A Scientific Pore over a Solar Cooking Systems

Piyushkumar M. Mistri, Kedar A. Pathak

Abstract*: Energy is essential to life and all living organisms. It is fulfilling our daily needs: cooking, lighting, water heating and purifying, etc. It is also very significant to the human to maintain good health which is largely ignored. Three billion around people are using wood, cow dung, coal and other conventional fuels inside their homes resulting in indoor pollution. To conquer the said problem, solar energy cooking is the only solution. A large amount of solar energy is available in various parts of the world, which is pollution-free and easy to harness. More than 36% of the total generated energy is consumed for cooking in India. Hence there is a need to develop alternative cooking mode which will be easy, pollution-free and economical. However, the utilization of this form of energy at a large scale is only possible by developing an efficient cooking system with solar thermal energy storage technology and conventional cooking option which will enable the odd hours cooking.

In this review paper, an attempt has been made to study the history and recent advancement in the field of solar energy cooking. The paper provides a detailed review of such kind of technology with cooking principle, types of cookers and their performance. Moreover, the review has been done on the use of Phase Change Material (PCM) in a solar cooking system which enables the night cooking.

Keywords: Cooking, Solar Energy, Pollution, Phase Change Material (PCM).

I. INTRODUCTION

Commonly used conventional energy sources for cooking are firewood, dung cake, kerosene, piped natural gas (PNG), liquefied petroleum gas (LPG), electricity, biogas etc. Three billion around people are using wood, cow dung, coal and other conventional fuels inside their homes for cooking resulting in indoor pollution. Every year more than 1.5 million people died because of indoor pollution mainly children and their mothers [1]. Many more people go through breathing problem daily. Furthermore, it's an obstacle to achieve development goals. Using wood as a fuel for cooking will destroy the forest also.

Developing countries people are largely depended on the conventional source of energy as wood, coal, dung cakes etc. for cooking and on liquefied petroleum gas (LPG) and piped natural gas (PNG) for cooking in city areas. A developing country like India has an abundant amount of solar energy in the majority parts of it.

An average of 300 sunny days per year with an enormous land area, theoretically India provides $5X10^{12}$ kWh of clean and renewable solar energy every year across its cross-section [2]. Cooking by solar energy is simple, safe and environment-friendly. Hence solar energy is the energy which offers a solution for pollution-free cooking. Solar cooking is also identified as most suitable technology as it has numerous advantages such as no running cost, clean, reduces the hard work, easily available, safe and keeps the high nutritional value of food.

Although these advantages, there is a resistance to the acceptance of such kind of cooking. It depends on the sun and clear weather conditions. There are also a space, cost and convenience issue with solar cooking. As far as the cooking time is a concern, everybody wants fast cooking. Therefore good research is required to overcome this all difficulties and will increase the acceptance of such technology. Pia Piroschka Otte [3] concluded in his research that to implement solar cooking in routine, it has to be correlated with the socio-cultural belief of the region. As per F. Yettou et al. [4], research in the field of solar energy cooking is continuously going on but a very little is converted into real use. Major work on solar energy cooking is done for research purpose only.

A historical review of the solar cooking technology, solar cooking principle and detailed study on types of solar cookers are cover in this paper. An attempt also made to cover the recent development or advancement on the solar cooking system which enhancing the cooking efficiency, faster cooking and night cooking which is difficult in the ordinary solar cooking system. Moreover, a detailed study is also presented on the solar cooker with heat storage materials which enable the cooking at night.

II. PRINCIPLE OF COOKING

Initially, the maximum portion of the total energy supplied in cooking is consumed to raise the temperature of food which is kept in a cooker and then it is maintained steady for a while to get cooked food. Maximum types of food contain a high amount of water, and heating them to cooking temperatures requires nearly 1 Cal per kg per °C [5]. George O. G. Lof, concludes that low and high amount of energy supply in the form of heat may not show a large difference in the time required for cooking that must be taken several hours to cook. For all types of cooking requirements, even if maximum temperature is below 100°C, it's necessary to provide energy source as heat at a considerably higher temperature if satisfactory cooking rates are to be obtained [6].

