SJIF Impact Factor (2023): 8.574| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 8 | Issue: 7 | July 2023 - Peer Reviewed Journal

REVIEW ON EFFICIENCY ENHANCEMENT TECHNIQUES FOR EVACUATED TUBE SOLAR COLLECTORS

Surbhi kori [1], Bhupendra Gupta[2], Jyoti Bhalavi [3]
[1]Jabalpur Engineering College, Jabalpur, M.P. , India

Article DOI: https://doi.org/10.36713/epra13853
DOI No: 10.36713/epra13853

ABSTRACT
As the demand of renewal sources of energy is increasing due to the degradation of conventional sources, Solar energy is getting vital importance as it is used in solar water heating in household and various industries. This research paper focuses on the performance enhancement techniques of the evacuated tube collector by various method, these include by using phase change material, nanofluids, reflectors and hybrid techniques and reviews were studied in which the system would give better results. The reviewed paper concluded that using phase change material, compound parabolic reflector and nanofluid simultaniously would give optimum results for better performance in evacuated tube collector.

1. INTRODUCTION

With population growth the demand for energy utilization has increased for various needs since conventional source of energy is depleting therefore the use of renewable sources plays a vital role in today's world. Solar energy plays a major role in such uses as it does not cause any harmful effect or depletion of natural resouces also it is cost-effective and it has immense potential for which it has been used in various technologies. Solar energy is environmentally friendly and important for human life **[1].** As it is considered an essential source of energy it has gained popularity globally due to which it has experienced massive growth **[2].** Solar energy has various applications as it can be used for cooling, heating, and solar design in air conditioners, water heaters, etc. Solar energy is mainly used for domestic water heating in residential buildings and industries. Solar water heaters are mainly preferred because it has less influence on global warming and minimum cost and it extends the lifespan of the working system **[3].** Heaters mainly used are flat plate and evacuated tube collectors for water heating. Nowadays evacuated tubes are preferred because due to their shape, it is able to receive heat from all directions which is helpful in their high-efficiency generation. An Evacuated tube collector performs better than a flat plate, especially when working with high temperatures **[4].**

Evacuated tubes consist of glass tubes which are made up of borosilicate material which has low thermal expansion and is resistant to external conditions. It consist of an outer tube that has low reflectivity and high trasmissivity through which radiation can pass through, it has a minimum reflection that reduces the heat loss from the system and is resistant to outside weather condition. The tubes consist of absorber coating which is helpful in absorbing heat in high amount for better performance of the system **[5].** Also, ETC has demonstrated that the combination of of selective coating and effective suppressor results in good performance of the system in high temperatures, vacuum is created between the outer surface of the inner glass tube and the inner surface of the outer glass tube which helps in reducing the conduction and convection losses of the system **[6].** An Evacuated tube collector is preferred over a flat plate collector because apart from having high efficiency, it impedes heat loss from the tube of the system **[7].** It can also be concluded that the geographical area, temperature, radiation and mass flow rate are the various factors on which the performance of the system depends. This research mainly works on various heat transfer techniques which will help in improving the performance of the system. Evacuated tube collectors can be classified as follows :

A. All glass ETCs : As the name suggests all the tubes are made up of glass, and the water from bottom of the tube travels upwards in evaporated form because of solar radiation and due to density difference it travels upwards and we get heated water. As this process occurs naturally therefore it is called thermosyphon solar water heater.
B. Heat Pipe ETCs : This type of evacuated tube consists of the heat pipe along with aluminium fin placed inside the tube which helps in trapping the solar energy from the sun and heating the fluid or refrigirant used within the tube.
C U tube ETCs : These type of evacuated tube consist of heat pipe made up of copper which has good heat absorbing capability and due to U shape the tramsmission of fluid from inner to outer surface of the tube takes place easier. Also an absorber coating is provided which helps to imbibe large amount of radiation.

