International Journal of Engineering, Science and Mathematics
Vol. 6 Issue 8, December 2017 (Special Issue)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind
Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Parametric Investigation on the Performance of Flat-Plate Solar Collector

Hitesh Bhatia[*]
Rahul Agarwal[**]
Vibhooti Vaibhav[***]
Vishnu Saini[****]

Abstract

Flat plate solar collector isan emerging category of solar power technology that intensifies on the solar collector performance. This performance is influenced by design parameter, operational parameter, meteorological parameter and the environmental parameter. In context to design parameter, collector tilt, incident solar flux, fluid inlet temperatures,absorber plate and the first cover are major factors directly relatedto the collector performance. Hence the present work deals with the analytical investigation of collector performance based on these factors using MATLAB2007a for various places in India.All these parameters are considered as function of efficiency. Moreover, increase in tilt angle, transmittivity, absorbtivity and solar intensity increases the efficiency of flat plate solar collector that additionally provides higher heat removal factor.

Keywords:

Solar energy;
Flat-plate solar collector;
Intensity;
Overall heat loss coefficient;
Heat removal factor;
Ambient Temperature.

Author correspondence:

Hitesh Bhatia,
Research Scholar, School of Mechanical Engineering
Lovely Professional University, Phagwara, Punjab, India

1. Introduction

Solar energy is currently the ultimate source of clean and non-conventional energy that has enormous tendency to provide energy in form of heat, if stored properly. This heat from solar energy is applied in domestic water heating, pool heating and various other industrial processes. However, the availability and intensity of solar energy is restricted to certain time duration which hinders the most widespread use of this energy.At a given instant of time, the solar energy depends on weather, location and also varies considerably within an hour or even minutes.

[*]Research Scholar, School of Mechanical Engineering, Lovely Professional University, Punjab, India
[**] Research Scholar, School of Mechanical Engineering, Lovely Professional University, Punjab, India
[***] Research Scholar, School of Mechanical Engineering, Lovely Professional University, Punjab, India
[****]Assistant Professor, School of Mechanical Engineering, Lovely Professional University, Punjab, India

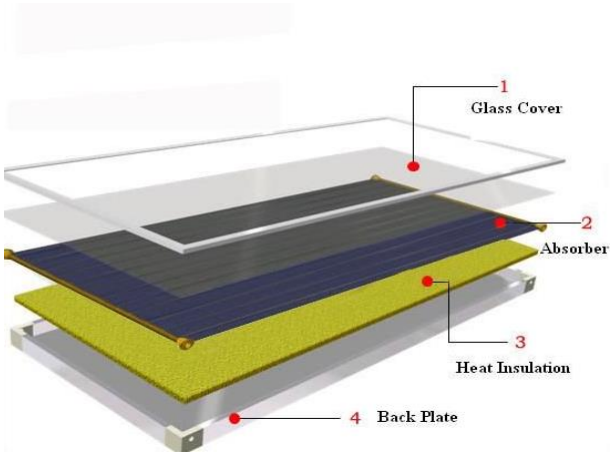

Figure 1. Schematic of Flat-Plate Solsar Collector

During winter season requirement forboth solar and thermal energy is highest yet relatively less amount of solar radiation is received from sun. This complication enforced to work on the storage of sunlight in form of solar collectors that transforms solar irradiation into thermal energy. The medium considered in this research work is liquid (water) used in solar collector. Solar collector consists of aluminium rigid frame, back plate, low iron solar safety glass for glazing, tin-copper based riser and header tubes, aluminium absorber plate having high thermal conductivity and coating for maximum absorption and minimum radiant emission, swirl flow devicesand polystyrene insulation.Flat plate solar collector can be installed in various ways depending upon the application and size of collector. Desalination of water [1] using solar heating has emerged as an advantageous technique .Analytical [2] numerical [3] computational and experimental model [4] of solar collector for its optimization, further enhancing its thermal performance has been studied in recent time. The anisotropic behaviour of sky using the mathematical model of the solar collector was conducted by Baccoli *et al.*[5]. Further, Ziqian Chen *et al.*[6] characterized the solar collector system by means of film (convection) transfer coefficient, plate emissivityor absorbtivitythrough nonlinear optimization techniques applicable to steady state conditions. Dawit Gudeta Gunjo *et al.*[7] and Mohamed Selmi [8]investigated on the solar collector system using CFD analysis. Mohsen Sheikholeslami [9] reviewed on heat transfer enhancement method by focusing on passive method for swirl flow devices. Twisted tapes,a type of swirl flow devices, has been a key element for improving and enhancing the thermal characteristics of solar collector. Swirl was generated byvarying twist ratio and rotation anglein an evenly spaced twisted-tape elements [10]. In addition, the thermal and hydraulic performance of twisted tape insert depends on the flow conditions, such as laminar or turbulent flow [11]. Later, a new dynamic test method was introduced by Weiqiang Kong *et al.*[12]providing improved transfer function. One parameter is time term, and the other is a second term mean fluid temperature.