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III. SOLAR COOKING HISTORY

People were not aware of cooking at the early age of civilization. They ate food as it was available naturally. German physicist named Tschirnhausen had done experiments on solar cooking from 1651 to 1708 as per Marlett Wentzel at el. [7]. He had boiled water by using a wide mirror to focus the sun's rays. Tschirnhausen work was published by Swiss scientist Horace de Saussure who also has invented a "hotboxes" to cook a fruit which was made of wood. He recorded 88°C temperature while cooking fruit with solar box type cooker. He was identified as the grandfather of solar cooking [8]. In the same period, a British soldier invented and patented a fairly sophisticated solar cooker in India. Shri M. K. Ghose designed and developed a box-type solar cooker around 1945 as a commercial product.

Countries like India and China encouraged the research on renewable energy as specifically on solar energy to alter the conventional fuel requirements for cooking. China held its first seminar on solar cooking in 1973 [6]. In 2010, R. M. Muthusivagami et al. [6] suggested that thermal energy storage is essential for odd hours cooking and given the new concept of the solar cooker with phase change material. In the same era, Prasanna U. R. [2] optimized the solar energy transport system for hybrid cooking applications which can be applied in newly designed cookers to enhance the efficiency. M .M. Valmiki et al. [9] proposed a new design in 2011 and manufactured a solar cooking stove which uses large Fresnel lens to concentrate the solar energy which improves the higher efficiency and safety of solar cooking. Smita B. Joshi and A. R. Jani [10] had designed and tested a photovoltaic and thermal hybridized solar cooker which has reduced the overall cooking time by connecting heater in it. Yogesh H. Shinde et al. [11] designed and developed an energy-efficient cooking system and tested it. Alberto Regattieri et al. [12] in 2016 suggested an innovative portable solar cooker which was built from the recycled cardboard packaging waste. The cooker can be used for various purposes like heating, cooking and boiling the water. They have tested many geometrical shapes and found that the parabolic configuration gives the best results with an average efficiency of about 14-18%. Abhishek Saxena and Nitin Agarwal developed a new hybrid solar box cooker (SBC). It has been developed and tested for thermal performance evaluation in the climatic condition of western Uttar Pradesh, India [13]. After testing and evaluating the performance of SBC, they have observed 45.11% thermal efficiency and cooking power has been estimated 60.20 W. Pinar Mert Cuce [14] in 2018 has suggested the Box type solar cookers with the heat energy storage material. He found that the cooker with thermal storage material was efficient around 35.3 to 21.7% as compared to the conventional solar cooker which has 27.6 to 16.9 %.

IV. SOLAR COOKING PRINCIPAL AND CLASSIFICATIONS OF SOLAR COOKERS

A solar cooker receives the solar irradiation and converts into heat energy, which is used to cook food, kept in the solar cooker. Initially, it adds the sensible heat to the pot and then food is being cooked after a certain period. As we have seen that there are so many types of solar cookers available and research continuously. They are classified mainly in three categories like box-type cookers, concentrating-type cookers, and non-focusing type cookers [4].

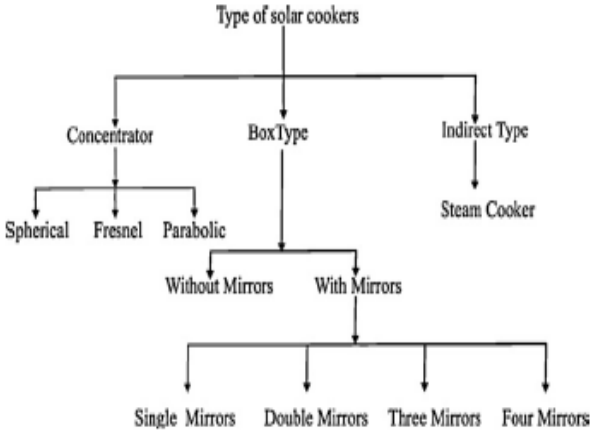

Fig. No. 1 Classifications of Solar Cookers

A. Box-type solar cooker

Box type of solar cooker is most common and conveniently used for two centuries. It is the simplest device to convert solar irradiation energy into heat energy. Heat energy finally cooks the food kept in the cooker [15]. Fig. no. 2 shows the simple box type of solar cooker. Box type solar cooker works efficiently even though there was a heat loss by surround wind, cloudy atmosphere or low ambient temperature. They were able to store food for 3 hrs after sunset [16]. Furthermore, performance may be enhanced by using reflectors and energy storage materials. The energy efficiency of the box type of solar cooker with thermal energy storage material is in between 35.3 to 21.7 % while it is 27.6–16.9% of conventional solar cooker [14].