SJIF Impact Factor (2023): 8.574| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 8 | Issue: 7 | July 2023 - Peer Reviewed Journal

2. HEAT TRANSFER ENHANCEMENT OF EVACUATED TUBE COLLECTOR

a) Using thermal energy storage (TES) materials : Basically these materials are used when the amount of energy requirement is large usually during night where no or less solar radiation is present. These materilas absorbs latent heat and releases same when in need.
b) Use of Nanofluid : nanofluid basically helps in enhancement of heat transfer performance in different types of heat pipe and increasing the efficiency of the system **[8]** .
c) Using Reflectors : Used in increasing the amount of solar radiation from the present amount which helps in better performance of the system and also other methods such as baffels, twisted tapes can also help in bringing out optimum results.
d) By means of hybrid techniques : these are used when two or more than two techniques are used to increase the heat transfer rate of the system

2.1 Performance enhancement using Thermal Energy Storage Materials

Many research work has been carried out in which TES meterials are used in the evacuated tubes. These materials stores the latent hend required when the radiation is low and can later be used to heatup the fluid when required. Usually these materials are called phase change materials they utilize latent heat when required to change the phase from solid to liquid when releasing energy and vise vera. Due to its good properties it is used along with evacuated tube to improve or enhance the performance of the system. Certain properties of such materials are described below:

Properties of Phase Change Materials

Thermal	Chemical	Physical	Economical
Required PCM temperature	Non reactive	Low vapour pressure	Easily Available
High thermal conductivity	is non (flamable,toxic and corossive)	High density	Low cost
High latent and specific heat	Congenial with container material	Phase change density is small	Can be reused

Fig. 1. Properties of Phase Change Material

2.1.1 Reviews in using PCMs along with Evacuated tube collector

Papadimitratos et al. evaluated that when two different PCMs Tritriacontane and Erythritol were used whose melting temperatures are 72 ◦C and 118 ◦C an 26% improvement can be seen when compared with evacuated tube without phase change material **[9].** K Chopra et al. concluded that when the tube was integrated with SA-67 PCM with five different flow rates of (8,12,16,20,24 L/hr) the thermal efficiency varied from 79-87% also the energy efficieny was 32.73% higher than the normal evacuated tube collector **[10].** Also Vivek R. Pawar et al. says when PCM is embedded with copper porous in heat pipe evacuated tube collector system with radiation in peak increases the temperature by 21°C with maximum energy efficiency of 85.64% and saving in hot water production was 11.57% **[11].** Li- Feng et al. tells that when theirs is reduction in PCM melting point from 50-35°C it can elevate the efficiency of the ETC-PCM device as material with HMP remains solid during day thus, it has less effect on the ouput of the system cannot be reduced and latent heat of 160 KJ/Kg has best performance **[12].** Piotr Felinski et al. suggest latent heat storage (technical grade paraffin) inside the evacuated tube collector the charging efficiency of the collector ranges from 33 to 66% was obtained depending on radiation and temperature of the PCM ,also the annual solar fraction was increased by 20.5% with storage **[13].** Yong-Li et al. tells PCM **c**an reduce energy fluctuations by storing excess thermal energy and releasing to night. When melting temperature of PCM was 323K the reduction of the heat transfer fluid if 7.4 K. Thermal η and storage temperature η 50.72 and 19.2% also enlarging glass tube leads increase in both efficiencies **[14].** Chopra et al. analyzed performance of evacuated tube with and without phase change material (palmitic acid) and concluded that daily exergy efficiency and ηth of the collector with PCM enhanced within the range of 28–35%, and 36–44% as compared without PCM **[15].** Abokersh et al. says when 0.8 kg of paraffin wax (Alex wax 600) was filled in each evacuated tube, the heat transfer takes place through convection process, where the collector's efficiency was 14% higher without fin that is 85.7% **[16].**

SJIF Impact Factor (2023): 8.574| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 8 | Issue: 7 | July 2023 - Peer Reviewed Journal

2.2 Performance Enhancement using nanofluids

Previously the performance of the evacuated tube was analysed using methods to capture the radiation of sun on the outer surface of the tube. Nowadays ways are taken out which would increase the performance of the system by allowing materials inside the tube to enhance its working, one such way is by using nanofluid.

2.2.1 Introduction to Nanofluid

Nanofluid is prepared when the nanomaterial of unit size (1-100nm) is used along with the base solution to form the colloidal mixture.These are then inserted into the tube to increase the thermal performance and efficiency of the system.

2.2.2 Advantages of using nanofluid

These particles used in nanofluid have higher conductivity and high heat transfer coefficient . Due to its small size the nanofluid are more stable in pipe clogging because of which it is used in variety of applications. It also reduces the heat transfer surface of the thermal system, also the concentration of the particle can be varied to increase the performance of the system.

