PAPER NAME

Amrizal-JARFMTS

AUTHOR

Amrizal Amrizal

WORD COUNT

5640 Words

CHARACTER COUNT

28218 Characters

PAGE COUNT

12 Pages

FILE SIZE

540.2KB

SUBMISSION DATE

Dec 2, 2022 10:38 PM GMT+7

REPORT DATE

Dec 2, 2022 10:38 PM GMT+7

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Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Performance Analysis of PV/T-TEC Collector for The Tropical Climate Conditions of Indonesia

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ARTICLE INFO

Article history:
Received 1 February 2022
Received in revised form 22 April 2022
Accepted 24 April 2022
Available online 25 May 2022

Keywords:
Photovoltaic; thermal; electrical; fins; TEC

ABSTRACT

A photovoltaic (PV) collector converts sunlight directly into electrical energy about 20% while the rest is wasted as heat energy. This heat energy increases the operating temperature of the PV collector which has negative impacts on the semiconductor material and electricity production. Concerning the issue, the PV collector is then integrated by both the finned absorber and Thermoelectric Cooler (TEC) modules which is known as a PV/T-TEC collector. This study aims to determine the performance of the PV/T-TEC collector based on the tropical climate condition in Bandarlampung, Indonesia (latitude 5°27ʹS and longitude 105°16ʹE). Furthermore, the finned absorber and TEC modules are attached underneath the PV collector surface to act as a heat sink. Air as a working fluid was specifically passed through the PV/T-TEC collector to absorb the unused waste heat. Thus, the radiation level and air mass flow rate are varied in the range of 700-1000 W/m^2 and 0.0075-0.075 kg/s, respectively. Based on data obtained from the experimental tests, the highest values of the thermal and electrical efficiency are found to be 26.3 % and 9.8 %, respectively. The temperature difference between the two sides of the TEC is found to be less than 2.2 ºC and there is a 0.3% increase in the total electric power generated from the TEC modules which cover 12% of the PV collector surface.

1. Introduction

One of the renewable resources that can potentially be developed is solar energy. A Photovoltaic (PV) collector is a device that converts solar energy into electricity about 20% and the rest is wasted as heat energy [1]. Concerning the unused waste heat of PV collector, Zulkurnain *et al.,* conducted research on residual heat of PV systems which is be implemented in AC systems. It is reported that the solar PV waste heat has possibility to be utilized for desiccant solution regeneration [2]. Furthermore, the unused waste heat may also cause a decrease in the electrical efficiency of the PV collector [3]. Moharrama *et al.,* reported that the electrical efficiency of the PV panel decreases about 0.5% when the operation temperature rises about 1 ºC [4]. In other words, the electrical efficiency of the PV collector rises every time the temperature of the PV surface decrease [5].

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https://doi.org/10.37934/arfmts.95.2.7283

To reduce the operating temperature of the PV collector, it is necessary to combine the PV panel with the thermal collector which is known as PV/T collector to absorb the unused waste heat. The development of this type of collector began in 1970 as reported by Chow [6], where the PV/T collector keeps the operating temperature remains constant and at the same time produces the hot fluid as a working fluid that can be used for various purposes. Meanwhile, the testing methods for thermal and electrical performances contribute to the development of the PV/T collector as well [7-8]. Additionally, Zwalnan *et al.,* also investigated numerically the effect of building thermal load for building applications. It is concluded that the low emissivity PV collector is recommended for building applications [9].

Concerning the working fluid of a PV/T collector, it can be air or water which acts as a heat transfer medium, where the water-based PV/T system has higher electrical efficiency than that of an air-based PV/T system [10]. Based on the structure of a PV/T collector, the heat transfer area can be extended by using fins that serve as a heat sink for increasing the heat transfer rate [11]. To implement fins in heat transfer system, the cooling technique using rectangular microchannel heat sinks was also developed by Wan [12]. In this case, the thermal resistance in the developed region is higher than the hydrodynamic entrance region.

Based on the climatic condition of the testing, Bashir *et al.,* implemented the experiments of several different PV collectors in Taxila, Pakistan [13]. The results revealed that the electrical power of the different PV collectors increases with the rise of solar irradiation. Ali *et al.,* tested the performance of a PV panel during the peak of summer and found out that the efficiency was much lower than that at the same location in January [14]. Antoni and Saro developed a numerical design model and a parameter simulation of the solar thermal collector for the European climate, which were applied during winter at inlet fluid temperature of -5 ^oC and a mass flow rate of 45 kg/s/m^2 [15]. The result stated that the energy rate was about 460.77 kWh/m^2/y and the average heat flux was 93.03 W/m^2 for the climate of Stuttgart-Germany. Thus, Narkwatchara *et al.,* reported that the tropical climate region contributes to the negative impacts on the electrical production of PV collectors [16]. Furthermore, Misha *et al.,* conducted simulation and experiments tests of the PV/T water system under Malaysian weather conditions. The results concluded that with the increase in the mass flow rate, the cell temperature is decreased. The maximum electrical efficiency is found to be 11.71% [17].