Fig. No. 2 Box-type Solar Cooker

B. Concentrator type of solar cooker

Parabolic reflector type direct solar cooker concentrate the reflecting energy in a point focus and that energy can be utilized for direct or indirect cooking. Fresnel lens, multifaceted mirrors, etc. are utilized to manufacture a concentrating type of solar cooker which is suitable for all type of cooking [4]. Fig no. 3 shows the best design of parabolic dish type solar cooker. It consists of a simple parabolic reflector and cooking pot which is located on a focal point of the reflector. A stand is provided to withstand the wind load.

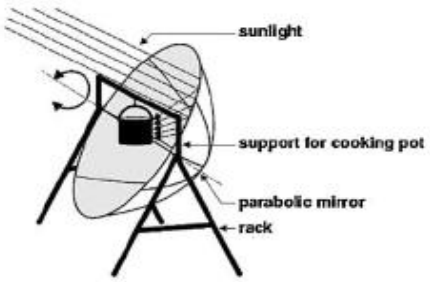

Fig. No. 3 Parabolic reflector type concentrating Solar Cooker

J. A. Duffle, G. O. G. Liif, and B. Beck [17] tested a solar cooker made with a thin plastic reflector in the shape of the parabola to cook food with the suitable support and food holder. They concluded that the rate of delivery of energy to a blackened vessel under desirable conditions of use is typically 300 to 500 watts. Hosny Z. and Abou-Ziyan [18] tested full tracked solar cooker named as a parabolic dish solar cooker in the winter season. They reported that the parabolic dish solar cooker has a higher rate of cooking (more than 2 to 6 times) and can achieve higher temperatures then box type solar cooker. They also have concluded that the use of windshield reducing the wind effect and it is confirmed by thermal analysis that reduction of 24 to 35 % in the heat loss from the receiver with the presence of a windshield.

C. Indirect type of solar cooker

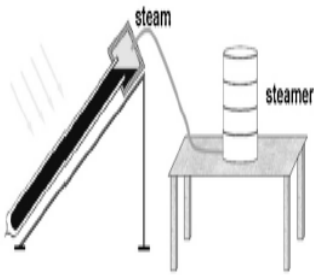

Fig. No. 4 Flat plate collector type indirect solar cooker

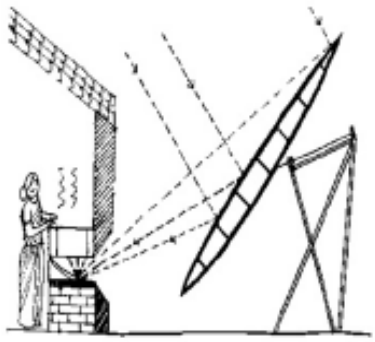

Fig. No. 5 Flat plate collector type indirect solar cooker

Flat plate and the parabolic reflector type indirect solar cookers (fig. no. 4 and 5) consist of vacuum tubes and parabolic reflector respectively to transfer the sun energy into food. Indirect type of solar cookers is most suitable for indoor cooking applications. Cost of such types of cookers is high compared with other types of the cooker. Mohammad Hosseinzadeh, et al. [19], they investigated the performance of a solar cooker consist of portable evacuated tubes with a stainless steel tank. They found that solar radiation and vacuum level are most effective parameter affecting the performance of the solar cooker. Hence selection of vacuum level in the tube is critical.

V. SOLAR COOKER WITH ENERGY STORAGE

Box type solar cookers receive direct solar irradiation while the indirect cookers use a heat transfer fluid to transfer the heat from the collector to the cooking unit. In both the type of cooking system, it's difficult to cook food in non-sunshine hours.

D. Buddhi et al. [20], designed and developed a solar cooker to store the energy during a day and it can be utilized to cook food in the evening or late night. Phase change material storage unit enables cooking in the late evening. R. M. Muthusivagami et al. [6], studied the solar cooker with and without the use of thermal energy storage material. They found that using thermal energy storage material, it is possible to design a modular indoor kitchen for community and residential application which may give the solution to each solar cooking problem. U.R. Prasanna and L. Umanand [21] optimized and designed an efficient energy transfer system for cooking. As per the review by Gang Li and Xuefei Zheng [22] on the thermal storage system, they suggested thermal energy stored solar cooker which can be used to enhance the performance of solar cookers. Further, K. K. Pillai and B. J. Brinkworth [23] found that phase change materials have a good capacity to store low-grade thermal energy in a compact system. They have optimized the different parameter relate with the PCM system, now can be used. S. K. Gupta [24] suggested materials for solar water heating system which is utilized further for new development. M. R. I. Ramadan et al. [25] designed a two pots solar cooker with energy-storing material (sand) which has improved the performance tremendously.