2.2.3 Effects of nanofluid in ETCs

Table 1 Reviews for previously studied nanofluid and its outcome

Author	Model/ ETC type	Nanofluid/ Avg size (nm)	Volume Percent	Obsevations
Sarafeldin et al.(2019) **[17]**	Experimental/ Thermosyphonic	Water/WO_3 (90nm)	0.014,0.028, 0.042	- shows that temp difference was 21% raised by adding WO_3 - heat transfer increased by 23% - thermal optical η reached 72.8%
Huseyin Kaya et al. (2020) **[18]**	Numerically/ U tube	Pure water/U tube	1,2,3,4	-highest efficieny obtained was 67.1% for 4.0vol% nanofluid which was 19.1% higher than Pure water
Javad et al. (2016) **[19]**	Experimental/ Thermosyphonic	Distilled water/ Al_2O_3 , (40nm)	0.03 and 0.06	-shows maximum η 57.63% for 0.06vol% of nanofluid with flowRate of 60l/hr
Mahbubul Et al. (2018) **[20]**	Experimental/ Heat pipe	Water/ Carbon nanofluid (1-2nm)	0.05,0.1, 0.2	- results indicated 66%η of nano-fluid and 56.7%in normal water with 0.2vol%
Roonak et al. (2018) **[21]**	Experimental/ Heat pipe	Water/Cuo Water/TiO_2 Water/MWCNT	0.1	- using MWCNT, CuO,TiO_2 η increased by 25,12,5% as compared to normal water
Adel A Eiden Et al. (2018) **[22]**	Experimental/ Heat pipe	Acetone /Al_2O_3 Acetone CuO (20,25nm)	0.25, 0.5	- system should be charged with nano-fluid for performance enhancement 20-54% and η (15-38%)
MD Hassan (2023) **[23]**	Experimental/ Heat pipe	SWCNTs	-	- says that using SWCNT maximum η enhanced of 93.43% repectively
Kaya et al. (2018) **[24]**	Experimental/ U tube	Water/ethylene-glycol/ZnO (30nm)	1,2,3,4	- says maximum η was 62.87% for 3vol % and mass flow of 0.45kg/s
Kaya andArslan (2019) **[25]**	Neumerical/ U tube	Water-Ethyleneglycol/ MgO, Ag and ZnO	1,2,3,4	- maximum collector effectiveness is 68.7% at 4vol% with water Ethylene-glycol/Ag nanofluid and is 26.6% efficient then water

From the above reviewed papers it can be concluded categories of ETSCs are investigated and it was found that the thermosyphon and U-pipe models are suitable for low-temperatures applications (T < 100 C) while the heat pipe model is appropriate for medium and high-temperatures ones (100 < T < 300 and T > 300 C) **[26].**

2.3 Performance Enhancement Techniques using reflectors and other methods

Reflectors are basically used in evacuated tube collector system to reflect more amount of solar radiaition to the heating plate which would help in increasing the efficiency of the system upto maximum and also inserted baffels and other means can also help in achieving the same.

Shaowai Chai et al. says that reflective coating is as a method to heighten the thermal η due to solar irradiation could be reflected by the coating on the lower half of the outer glass tube and concentrated to the essentric inner absorber, best coating angle is senn to be 180º , also thermal efficiency can reach upto 72% at radiation of 750 W/m^2 and temp. of 70°C the efficiency is raised by 10% **[27].** A .Veera Kumar et al. says that when the experiments were performed between the flow rates of 100-1000kg/hr the maximum temperature of 42.8°C was achieved with efficiency of 35.13% at 100kg/hr and also when baffels are inserted there is an increase in thermal η and says baffel length has positive effectc on thermal efficiency asnd temperature rise **[28].** Hong- Jin Joo et al. tells inserting twisted tapes enhances the heat transfer performance by eliminating the stagnant flow and reducing the degree of flow slowness. Twisted tapes improves the overall performance by 7.7% **[29].** Yu Yuan et al.performed experiment with solar dish collector along with evacuated cylindrical tube recievers and concluded that thermal efficiency of the system was about 47.3% **[30].** Saleh et al. suggests impact of using upper, lower, upper and lower reflectors increased the thermal efficiency 76.25% as compared to without reflectors and thermal performance curved η increased by 16% respectively **[31].**Guangbai Ma et al. tells that using compound parabolic collector along with ETC the instantaneous efficiency based on gross area can reach to about 0.46 at temperature of 150°C and novel CPC can produce steam from water with temperature about 108-145°C during sunny days **[32].** Aseem Dubey tells that using dual slope solar distiller can bring out the energetic and exergic η about 0.8-0.6 with flow rate of 0.01-0.24kg/s the overall exergy and gross efficiency was found to e 4.9 & 1.7 % increase respectively **[33].** Selvakumar et al. inspected the working of parabolic trough integrated ETSC using therminol D-12 as the fluid to transfer suggested that the outcome possessed by the system was 30% more thermal efficiency as compared with normal **[34].** F. Chen compared compound parabolic collector and normal evacuated tube collecotr and found that the average optical efficiency for CPC was 70.5% and for normal collecotr it was 55.7% respectively **[35].**

