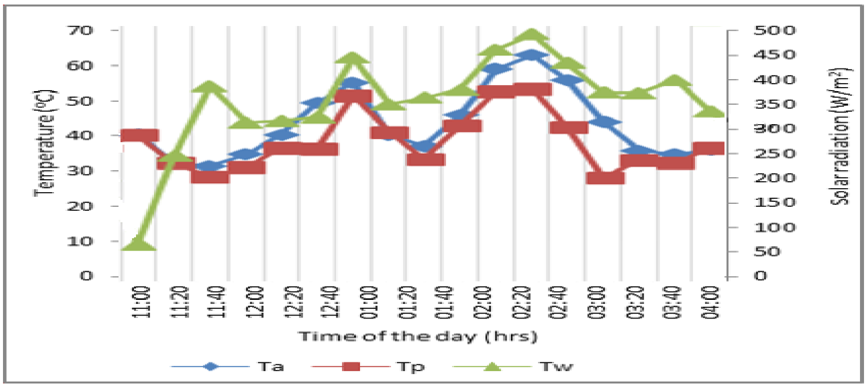


Figure 6. Solar cooker performance curve during heat test of water

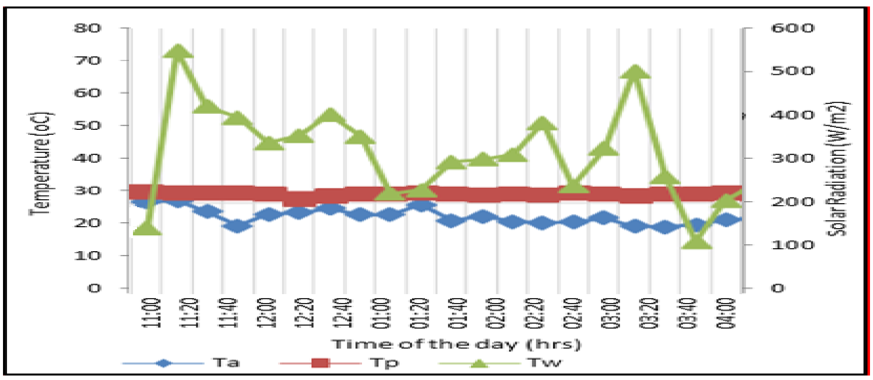


Figure 7. Solar cooker performance curve during heat test of water

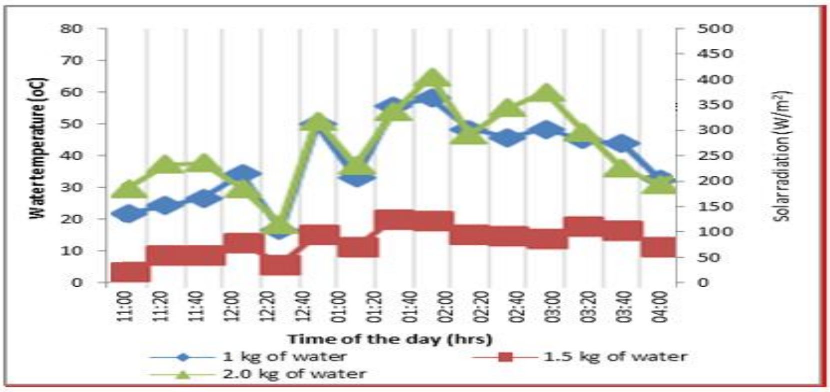


Figure 8. Temperature variation of water with time for dissimilar load

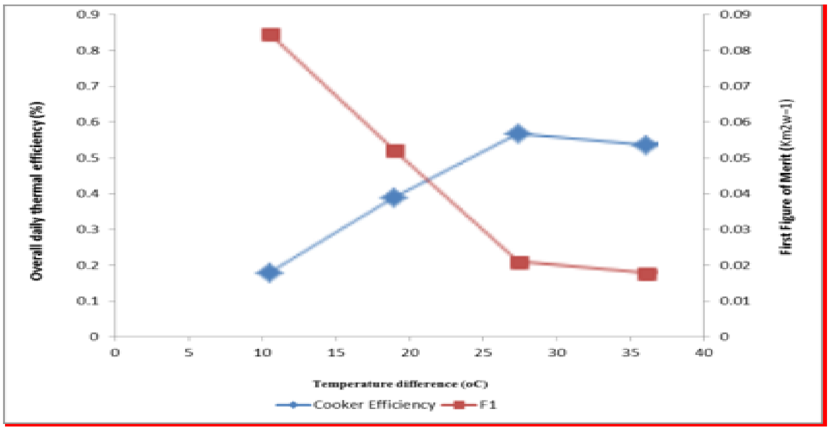


Figure 9. Overall thermal efficiency vs the varied difference in temperature

As Shown in Fig, 3, 4, 5, and 6, the connection between first figure of legitimacy and the general cooker warm effectiveness show that as the estimation of first figure of legitimacy expands, by and large warm proficiency of the cooker increments. At higher estimation of figure of value of 0.075, cooker warm productivity is 0.7 and this happen at temperature distinction of 20°C. Over this temperature, generally warm effectiveness of the cooker diminishes.

Conclusion

The paper introduced the test system and the warm presentation of allegorical sun based cooker actualized in Cyprus, an occasional cloud of climate was seen all through the trial and it caused vacillation in sun-powered radiation. The most extreme segregation of 520 W/m^2 at 2.00 pm and the least of 246W/m^2 at 11.00 am were watched. The normal sun-based radiation and surrounding temperature seen during the time of the test were 403 W/m^2 and 40^{0}C separately. The water temperature esteems somewhere in the range of 60 and 67^{0}C were seen at insolation esteems somewhere in the range of 398 and 520 W/m^2. These happen between the hour of 1:20 pm and 4:00 pm with the most noteworthy water temperature of 67oC at 3:00 pm. The presentation of the cooker as far as the first figure of legitimacy, the second figure of legitimacy, and warm effectiveness show that the cooker contrasts well and worldwide standard. The cooker has a better maintenance limit; this exhibited its appropriateness for cooking even in changing weather. From the presentation assessment of the explanatory sun-based cooker, the qualities standardized cooking power, stagnation temperature; standard reasonable warming time, unattended cooking time, and cooking power at a temperature of 40^{0}C.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Acknowledgements or Notes

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