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Role of Parabolic Dish in Solar Cooking System: A review

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Abstract: A review on various aspects of solar energy for cooking is presented. The review includes design, experimental, applications and potential aspects of solar energy for cooking. A literature is based on various parabolic dish type solar cooker and its various components. State of the art concentrating solar technologies suitable for institutional level cooking includes Parabolic dish and Scheffler dish. A thorough literature survey of applications and potential of solar energy are summarized. Also, the solar tracking system and various heat storage system literatures are reported. Design, construction and operational details of solar cookers have been discussed. Major findings and observations on various aspects of the same are presented.
Keywords: solar cooker, parabolic dish, design, application, potential.

I. INTRODUCTION

This Sun is a huge heat energy source at its origin. At the Sun's surface irradiance is about 63 MW/m^2. However, Sun–Earth geometry dramatically decreases the solar energy (heat energy) flow down to around 1 kW/m^2 on the Earth's surface [1]. This is big loss of clean and free form of energy. This loss can be overcome by using concentrating solar systems which transform solar energy into another type of energy (usually thermal). Solar radiation is converted into thermal energy in the focus of solar thermal concentrating systems. In thermal concentrating systems, parabolic dish are mainly used to concentrate solar energy at one focus which would give high temperature concentration for longer time.

Solar energy can used directly in a variety of thermal applications like heating water or air, drying, distillation and cooking. Cooking process is mainly depends on fuels like liquefied petroleum gas (LPG), wood, kerosene etc. Use of solar energy as a fuel in cooking is the best renewable energy source among other sources. In this literature, various aspect of solar energy utilization, system design and potential of solar energy available on earth are thoroughly presented based on various researchers' studies. Review is specially focused on solar cooking and also some applications are discussed.

A. Review on Design of Parabolic dish type solar system

Wolfgang Scheffler [2] is the inventor of Scheffler Reflectors, large, flexible parabolic reflecting dishes that concentrate sunlight for solar cooking in community kitchens. Nyahoro P. [3] used a finite-difference method to simulate the thermal performance of short-term thermal storage for a indoor institutional solar cooker. They made simulations for a given pot capacity with the storage block made from either cast iron or granite (rock). The effects on cooker performance were compared for a variety of height to diameter ratios of the storage block and size of the area of solar input zone. Their results showed that cast iron have shorter cooking times and less heat loss than granite. The results also indicated that the height of the storage block should be at least one-fifth of the diameter of the block. Schwarzer K. [4] described the solar cooking system with or without heat storage for families and institutions. It has two basic components which are the solar collectors with reflectors and a cooking unit. When thermal storage is needed, a tank filled with pebbles is added to the system. The working fluid, usually a vegetable oil, circulates in natural, thermo-siphon flow through a copper piping that connected this components. The system presented interesting features such as the possibility of indoor and night cooking.

Kumar N. [5] applied an exergy based analysis to solar cookers of different designs. Their study developed a uniform test standard for evaluating the thermal performance of solar cooker with respective their geometric construction. For this, four different geometries of solar cookers are considered. Dafle V. and Shinde N. [6] designed, developed & performed evaluation of concentrating monoaxial parabolic solar concentrator for water heating and low temperature Industrial steam application. He concluded the achievement of concentrating solar thermal devices using Scheffler technology.

Rathore M. [7] reported a few standards for testing and evaluation of thermal performance of solar concentrators based on sensible heating of working fluid. The preceding standard measured only the cooking efficiency and cooking capacity. Apart from thermal efficiency, there is an imperative need for other important parameters of the solar concentrators such as its stagnation temperature, cooking capacity, cost per watts delivered, weight of the cooker, ease of handling and aesthetics. The proposed protocol aimed for evaluation of

thermal performance of solar cooking system and standardization of reporting the test results so that anyone can easily recognize and use it.

Kumaresan G. [8] worked on the performance evaluation of a newly developed double walled cooking unit (tava type) suitable for an indirect type solar cooking application integrated with thermal energy storage system. An experiment was also conducted to evaluate the average heat loss encountered in the system under no load condition and it was found that there was considerable heat loss in the flow circuit during the discharging process. This study will be very useful for the design of solar based indoor cooking units. Phillip Liedke [9] worked on the potential of chain gears as precise and low cost driving systems for rim drive heliostats. After explaining chain gear basics the polygon effect and chain lengthening are investigated. The polygon effect could be measured by a heliostat with chain rim gear and the chain lengthening with an accordant test set up. This work included two gear stages: a rim gear and an intermediate gear. Dimensioning, pretensioning and designing for both stages were explained.