2.4 Performance enhancement techniques using Hybrid Technique

Hybrid technique are usually used to increase the performance of the system by increasing the heat transfer enhancement or the efficiency in this technique two or more materials such as PCM , nanofluid , and also changing the tilt angle may help to bring better result.

Enzy Elshazly et al. analysed working fluids MWCNT/ Al_2O_3, and hybrid MWCNT/Al_2O_3 in 50:50 ratio were experimentally examined for the thermal efficiency enhancement of the ETC. For each type of nanofluid four volume concentration of (0.5,0.25,0.01,0.005)%. Results says using hybrid MWCNT/Al2O3 50:50% delivers an efficiency boost of about 20% overusing Al2O3, and it was found that the utilization of 0.5% MWCNT/water nanofluid at 3.5 L/m can enhance the ETSC's energy and exergy efficiency to reach 73.5% and 51% respectively while reaching approximately 60% and 44% for Al_2O_3, and 69% and 38% for hybrid MWCNT/Al_2O_3 (50:50%) under the same test conditions **[36].** Fuyi Cui Says using water, Fe_3O_4 nanofluid and Fe_3O_4/ MWCNT hybrid nanofluid concluded when hybrid system was used in ratio of 1:4 the maximum thermal efficiency was 26.4% higher and exergy efficiency os using 0.1% hybrid and normal fluid η were 55.2 & 42.1% **[37]**. Shady M. Henein et al. when water,MgO and MWCNT were used with mass flow rates of 1-3L/min the increase in optical efficiency was about 78.1%, average heat gain increased from 240-495W also the enhancement in the inlet and outlet temperature difference by 56% and reduction in gross area by 36% this hybrid also caused reduction in CO_2 reductions and helps in energy savings **[38].** Ipek Aytac et al. says using MgO- CuO/water hybrid nanofluid with flow rates of 0.016,0033 and 0.050kg/s tells thermal efficiency of deionized water was 49.62 and 56.18%, and average thermal efficiency was around 69.89 and 77.21% overall ot helps in improving the thermal performance of the system **[39].** Saurabh Agrawal et al. reviews investigated that the thermal enhancement of ETC with various hybrid systems such as ETC with CPC reflector and paraffin wax, nanofluid and reflectors, and paraffin wax embedded with nanofluids. It was found that by using PCM incorporated with CuO nanoparticles, maximum thermal enhancement of 88.5% was attainted for 3 l/h of mass flow rate **[40].** Mohammed J. Alshukri says that influence of integrating Micro ZnO and nano-CuO particles along with paraffin wax used as PCM the two different tanks of different particles were used and that is nano-CuO particles with paraffin was and ZnO with same the efficiency improvement was seen as 36.8-50% and 25.3-41.4% **[41].** Pablo Sampaio Gomes et al. says when experiment was performed with parabolic concentrator using multilayer graphene based with different mass flow rates and best performance was found at 40l/hr further the concentrator increased efficiency by 298%. And MLG nanolfuid with 0.00045vol%and 0.00068vol% increased thermal efficiency by 31% and 76% in comparison with base fluid **[42].**

SJIF Impact Factor (2023): 8.574| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 8 | Issue: 7 | July 2023 - Peer Reviewed Journal

3 CONCLUSIONS

This review paper mainly focuses on the parameters which would help in increasing the efficiency of the evacuated tube collector system for which the phase change material, nanofluids, reflectors and hybrid materials are taken into considerations and it draws the following results:

- Phase change materials are used to store energy of materials, when it melts a large amount of energy is released when required and then it again solidifies. In this review the PCMs are mixed in ETCs and the maximum thermal efficiency was found to be between 79-87% with different flow rates.
- The nanofluids are basically used to increase the heat transfer and thermal efficiency of the system. In this paper various nanofluids are reviewd and better perfomance can bee seen with SWCNT with efficiency enhancement of 93.43% can bee seen.
- The reflectors helps to capture heat in solar collectors, they can be of various types such as flat, diffused, solar dish collector, parabolic trough and CPC.Paper concludes that using upper, lower, upper and lower reflectors increases the efficiency for about 72%. And also among different reflectors CPC possesses better outcome.
- Hybrid techniques consist of using more then one technique which would help in improving the performance of system such as PCM, reflectors, nanofluid etc at same time. In the reviewed paper the better results were seen in using CPC reflector, with paraffin wax and CuO nanofluid increased the efficiency by 88.5%

4. REFERENCES

1. *Sahdev Sahu, Narendra Kumar Sahu, Bharat Lal Sahu, Shobhana Ramteke [2023]. Solar Energy in India, Achievements, The Potential of Solar Energy and their Performance. sahdevsahurkv@gmail.com.*
2. *Priyanka Sati, Ankita Kumari, Sudesh Kumar [2023]. Solar Energy Advancements and their Environmental Impacts. sathipriyanka789@gmail.com.*
3. *Sumair Faisal Ahmed, Mohammed Khalid, Mahesh Vaka, Rashmi Walvekar,Arshid Numan, Abdul Khaliq Rasheed, Nabisab Mujawar Mubarak [2021]. Recent progress in Solar Water Heaters and Solar Collectors. https://doi.org/10.1016/j.tsep.2021.100981*
4. *Siddharth Arora, Shobhit Chitkara, R. Udayakumar, Muhammad Ali. [2011]. Thermal Analysis of evacuated solar tube collector.http://www.academicjournals.org/JPGE.*
5. *Zhao Hui-zhong, Lui Zhen-yan, Zhang Min, Huang Chen, Wang Li-Hui, Zou Zhi-Jun. [2014]. A mechanical and experimental study on the heat loss os solar evacuated tube. DOI: 10.1007/s12204-009-0052-0.*
6. *Madhulesh Yadav, Dr. N.K. Saikhedkar [2017]. Simulation modelling for the performance of Evacuated tube solar collector. DOI:10.15680/IJIRSET.2017.0604120.*
7. *Liangdong Ma, Zhen Lu, Jili Zhang, Ruobing Liang [2010]. Thermal performance analysis of the glass evacuated tube solar collector with U-tube. https://doi.org/10.1016/j.buildenv.2010.01.015.*
8. *Yuguo Gao, Qianchao Hu, Yitao Ren, Xinyu Wang, Shuman Guo, Zhongian Hou Pengyan Guo [2023]. Applications of Nanofluids in heat pipes. https://doi.org/10.1007/s10973-023-12115-2.*
9. *Alexious Papadimitratos, Sarvenaz Shobansarbandi, Vladimir Pozdin, Anwar Zhakhidov, Fatehmeh Hassanipour [2016]. Evacuated tube Solar Collector integrated with Phase Change Materilas. https://doi.org/10.1016/j.solener.2015.12.040*