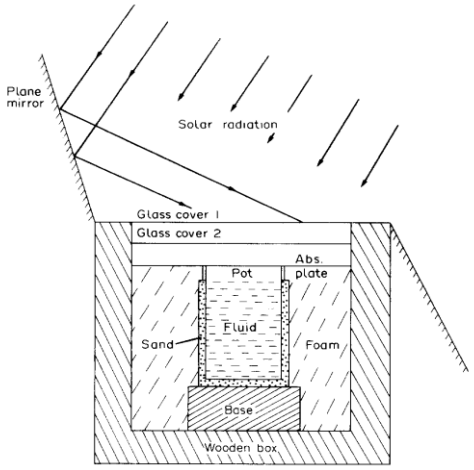

Fig. No. 6 A schematic diagram of PCM based solar cooker

The proposed (fig. no. 6) solar cooker which gives 28.4% overall energy conversion efficiency is best as compare to other available cookers. Further, they investigated that PCM such as paraffin may be good enough and future research can be done.

David I. Bushnel [26] constructed (fig. no. 7) a new heat exchanger that transfers rapidly the heat hence cooking time can be reduced.

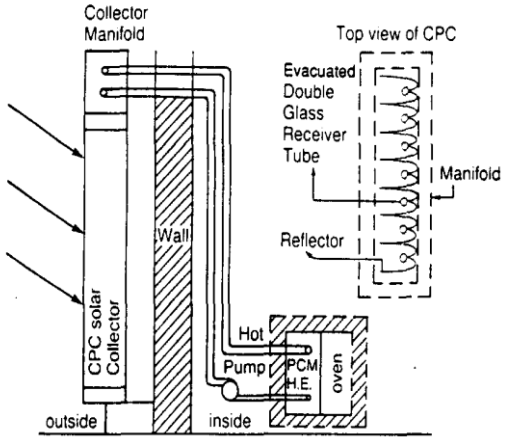

Fig. No. 7 A schematic diagram of PCM based solar cooker

A modular design is proposed which allows the numbers of energy-storing modules results in more heat distribution and convective heat transfer between temperature ranges of 215°C to 270°C. R. Domanski et al. [27] had tested experimentally the possibility of cooking during odd hours with phase change materials like stearic acid or magnesium nitrate hexahydrate. They reported that the resulting values of efficiencies are 3-4 times higher than the heat pipe and steam solar cookers which can be used in the kitchen. D. Buddhi and l. K. Sahoo [28] proved with the experiment that it is possible to cook food in the evening or late night is possible with phase change material. S. D. Sharma et al. [29] constructed a PCM storage unit for a solar cooker which receives and stored the energy during a day and can be utilized in the night for odd hours cooking. They noted that the storage of energy in the day doesn't affect the cooking efficiency in a day.