Bhave and Thakare [10] developed a concentrating type solar cooker using magnesium chloride hexahydrate (melting point = 118 °C) as the thermal storage material. It was designed for boiling type of cooking. The developed device was able to store a charge of heat in about 50 min and cook about 140 gm of rice in 30 min from the stored heat. Reddy S. [11] proposed parametric design charts for the Scheffler reflector, which has distinctive advantages such as flexible surface curvature, fixed focal area and shadow less concentration over other solar concentrators. Manufacturers would require design charts for quick estimation of various design parameters like section plane angle, concentration ratio and dimensions of crossbars for the Scheffler reflectors. The input parameters required for the development of design charts are aperture area and focal length, which are dependent on customers' need. The governing equations of the Scheffler reflector have been solved iteratively to obtain the design parameters, which are then used to develop various design charts. Due to design constraints of the Scheffler reflector, inclination angle could not be varied beyond the range of 42° to 44.9°. Error due to circular approximation of crossbars is quantified and is found to be insignificant. A general equation for seasonal change in parabolic profile of the Scheffler reflector has been proposed. Hafez A. [12] presents a comprehensive review on solar tracking systems and their potentials in solar energy applications. His literature overviews the design parameters, construction, types and drive system techniques covering different usage application. There are two main solar tracking systems types that depending on their movement degrees of freedoms are single axis solar tracking system and dual axis solar tracking system. The solar tracker drive systems encompassed five categories based on the tracking technologies, namely, active tracking, passive tracking, semi-passive tracking, manual tracking, and chronological tracking.

B. Review on Performance of Parabolic dish type solar system

Schwarzer K. [13] explained basic characteristics and experimental procedures to test the different types of solar cookers. The variables measured in these procedures are necessary to calculate parameters, which were used to compare the thermal performance of the solar cookers. A simplified analytical model was presented to design simple cooking systems. Gadhia D. [14] discussed the use of Scheffler Solar Concentrators for cooking, both by Direct heating and with Solar generated Steam. He shared some successful installation of the parabolic dish Concentrators. It was found that high capacity installation required complicated sun tracking mechanism which contains sensors, computer controller, high capacity motors etc. It required technical person to operate. Chandak A. [15] presented the Comparative Analysis of SK-14 and PRINCE-15 Parabolic Solar Concentrators. He found that SK-14 is bulky and have transportability problem. He developed a new geometry of solar concentrators with square or rectangular shape called as PRINCE-15

Patil R. [16] studied the performance of Scheffler reflectors. In this system storage reservoir was installed at focus point. It has a single large diameter drum which serves the dual purpose of absorber tube and storage tank. This study suggested that such types of systems must be equipped with necessary mountings and instrumentations to monitor and control the desired thermal parameters during temperature sensitive industrial processing. Ruelas J. [17] developed and applied a new mathematical model for a Scheffler-type solar concentrator (STSC) based on the geometric and optical behavior of the concentrator in Cartesian coordinates. This system was coupled with Stirling engine. It was found that the STSC receiver showed a 7% increase in the thermal efficiency compared with the efficiency of the parabolic receiver. Mussard M. [18] presented a comparative experimental study of the widespread SK14 cooker and a prototype of a solar concentrator (parabolic trough) using a storage unit. Cooking takes placed directly on the top of the storage. Cooking on heat storage with optimized surface contact was proved to be competitive with standard solar cookers or other cooking devices.

Patil R. [19] presented the work which was carried out on the Scheffler reflector. The dimensional analysis showed that generated water temperature is determined by ratio of product of wind speed and time of operation to Dish area. It showed the scope for experimental data based modeling to establish relationship in different variables of Scheffler reflector. Phate M. [20] studied the performance of 2.7 m^2 Scheffler reflector. The

dimensional analysis showed that generated water temperature is determined primarily by ratio of product of angle and Dish area to the wind speed.

C. Review on Applications of Parabolic dish type solar system

Scheffler W. [21] described some ideas about the design of the Scheffler reflectors and how it was developed. Parabolic Scheffler Reflectors can provide high temperature heat for all types of cooking, steam generation and many other applications. Their specialty is a flexible surface curvature and a nonmoving focal area. Chandak A. [22] designed and experimented with multistage evaporation system for production of distilled water. Two Scheffler concentrators of 16 m^2 each were used for generating steam at 8 bar pressure. This system has great potential in food processing industry. Authors recommended some other renewable energy backup system like biogas or biomass for overnight operation. Munir A. [23] used a parabolic dish fixed focus concentrator for the solar distillation system. This system consist a primary reflector of 8 m^2 area and photovoltaic tracking system.

Kumar S. [24] demonstrated how effectively hoteliers and corporate can architect and utilize both solar thermal and green gas energy for the production of zero carbon foot print food products. The methods developed in this project may also be implemented in vast rural mass and community centre for cost effective and hygienic food production. Munir A. [25] this work provided a fixed focus on a receiver from morning to evening and in summer and winter, flexible crossbars have been used to achieve the desired shapes of the reflector. This research also covered all the details regarding design, development, site specific installation and tracking system etc. The research concluded that different kind of medicinal and aromatic plants could be processed effectively using solar distillery. Tesfay A. [26] performed experiments of heat collection, transportation and storage for using parabolic dish concentrators, in which steam act as heat carrier and phase change material (PCM) act as heat storage. The design of the system has been focused to meet the demand for high temperature heat storage, in an economical, safe, robust and simplified way. The stored heat was tested for Injera baking purpose, the national food of Ethiopia, which requires intensive energy.