10. *K. Chopra, Atin K. Pathak, V.V. Tyagi, A.K. Pandey, Sanjeev Anand, Ahmet Sari [2019].Thermal performance of phase change material integrated heat pipe evacuated tube collector. https://doi.org/10.1016/j.enconmen.2019.112205*
11. *Vivek R. Pawar, Sarvenaz Sobhansarbandhi [2022]. Heat transfer enhancenent of a PCM-porous metal based heat pipe evacuated tube solar collecotr. https://doi.org/10.1016/j.solener.2022.10.054*
12. *Li Feng, Jiajun Liu, Yuning Chen Shenyu Wu [2022]. A parametric study on the efficiency of a solar evacuated tube collector using phase change materials. https://doi.org/10.1016/j.renene.2022.09.029*
13. *Piotr Felinski, Robert Sekret [2017]. Effect of PCM application inside an evacuaetd tube collector on the thermal performance of a domestic water heater. https://doi.org/10.1016/j/enbuild.2017.07.065*
14. *Youg Li, Xiaoyu Liang, Wang Song, Tong Li, Dangjia Wang, Yanfeng Liu [2022]. Optimization and thermal performance of U tube evacuated tube solar collecotr filled with phase change material. https://doi.org/10.1016/j.egyr.2022.04.054*
15. *K. Chopra, Atin K. Pathak, V.V. Tyagi, A.K. Pandey, Sanjeev Anand, Ahmet Sari [2019]. Experimental performance evaluation of a novel designed phase change material integrated manifold heat pipe evacuated tube solar collector system. https://doi.org/10.1016/j.enconmen.2019.111896*
16. *Mohammed Alshukri, Adel A. Eidan, Saleh Ismail Najim [2021]. Thermal performance of heat pipe evacuated tube solar collector integrated with different types of phase change materials at various location. https://doi.org/10.1016/j.renene.2021.02.243*
17. *M.A. Sharafeldin, Gyula Grof [2019]. Efficiency of evacuated tube solar collector using WO_3/ water nanofluid. https://doi.org/10.1016/j.renene.2018.11.010*
18. *Huseyin kaya, Mohanad Alkasem, Kamil Arslan [2020]. Effect of nanoparticle shape of Al_2O_3/ Pure water nanofluid on evacuated U-tube soalr collector efficiency. https://doi.org/10.1016/j.renene.2020.08.039*
19. *Javad Ghaderian, Nor Azwadi Che Sidik [2016]. An experimental inveatigation on the effect of Al_2O_3/ distilled water nanofluid on the energy efficiency of evacuated tube solar collector. https://doi.org/10.1016/j.ijheatmasstransfer.2016.12.1011*
20. *I.M. Mahbulbul, Mohammed Mumtaz A. Khan, Naisiru I. Ibrahim, Hafiz Muhammad Ali, Fahad A.Al-Sulaiman, R. Saidur [2018]. Carbon nanotube nanofluid enhancing the efficiency of evacuated tube solar collector. https://doi.org/10.1016/j.renene.2018.01.006*
21. *Roonak Daghigh, Pooya Zandi [2018]. Improving the performance of heat pipe embedded evacuated tube collecotr with nanofluids and auxiliary gas system. https://doi.org/10.1016/j.renene.2018.11.090*