2. Research Methodology

In the research preset work, the influnce of various parameters on the efficiency of flat-palte solar collector is estimated.Assumptions such as no heat are inflitrated from the solar system in order to reduce the overall time for analyses are made.

2.1 Problem Description

A flat-plate solar collector is a solar thermal energy absorption system, consisting of the following primary components:

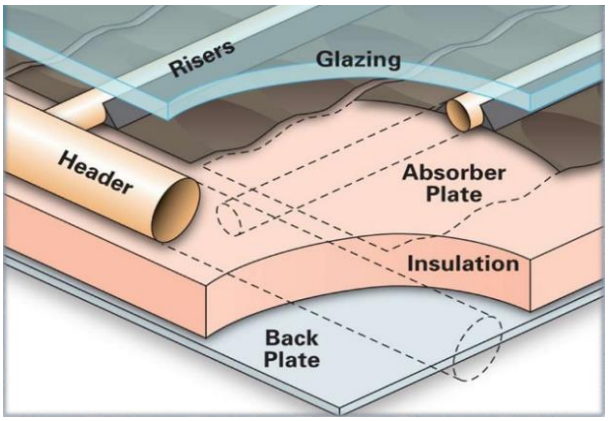

Figure 2. Components of Flat-Plate Solar Collector

- Glazing (A transparent cover that reduces the heat loss)
- Riser and header tubes
- Absorber plate
- Insulation
- Black sheet
- Aluminium rails

Absorber Plate

Absorber plate is primary made up of copper, steel or plastic covered with a flat black material of high absorptance.

Cover plates

A transparent glass covers the absorber plate and functions to reduce the heat loss. The material most commonly used is glass. Glass materials are opaque to long-wavelength radiation emitted by the absorber plate. Some plastic materials can be used for collector glazing becausethey are economical and lighter than glass and high transmittance.

Table 1. Thermal properties of glazing materials

S. No	Material	Transmissivity (T)	Absorbtivity (T)	T * A
1	Glass	0.8842	0.04 to 0.40	0.352
2	Polycarbonate	0.85	0.16 to 0.35	0.2975
3	Polyethylene	0.81	0.94	0.7614
4	Polyvinyl fluoride (tedlar plastic)	0.89	0.94	0.8366
5	Polystyrene	0.88	0.3 to 0.47	0.4136
6	Polyester	0.81	0.2 to 0.5	0.405

Table 2. Average thermal conductivityof insulation components

S.NO	Material	Thermal Conductivity (W/m-k) at 25° C
1	Acrylic	0.2
2	Asbestos	0.14 to 0.74
3	Balsa wood	0.048
4	Cotton wool	0.029
5	Fiber glass	0.04

6	Polyester	0.05
7	Polystyrene	0.03
8	Slag wool	0.042
9	Timber	0.17
10	Polyurethane foam	0.03

Insulation/Enclosure

These are materials made of fibreglass at the back and sides of the collector. The collector is basically made of steel, aluminium or fibre glass. Insulation is placed behind the absorber plate. Low thermal conductivity is equivalent to high insulating capability.

2.2Solution Methodology

A flat plate solar collector is considered with standard design specification with a twisted tape inside the tubes. Various factors such as tilt angle, transmittivity, absorbtivity and solar intensity is considered to estimate the efficiency of collector. Useful programs are generated in MATLAB2017a and all parameters are considered in order to achieve better efficiency.