Akhade A. [27] reviewed the different Scheffler reflectors. This study explained the design principal, performance analysis and applications of scheffler reflector. It was concluded that Scheffler reflector can be used for low as well as medium temperature applications like food processing industries, cooking, steam generation, crematorium. The performance analysis of scheffler reflector was done by correlating experimental results and the mathematical modelling. It can be understood that there is big potential to work on scheffler technology like material indigenization, improving geometric concentration ratio, radiation enhancement etc. Indora and Kandpal [28] explained various cooking technologies developed for institutional solar cooking. Sansaniwal S.[29] concluded that the solar energy is an effective alternative and clean source of energy for the sustainable development of the society worldwide. Solar energy is a cheap, abundant and everlasting source of renewable energy. It can be integrated with different systems deals with energy consumption to overcome the dependency of present society on conventional fuels. The main objective of his article is to bring out valuable recommendations for wide exploitation of solar energy systems for different applications, from a thermodynamics perspective. He has summarized the previous findings on energy and exergy analyses of different solar energy systems.

Mendoza J. [30] have been analysed the sustainability benefits of using solar cookers in developing countries. Home-made solar cookers represent a promising opportunity to motivate behavioural changes towards a circular economy and sustainability in developed countries which is shown in figure 1.

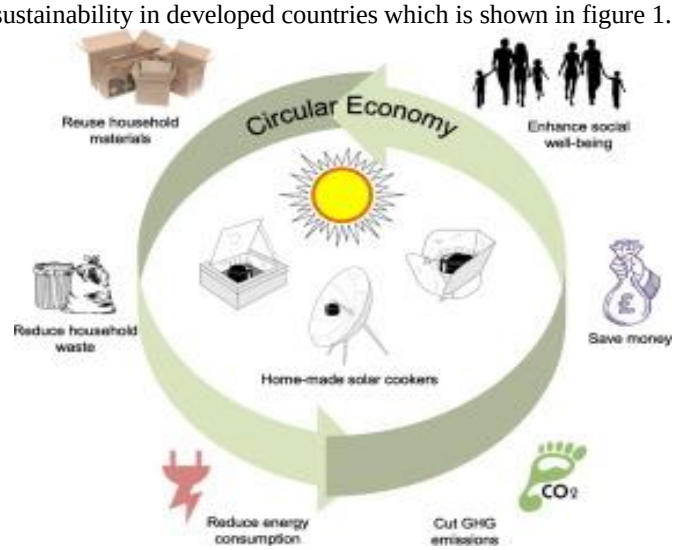

Fig. 1. Circular Economy by Solar cooker.

D. Review on Potential of Solar energy

Ummadisingua A. [31] studied the various concentrators available. It also evaluates the Concentrated Solar Power (CSP) potential of India. The study also explains the various scheme and policy planned by government of India. Soni M. and Gakkhar N. [32] identified operating parameters of the solar power plants in India using various technologies. The given work was identified through the literature review and discussion with the experts. Analysis of survey showed that location of the site and direct investment cost are the highest preferred technical and economical parameters respectively. The results of this study will help to decision makers and policy makers of solar technologies in India. Mahtta R. [33] presented maps of the district-wise potential for concentrating solar power (CSP) . The result showed the potential sites for installation of CSP.

WWF India Report [34] was named as Renewable for lifestyle shift. This report gave a current scenario of solar cookers in India. This report stated the benefits, associated limitations, cost of technology, applicable subsidy and application potential related to solar cooking system. Zhongyue Xu [35] reviewed the methods to reduce the carbon footprint of cooking units according to the principles of life cycle assessments. The types of food, fuels and cookware, improved performance of cookware and cooking waste were discussed. It concluded that solar cooking is the cleanest mode developed very fast and had great potential to reduce energy use and GHG emissions. Sindhu S. [36] identified and analysed the barriers in implementation of solar energy in Indian rural sector. 'Social and Environmental barriers' have been identified as dependent barriers and 'Marketing and Policy barriers' emerged out as independent barriers. The developed integrated structured model will be beneficial in understanding the interrelationship and dependencies among the identified barriers in the diffusion and adoption of solar energy in Indian rural sector.

Kannan N. [37] discussed about the need of solar industry with its fundamental concepts, worlds energy scenario, highlights of researches done to upgrade solar industry, its potential applications and barriers for better solar industry in future in order to resolve energy crisis. This brief representation is very useful for solar system manufacturers, academics, researchers and decision makers to give significant contribution to this sector to make future world energy wise efficient.

II. CONCLUSION

The thorough literature survey of parabolic dish type solar cooking systems is carried out. In this article review is based on various parameters like design solar cookers, type of experimentations on such system, applications of solar energy based devices and potential of solar energy. This review paper shows the importance of concentrated solar power in cooking system and it only achieved by using Parabolic Dish size collector. Also, lots of other applications are discussed. The heat storage devices and tracking system literatures are also studied. It is found that, use of solar energy as a fuel is best option for cooking as compared to other fossils fuel. It's a clean fuel and available free of cost everywhere. It reduces the dependency on fossils fuel and results in to zero carbon foot print product. Still, the solar cookers are that not much popular in society, therefore, it's a great scope to do research in solar cooking system and make it popular among society.

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