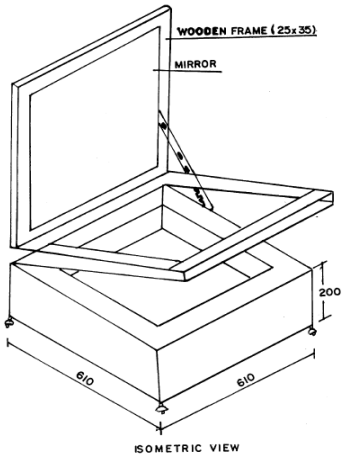

Fig. No. 8a Iso-metric view of a hot box storage solar cooker

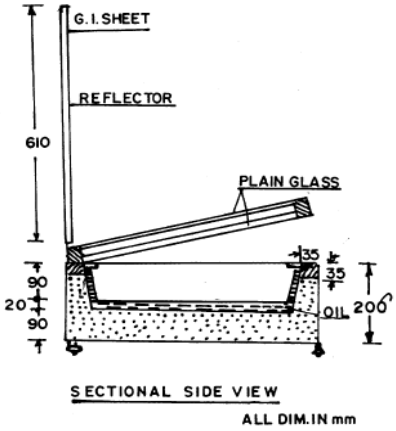

Fig. No. 8b Side view of a hot box storage solar cooker

N. M. Nahar [30] designed, fabricated and tested a hotbox solar cooker (fig. no. 8a and 8b) with engine oil as thermal energy storing material. They performed the experiment to cook green gram and rise in non-sunshine hours during 17:30 hrs and 20: 00 hrs in hot box type storage solar cooker which is not possible in the conventional box-type solar cooker without storage. They found that the efficiency of the proposed solar cooker is 27.5%. Beln Zalba et al. [31] had classified more than 150 energy storage materials and gathered all required details in one research paper. Klemens Schwarzer et al. [32] had built more than 250 cooking system and installed all over the world. From the experimental results, they had concluded that solar cooker has a very good chance for large scale cooking like in big families, schools, old age homes etc. provided with financial assistance. S.D. Sharma et al. [33] designed and tested a solar cooker with phase change material storage based on evacuated tube type collector.

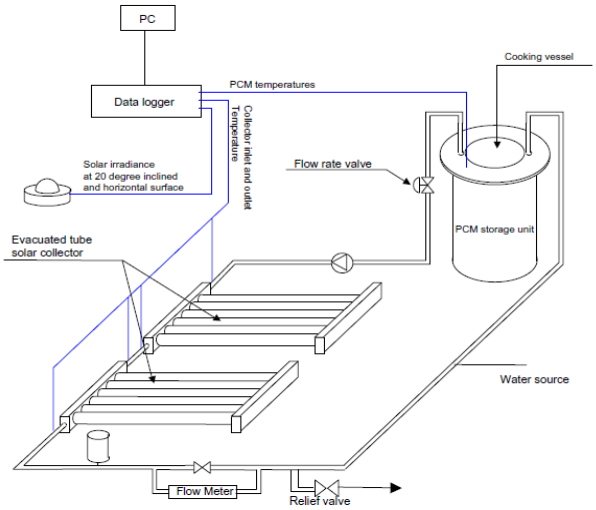

Fig. No. 9 Solar cooker based on evacuated tube solar collector with a PCM storage unit

The proposed system is shown in fig. no. 9 is quite expensive but can be used efficiently in community cooking requirements. They noted that it provides high PCM temperature up to 130 °C without tracking and allows also a kitchen cooking unlike that of conventional cookers.

Murat Kenisarin and Khamid Mahkamov [69] have registered that to minimize the use of a conventional source of energy and to protect the environment from greenhouse gas emissions, it is very essential to use renewable sources of energy for various energy requirements. However, the utilization of it at large scale is only possible by storing the energy. They have also suggested that before the commercialization of PCM based solar cookers, it is necessary to check it for 1000 thermal cycles.

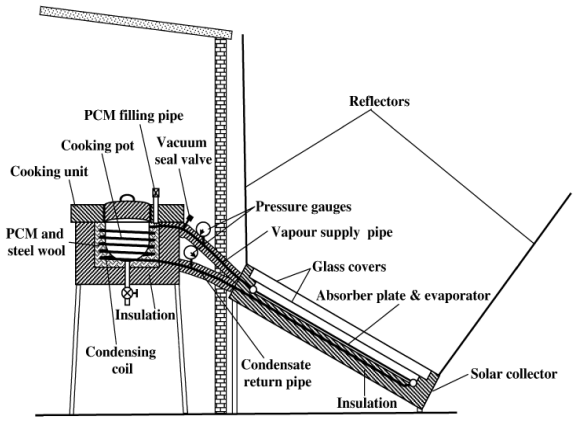

Fig. No. 10 Indirect Solar Cooker

H.M.S. Hussein at el. [70] designed an indoor solar cooker (fig. no. 10) with thermal energy storage material as magnesium nitrate hexahydrate (T_m = 89 °C, latent heat of fusion 134 kJ/kg). They found that the present design can cook a different type of food at any time.

VI. REVIEW RESULT

From reviewing this work, three areas for research and development are suggested,

1.	2.	3.
Hybridization of Solar Thermal with PCM material, Solar Photovoltaic and Conventional Source of Energy like PNG.	Investigation on Large family or Community cooking with a hybrid solar cooker.	Use of the solar cooking system for Industrial Applications.

VII. CONCLUSIONS

A comprehensive review on solar cookers has been carried out and the following conclusions are made from the present study.

1. The solar energy source is one of the promising sources for cooking which will be free from pollution and maintain the vitamin values.

2. The people living in a rural area can use box-type direct solar cookers for their afternoon meal cooking which is commercially available in India.