3. Results and Analysis

3.1 Effect of Tilt Angle on the Efficiency

Solar collector tilt angle range from 15 to 45 degrees. The efficiency of the collector will be increased if the solar radiation will fall perpendicular to the collector and vice versa. If the solar collector is being installed in an angular roof then the tilt angle requirement will get decreased. The angle for the collector gets steeped during winter season because the sun does not remain at peak for long time and vice versa.

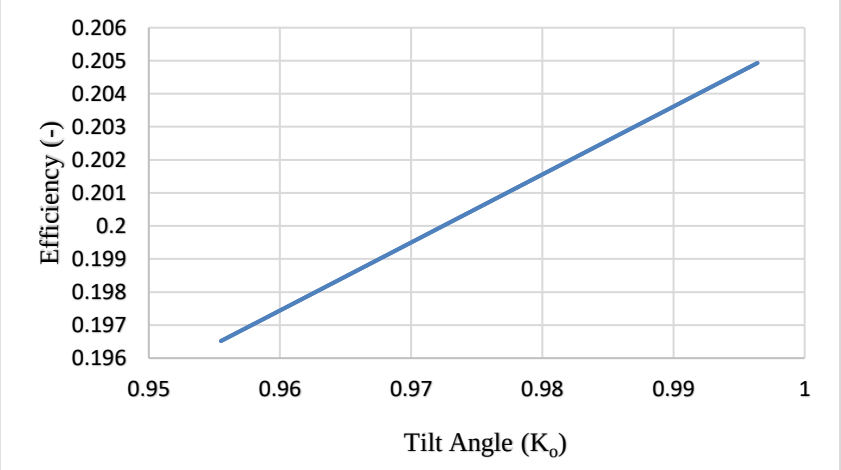

Figure 3. Influence of tilt angle on the thermal efficiency of solar collector system

3.2 Effect of Transmittivity on theEfficiency

Transmittivity is the degree to which a medium allows something, to pass through it. Efficiency of collector increases with increase in Transmittivity it is due to the reason that more radiation will be allowed to enter the collector if material having better Transmittivity and it will further increase the temperature of the absorber plate so after all efficiency will be improved. Mostly for solar collector we use having low iron based glazing because it is having better transmittivity.

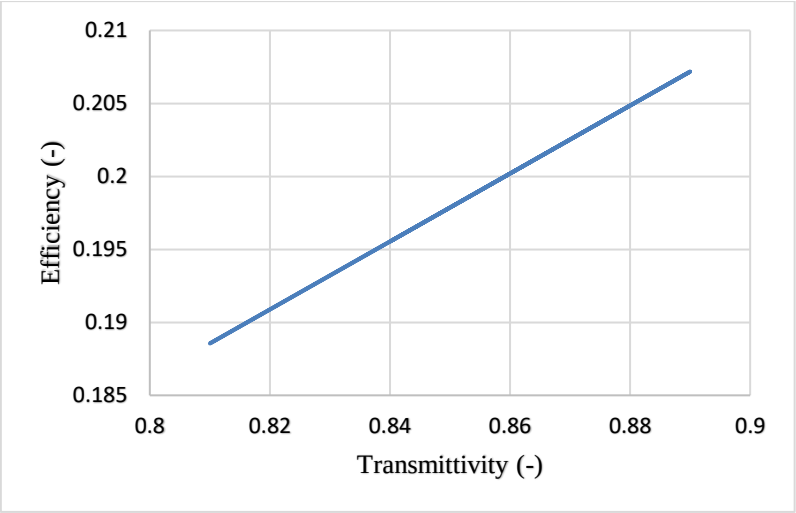

Figure 4. Influence of transmittivity on the efficiency of solar collector

3.3Influence ofAbsorbtivity on thermal Efficiency

The property of a body that determines the fraction of incident radiation absorbable by the body is called absorbtivity. As more of the solar energy will be absorbed by the absorber plate we can say that water will get heated quickly so overall efficiency will be increased. To increase absorbtivity black chrome paint has been painted on the absorber plate. And the material should be specified having of good thermal properties.