SJIF Impact Factor (2023): 8.574| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 8 | Issue: 7 | July 2023 - Peer Reviewed Journal

22. *Adel A. Eiden, Assad Alsahlani, AhmedQasim Ahmed, Mohammed AL-Fahham, Jalal.M. Jalil [2018]. Improving the performance of heat pipe evacuated tube solar collecotr experimentally by using Al_2O_3 and CuO/ acetone nanofluids. https://doi.org/10.1016/j.solener.2018.080013*
23. *Mohd Hasan [2023]. Review of the impact of nanomaterial on the thermal efficiency of an evacuated tube solar air heater. DOI:10.1016/maptr.2023.01.229*
24. *Huseyn Kaya, Kamil Arslan, Nuretin Eltugral [2018]. Experimental investigation of thermal performance of an evacuated U-Tube solar collector with ZnO/Etylene glycol-pure water nanofluids. https://doi.org/10.1016/j.renene.2018.01.115*
25. *Huseyn Kaya, Kamil Arslan [2019]. Numerical investigation of efficiency and economic analysis of an evacuated U-tube solar collector with different nanofluids. https://doi.org/10.1007/s00231-018-2442-z*
26. *Sorabh Aggrawal, Raj Kumar, Deiho Li, Sushil Kumar, Tej Singh [2023]. A comprehensive review of techniques for increasing the efficiency of evacuated tube solar collectors. https://doi.org/10.1016/j.heliyon.2023e.15185*
27. *Shaowai Chai, Jian Yao, Jyun-de-Liang, Yuan-ching-Chiang, Yao ZhaoSih-li-Chen, Yanjun Dai [2021]. Heat transfer analysis and thermal performance investigation on an evacuated tube solar collector with inner concentrating by reflecting coating. https:/doi.org/10.1016/j.solener.2021.03.048*
28. *A.Veera Kumar, T.V. Arjunan, D. Seenivasan, R. Venkatraman, S. Vijayan [2020]. Thermal performance of an evacuated tube solar collector with inserted baffels for sir heating applications. https://doi.ogr/10.1016/j.solener.2020.12.037*
29. *Hong-jin Joo, Hee-youl Kwak, Minsuk Kong [2022]. Effect of twisted taper inserts on thermal performance of heat pipe evacuated tube solar thermal collector. https://doi.org/10.1016/j.energy.2022.124307*
30. *Yu Yuan, Gang Wu, Qichang Yang, Ruifeng Cheng, Yuxin Tong, Yi Zhang, Hui Fang, Qianlei Ma [2021]. Experimental and analytical optical-thermal performance of evacuated cylindrical tube reciever for solar dish collector. https://doi.org/10.1016/j.energy.2021.121301*
31. *Saleh Abo Elfadl, Hamdy Hassan, M.F.Dosoky [2020]. Energy and exergy assessment of integrating reflectors on thermal energy storage of evacuated tube solar collector heat pipe system. https://doi.org/10.1016/j.solener.2020.09.009*
32. *Guangbai ma, Zhiqiang Yin, Xijie Liu, Jing Qi, Yanjun Dai [2020]. Developments of CPC solar evacuated glass tube collecotr with a novel selective coating. https://doi.org/10.1016/j.solener.2020.08.052*
33. *Aseem Dubey, Samsher, Anil Kumar. [2021]. Energetic and exergetic study of dual slope solar distiller coupled with evcuated tube collector under force mode. https://doi.org/10.1016/j.matpr.2021.04.135*
34. *P. Selvakumar, P. Somasundaram, P. Thnagavel [2014]. Performance study on evacuated tube solar collector using therminol D-12 as heat transfer fluid coupled with parabolic trough. https://doi.org/10.1016/j.enconmen.2014.05.069*
35. *Fie Chen, En-tong Xia, Yu Bie [2019]. Comparative investigation on photo-thermal performance of both compound parabolic concentrator and ordinary all-glass evacuated tube absorbers: An incorporated experimental and theoretical study. https://doi.org/10.1016/j.solener.2019.04.036*
36. *Engy Enshazly, Ahmed-A-Abdul-Rahim, Imam el- Mahallwawi [2022]. Thermal performance enhancement of evacuated tube solar collector using MWCNT, Al2O3, and hybrid MWCNT/ Al2O3nanofluids. https://doi.org/10.1016/j.ijft.2022.10260*
37. *Fuyi Cui, Fuhai Liu, Yijie Tong, Shifeng Wang, Weiganag Guo, Tianlong Han, Xudong Qui [2022]. Energy and exergy assessment of evacuated tube solar collecotr using water, Fe_3O_4 nanofluid and Fe_3O_4/ MWCNT hyberid nanofluid. https://doi.org/10.1016/j.psep.2022.05.023*
38. *Shady M. Henein, Ahmed A. Abdel Rehim, Khairy el- Nagar[2022]. Energy, economic and environmental analysis of an evacuated tube solar collector using hybrid nanofluid. https://doi.org/10.1016/j.applthermaleng.2022.119671*
39. *Ipek Aytac, Azim Dogus Tuncer, Ataollah Khanlari, Halilm Ibrahim Variyenli,, Sedat Mantici, Levent Gungor, Sinan Unvar. Investigating the effects os using MgO-CuO/ water hybrid nanofluid in an evacuated soalr water collector. https://doi.org/10.1016/j.tsep.2023.101688*
40. *Sorabh Aggrawal, Raj Kumar, Deiho Li, Sushil Kumar, Tej Singh [2023]. A comprehensive review of techniques for increasing the efficiency of evacuated tube solar collectors. https://doi.org/10.1016/j.heliyon.2023e.15185*
41. *Mohammed Alshukri, Adel A. Eidan, Saleh Ismail Najim [2021]. The influence of integrated Micro-ZnO and Nano-CuO particles/paraffin wax as a thermal booster on the performance of heat pipe evacuated solar tube collector. https://doi.org/10.1016/j.est.2021.102506*
42. *Pablo Sampio Gomes Natividade, Gabriel de Moraes Moura, Elson Avallone, Enio Pedone Bandarra Filho, Rogerio Valentim Gelamo, Julio Cesar de Souza Inacio Goncalves [2019]. Experimental nalysis applied to an evacuated tube solar collecotr equipped with parabolic concentrator using multilayer graphene-based nanofluids. https://doi.org/10.1016/j.renene.2019.01.091*