3. A large scale community cooking, parabolic concentrating types of cookers are successfully being utilized.

4. Solar cookers with thermal energy storage material can be used for late-night cooking.

REFERENCES

1. WHO report on Household energy and health, 2006.
2. Prasanna U. R., Modeling, optimization and design of a solar thermal energy transport system for the hybrid cooking application, a thesis submitted for the Ph.D., July 2010.
3. Pia Piroschka Otte, A (new) cultural turn toward solar cooking—Evidence from six case studies across India and Burkina Faso, Energy Research & Social Science 2 (2014) 49–58.
4. F. Yettou, B. Azoui, A. Malek, A. Gama, N. L. Panwar, Solar cooker realizations in actual use: An overview, Renewable and Sustainable Energy Reviews 37 (2014)288–306.
5. George O. G. Lof, Recent Investigations in the Use of Solar Energy for Cooking, U.N. Conference on New Sources of Energy, August 1961.
6. R. M. Muthusivagami, R. Velraj, R. Sethumadhavan, Solar cookers with and without thermal storage—A review, Renewable and Sustainable Energy Reviews 14 (2010) 691–701.
7. Marlett Wentzela, Anastassios Pourisb, The development impact of solar cookers: A review of solar cooking impact research in South Africa Energy Policy 35 (2007) 1909–1919.
8. N. L. Panwara, S. C. Kaushika, Surendra Kothari, State of the art of solar cooking: An overview, Renewable and Sustainable Energy Reviews 16 (2012) 3776– 3785.
9. M. M. Valmiki, Peiwen Li et al. A novel application of a Fresnel lens for a solar stove and solar heating, Renewable Energy 36 (2011) 1614-1620.
10. Smita B. Joshi and A. R. Jani, Photovoltaic and Thermal Hybridized Solar Cooker, ISRN Renewable Energy, Volume 2013, Article ID 746189, 5 pages.
11. Yogesh H. Shinde et al, Design and development of the energy-efficient continuous cooking system, Journal of Food Engineering 168 (2016) 231–239.
12. Alberto Regattieri et al. Innovative portable solar cooker using the packaging waste of humanitarian supplies, Renewable and Sustainable Energy Reviews57 (2016) 319–326.
13. Ndiaga Mbodj and Ali Hajji, Modeling, testing, and parametric analysis of a parabolic solar cooking system with heat storage for indoor cooking, Energy, Sustainability and Society (2017) 7:32.
14. Pinar Mert Cuce, Box-type solar cookers with sensible thermal energy storage medium: A comparative experimental investigation and thermodynamic analysis, Solar Energy 166 (2018) 432–440.
15. S. A. Channiwala and N. I. Doshi, Heat loss coefficients for box-type solar cookers, solar energy_ vol. 42. No. 6, pp. 495-501, 1989.
16. P. A. Funk and d. L. Larson, parametric model of solar cooker performance, solar energy vol. 62, no. 1, pp. 63–68, 1998.
17. J. A. Duffle, G. O. G. Liif, and B. Beck, Laboratory and Field Studies of Solar Cookers, In Proc. UN conf. new sources of energy, vol. 5. 1961. p. 339–46.
18. Hosny Z. Abou-Ziyan, Experimental investigation of tracking paraboloid and box solar cookers under the Egyptian environment, Applied Thermal Engineering 18 (1998) 1375-1394.
19. Hosseinzadeh M, Faezian et al., Parametric analysis and optimization of a portable evacuated tube solar cooker, 2019.
20. D. Buddhi, S.D. Sharma, Atul Sharma, Thermal performance evaluation of a latent heat storage unit for late evening cooking in a solar cooker having three reflectors, Energy Conversion and Management 44 (2003) 809–817.
21. U. R. Prasanna, L. Umanand, Optimization and design of energy transport system for the solar cooking application, Applied Energy 88 (2011) 242–251.
22. Gang Li, Xuefei Zheng, Thermal energy storage system integration forms for a sustainable future, Renewable and Sustainable Energy Reviews 62 (2016) 736–757.
23. Mirunalini Thirugnanasambandam et al., A review of solar thermal technologies, Renewable and Sustainable Energy Reviews 14 (2010) 312–322.
24. S. K. Gupta, Materials for low temperature solar thermal applications, solar energy centre, Department of non-conventional energy sources, New Delhi, India.
25. R. I. Ramadan et al., A model of an improved low cost-indoor solar-cooker in Tanta, solar & Wind Technology vol. 5. No. 4. Pp. 387 393, 1988.
26. David I. Bushnel, Performance studies of a solar energy storing heat exchanger, Solar Energy vol. 41. No. 6. Pp. 503-512. 1988.
27. R. Domanski, A. El-sebaii, and M. Jaworski, Cooking during off-sunshine hours using PCMs as storage media, Energy vol. 20. No. 7, pp. 607-616. 1995.