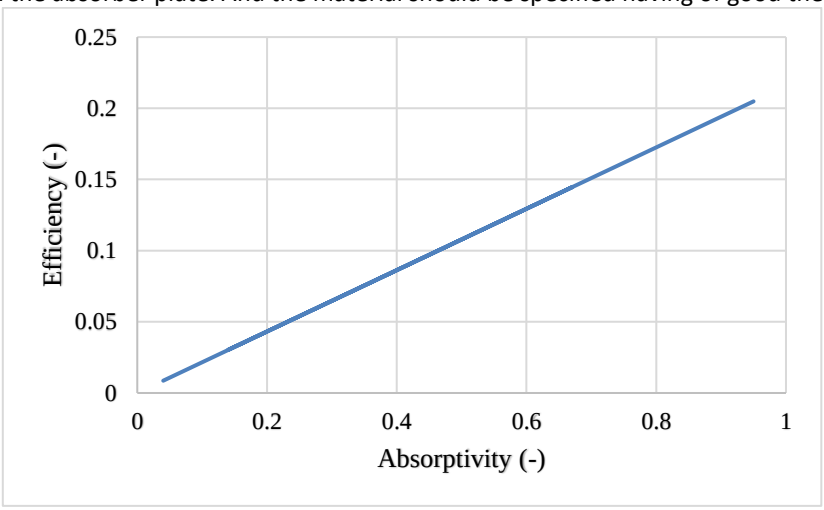

Figure 5. Influence of absorbtivity on the efficiency of flat-plate solar collector

3.4Influence of Inlet Temperature on the thermal Efficiency

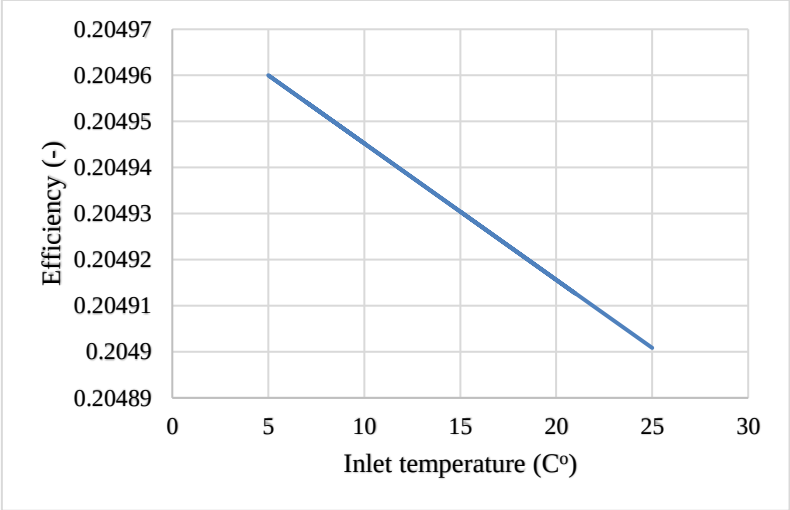

Figure 6. Influence of inlet temperature of working fluid (water) on the efficiency of solar collector

An increase in efficiency of inlet water having temperature having 15 degree but if the temperature will get exceeded the heat transfer rate to the water will be very low and it will not have great impact on the efficiency. The efficiency of the collector gets increased during winter as compared to the summer.

3.5 Influence of Ambient Temperature on theThermal Efficiency

Ambient temperature is the air temperature of an environment or object. It is observed that as ambient temperature rises the efficiency will get increased. The range of ambient temperature should lie between 20 to 45 degrees.

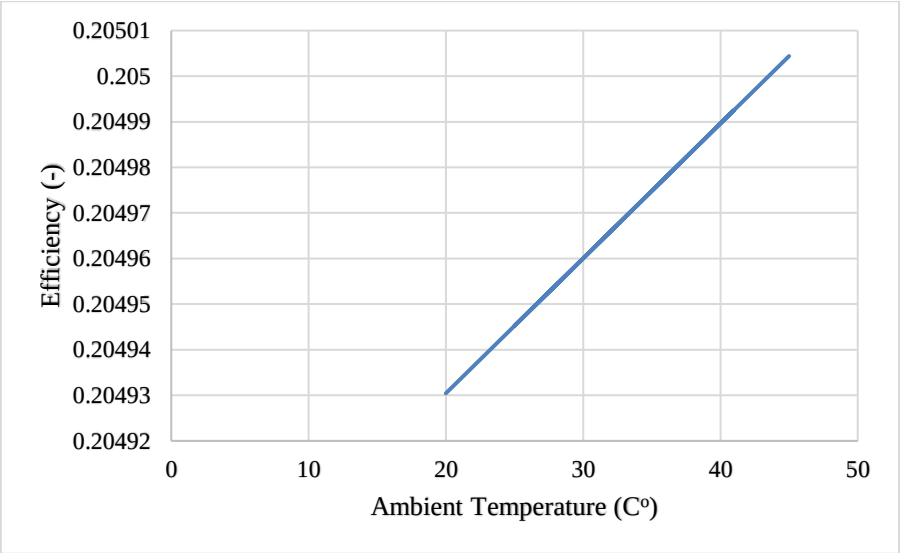

Figure 7. Influence of ambient temperature on the efficiency of solar collector

3.6 Effect of Solar Intensityon the Efficiency

As soon as the solar intensity coming from sun will increased the power transferred to the absorber sheet will get increased further then water inside riser pipes will get heated quickly so efficiency will get increased.

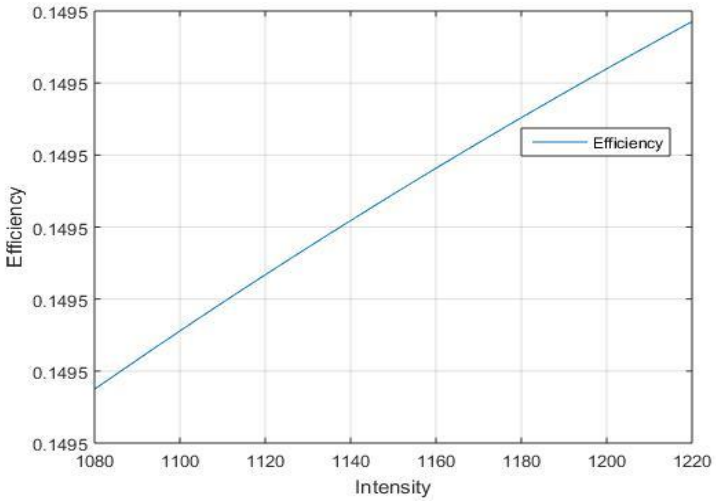

Figure 8. Influence of intensity of solar irradiation on the thermal efficincy of solar collector system

3.7 Effect of Heat Removal Factoron the Efficiency

It can be observed from the graph the efficiency gets increased with increase in heat loss removal factor. The collector heat removal factor (FR) of solar collector increases with decrease in the value of relative roughness pitch of the swirl flow upon diameter of pipe and with increase in the values of relative roughness height.

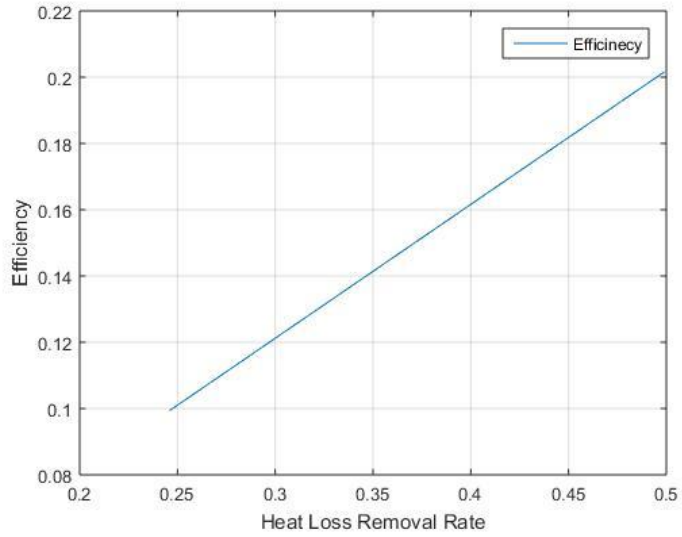

Figure 9. Influence of heat loss removal rate on the efficiency of the solar collector

3.8 Effect of Overall Heat Loss Factor on the Efficiency

The heat losses of solar collector is from top, bottom and sides. Most of the heat losses is from top and as soon as the heat losses increase the rate of heat transfer decrease so overall efficiency is effected and get decreased.