28. D. Buddhi and l. K. Sahoo, Solar cooker with latent heat storage: design and experimental testing, Energy Convers. Mgmt vol. 38, no. 5, pp. 493-498, 1997.
29. S. D. Sharma, D. Buddhi, R. L. Sawhney, Atul Sharma, Design, development and performance evaluation of a latent heat storage unit for evening cooking in a solar Cooker, Energy Conversion & Management 41 (2000) 1497-1508.
30. N. M. Nahar, Performance and testing of a hot box storage solar cooker, Energy Conversion and Management 44 (2003) 1323–1331.
31. Belen Zalba, Jose M Marın, Luisa F. Cabeza, Harald Mehling, Review on thermal energy storage with phase change: materials, heat transfer analysis and applications, Applied Thermal Engineering 23 (2003) 251–283.
32. Klemens Schwarzer, Maria Eugenia Vieira da Silva, Solar cooking system with or without heat storage for families and institutions, Solar Energy 75 (2003) 35–41.
33. S.D. Sharma, Takeshi Iwata, Hiroaki Kitano, Kazunobu Sagara, Thermal performance of a solar cooker based on an evacuated tube solar collector with a PCM storage unit, Solar Energy 78 (2005) 416–426.
34. Paul a. Funk, evaluating the international standard procedure for Testing solar cookers and reporting performance, solar energy vol. 68, no. 1, pp. 1–7, 2000.
35. N. M. Nahar, Design and development of a large size non-tracking solar cooker, Journal of Engineering Science and Technology Vol. 4, No. 3 (2009) 264 – 271.
36. Ishan Purohit, Testing of solar cookers and evaluation of instrumentation error, Renewable Energy 35 (2010) 2053-2064.
37. Prasanna U R, L Umanand, HYBRID SOLAR COOKING, ASME-ATI-UIT Conference on Thermal and Environmental Issues in Energy Systems 16 - 19, May 2010.
38. U. R. Prasanna, L. Umanand, Modeling and design of a solar thermal system for the hybrid cooking application, Applied Energy 88 (2011) 1740–1755.
39. Jyeshtharaj B. Joshi et al. Development of Efficient Designs of Cooking Systems. I. Experimental, Industrial and Engineering chemistry research, 2012, 51, 1878–1896.
40. Pranab J. Lahkar, Rajesh K. Bhamu, S. K. Samdarshi, Enabling inter-cooker thermal performance comparison based on cooker Opto–thermal ratio (COR), Applied Energy 99 (2012) 491–495.
41. Erdem Cuce, Pinar Mert Cuce, A comprehensive review on solar cookers, Applied Energy 102 (2013) 1399–1421.
42. H Terres1 A Lizardi S Chávez R López and M Vaca, Evaluation of the cooking power in three different solar cookers box-type, Journal of Physics: Conf. Series 792 (2017) 012013.
43. Hacienda Hashim, Wai Shin Ho, Jeng Shiun Lim, Sandro Macchietto, Integrated biomass and solar town: Incorporation of load shifting and energy storage, Energy (2014) 1- 9.
44. Pia Piroschka Otte, Solar cooking in Mozambique—an investigation of end-users needs for the design of solar cookers, Energy Policy, June 2019.
45. Simon Bachelor, Solar Electric Cooking in Africa in 2020 a synthesis of the possibilities, December 2015.
46. Mr. S. R. Gawali and Prof. C. V. Parade, Hybrid Solar Cooker, IJERT, ISSN: 2278-0181, Vol. 4 Issue 06, June-2015.
47. Okoro Chibuzo, Design and performance evaluation of a parabolic solar cooker, June 2015.
48. S.B. Joshi and A.R. Jani, Design, development and testing of a small scale hybrid solar cooker, Solar Energy 122 (2015) 148–155.
49. Lingkun Liu, DiSu, Yaojie Tang, Guiyin Fang, Thermal conductivity enhancement of phase change materials for thermal energy storage: A review, Renewable and Sustainable Energy Reviews 62 (2016) 305–317.
50. Harish Ronge,Vyenkat Niture, Mr D.S.Ghodake, A Review Paper on Utilization of Solar Energy for Cooking, Imperial International Journal of Eco-friendly Technologies, Vol. - 1, Issue-1 (2016), pp.121-124.