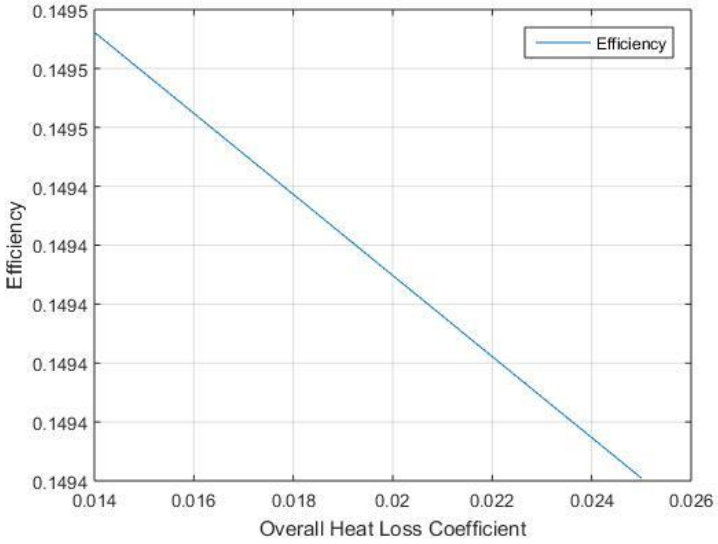

Figure 10. Influnece of overall heat loss coffecient on efficiency of the solar collector

4. Conclusion

Flat-plate collectors, used for various domestic and industrial purposes, arelong lasting, economical and reliable technique. However requires high initial cost for installation and continuous maintenance. The main benefit of using solar energy is that it pollution free.In this analysis use of swirl flow devices inside the riser pipes leads to increase in overall heat transfer coefficient. Also , energy output is incremented by installing of swirl flow devices such as twisted tubes that creates the turbulence in riser pipes. Moreover, the Reynolds number increases which may store energy with pressure inside the pipes and the temperature fo fludi inside riser get heated up to maximum level. Thus provides better efficiency for solar plate collector.

References

[1] B. Du *et al.*, "Area optimization of solar collectors for adsorption desalination," *Sol. Energy*, vol. 157, no. July, pp. 298–308, 2017.

[2] R. Eismann and H. Prasser, "Correction for the absorber edge effect in analytical models of flat plate solar collectors," *Sol. Energy*, vol. 95, pp. 181–191, 2013.

[3] N. Wang, S. Zeng, M. Zhou, and S. Wang, "Numerical study of fl at plate solar collector with novel heat collecting components ☆," *Int. Commun. Heat Mass Transf.*, vol. 69, pp. 18–22, 2015.

[4] P. V Ranjith and A. A. Karim, "A Comparative Study on the Experimental and Computational Analysis of Solar Flat Plate Collector using an Alternate Working Fluid," *Procedia Technol.*, vol. 24, pp. 546–553, 2016.

[5] R. Baccoli *et al.*, "A mathematical model of a solar collector augmented by a flat plate above reflector : Optimum inclination of collector and reflector," vol. 81, pp. 205–214, 2015.

[6] Z. Chen, S. Furbo, B. Perers, J. Fan, and E. Andersen, "Efficiencies of flat plate solar collectors at different flow rates," vol. 30, pp. 65–72, 2012.

[7] D. G. Gunjo, P. Mahanta, and P. S. Robi, "SC," *Renew. Energy*, 2017.

[8] M. Selmi, M. J. A. Ã, and A. Marafia, "Validation of CFD simulation for flat plate solar energy collector," vol. 33, pp. 383–387, 2008.

[9] M. Sheikholeslami, M. Gorji-bandpy, and D. Domiri, "Review of heat transfer enhancement methods : Focus on passive methods using swirl fl ow devices," vol. 49, pp. 444–469, 2015.

[10] "Compound Heat Transfer Enhancement of a Converging-Diverging Tube with Evenly Spaced Twisted-tapes*," vol. 15, no. 20776046, pp. 814–820, 2007.

[11] D. G. Kumbhar and N. K. Sane, "Heat Transfer Enhancement in a Circular Tube Twisted with Swirl Generator : A Review," pp. 3–7, 2010.

[12] W. Kong *et al.*, "Investigation of thermal performance of flat plate and evacuated tubular solar collectors according to a new dynamic test method," vol. 30, pp. 152–161, 2012.