51. J. Martínez-Gómez, D. Ibarra, S. Villacis, P. Cuji, P.R. Cruz, Analysis of LPG, Electric and induction cookers during cooking typical Ecuadorian dishes into the national efficient cooking program, Food Policy 59 (2016) 88–102.
52. G. Kumaresan et al., Performance assessment of a solar domestic cooking unit integrated with thermal energy storage system, Journal of Energy Storage 6 (2016) 70–79.
53. Lameck Nkhonjera et al., A review of thermal energy storage designs, heat storage materials and cooking performance of solar cookers with heat storage, Renewable and Sustainable Energy Reviews, October 2016.
54. Shubhangi Ambade et al, Cram of Novel Designs of Solar Cooker, International Journal of Mechanical Engineering Research, ISSN 2249-0019 Volume 7, Number 2 (2017), pp. 109-117
55. Ghassan Zubi. et al., Development and assessment of a solar home system to cover cooking and lighting needs in developing regions as a better alternative for existing practices, Solar Energy 155 (2017) 7–17.
56. Abhishek Saxena, Nitin Agarwal, Performance characteristics of a new hybrid solar cooker with air duct, Solar Energy 159 (2018) 628–637.
57. Rahul Aadiwal et al., an Overview Study of Solar Cookers, IRJET, and Volume: 04 Issue: Oct -2017.
58. Evangelos Bellos, Christos Tzivanidis, Angelos Papadopoulos, Daily, the monthly and yearly performance of a linear Fresnel reflector, Solar Energy 173 (2018) 517–529.
59. Atul A. Sagade et al., Enabling rating of intermediate temperature solar cookers using different working fluids as test loads and its validation through a design change, Solar Energy 171 (2018) 354–365.
60. Sara. Tahan Latibari, Seyed Mojtaba Sadrameli, Carbon-based material included-shaped stabilized phase change materials for sunlight-driven energy conversion and storage: An extensive review, Solar Energy 170 (2018) 1130–1161.
61. Evangelos Bellos, Progress in the design and the applications of linear Fresnel reflectors critical review.
62. V. Pranesh, R. Velraj, S. Christopher, V. Kumaresan, A 50-year review of basic and applied research in compound parabolic concentrating solar thermal collector for domestic and industrial applications, 2019.
63. Atika Qazi, Towards Sustainable Energy: A Systematic Review of Renewable Energy Sources, Technologies, and Public Opinions.
64. Subodh Kumar, Estimation of design parameters for thermal performance evaluation of box-type solar cooker, Renewable Energy 30 (2005) 1117–1126.
65. N. M. Nahar, Performance studies of a large size non-tracking solar cooker, Renewable energy vol. 2, no. 4,5 pp. 421430 1992.
66. K. K. Pillai and B. J. Brinkworth, The storage of low-grade thermal energy using phase change materials, Applied energy 1976; 2:205–16.
67. D. Buddhi, S.D. Sharma, Atul Sharma, Thermal performance evaluation of a latent heat storage unit for late evening cooking in a solar cooker having three reflectors, Energy Conversion and Management 44 (2003) 809–817.
68. S.D. Sharma and Kazunobu Sagara, Latent Heat Storage Materials and Systems: A Review, International Journal of Green Energy, 2: 1–56, 2005.
69. Murat Kenisarin, Khamid Mahkamov, Solar energy storage using phase change materials, Renewable and Sustainable Energy Reviews 11 (2007) 1913–1965.
70. H.M.S. Hussein, H. H. El-Ghetany, S.A. Nada, Experimental investigation of the novel indirect solar cooker with indoor PCM thermal storage and cooking unit, Energy Conversion and Management 49 (2008) 2237–2246.
71. Felix Regin, S. C. Solanki, J. S. Saini, Heat transfer characteristics of a thermal energy storage system using PCM capsules: A review, Renewable and Sustainable Energy Reviews 12 (2008) 2438–2458.
72. M. Mofijur at el., Phase Change Materials (PCM) for Solar Energy Usages and Storage: An Overview, Energies 2019, 12, 3167; doi: 10.3390/en12163167.

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