Nesarajah *et al.,* presented a detailed comparison between the Peltier element (also known as a Thermoelectric Cooler-TEC) and a Thermoelectric Generator-TEG for the generation of electrical energy [18]. The result of this research indicated that the temperatures within the range of 0-100°C, the TEC was as good as the TEG. This result is significant for the development of the thermoelectric utilization system where the TEC itself is 15 times cheaper than the TEG. Besides, Alghanima also investigated the effect of position and design parameters of the fan and TEC on the Refrigerator performance. It is concluded that the direction of the fan can contribute to the temperature distribution and the heat transfer process [19]. Furthermore, Chottirapong *et al.,* stated that TEG can also generate continual power up to 290 mW implemented to solar cells in Thailand climate [20].

Sourav *et al.,* reviewed the Photovoltaic–Thermal (PV/T) technology on applications and its advancement. It is reported that various parameters affect the performance of PV-TEG such as the method of integration of TEG, location, and properties of TEG and its thermal resistance [21]. Thus, Umar *et al.,* also reviewed the configuration of the PV/T-TEG system from several research results for increasing energy output both experimentally and numerically [22]. It is shown that increasing the concentration ratio increases the efficiency of TEG so that it contributes to the hybrid system. Meanwhile, Yoonbeom *et al.,* investigated different interfaces between the PV and TEG components in term of heat transfer enhancement. The result shows that interfaces with high solar-energyabsorption efficiency and the high thermal conductivity contribute to increase the PV/T-TEG performance [23]. Furthermore, evaluation of PV-TEG system in term of experimental and comparative performance were carried out by Muhammad *et al.,* as well. In this study, the operating temperature of the PV module decreases about 5.5% and consequently increase the PV-TEG output power about 19 % [24]. In addition, Song *et al.,* reported that solar thermoelectric generators without optical concentration become a promising alternative solar energy thermal utilization technology because they are also economical and simple to implement [25]. Jia *et al.,* also studied implementation of silicon grease to reduce the thermal contact between PV and TEC surfaces to enhance the performance of Photovoltaic-Thermoelectric [26]. Moreover, the performance of PV-TEC integrated with parabolic through collector was analyzed by Shohreh. The electrical performance is increased by placing them on the lateral area of absorber tube [27]. Meanwhile, three different type of PV modules such as opaque, semitransparent and aluminum base were investigated by Neha. It is concluded that the performance of aluminum base of PV/T-TEC is higher than the others [28].

The data regarding the characteristics of the PV/T-TEC collector especially in tropical climate regions remains limited. The different responses of collectors may occur because of certain variables, such as ambient temperature, testing regions, types of PV collectors, working fluids, the intensity of solar radiation, types of thermoelectric, and others. In the present study, the testing of the performance of a PV solar panel collector was combined with a thermal collector and TEC 1-12706 modules which act as a heat sink. The thermal collector connected with straight fins and TEC modules is then attached underneath the PV collector surface. This PV/T-TEC collector was tested with air as the working fluid. Therefore, the main objective of this study is to characterize the performance of PV/T-TEC in term of thermal and electrical efficiency based on Bandarlampung climate conditions (latitude of 5°27ʹS and longitude of 105°16ʹE).

2. Methodology

Figure 1 and 2 describe the design and photograph of the absorber as a heat sink with the common type of straight fins combined with TEC 1-12706 modules. Further, the dimension of straight fins and TEC is (25.4 mm high, 1 mm thick, 12.7 mm fin spacing) and (40 x 40 x 3.8 mm) respectively. The straight fins made from aluminum are the most widely used heat sink due to simple manufacturing, good conductivity, low density, and low cost. Furthermore, the TEC is a device that can act as a generator to produce electricity due to the different temperatures of the two sides of TEC. The TEC itself can be as good as the TEG within a range temperature less than 100 ^{o}C and much less costly than a TEG [15]. This can be a motivation to propose the use of TEC in the present study.

The design of the absorber proposed here is only 12% of the PV panel surface covered by the TEC modules. This is to see the influence of the temperature difference available of TEC sides during the test in Bandarlampung climate conditions. The TEC modules are then arranged in three rows (27 pieces) and attached close to the inlet of the PV/T-TEC collector.

The specifications of the Photovoltaic (PV) panel tested in this study can be seen in Table 1. Thus, several experiments are carried out to obtain the values of parameters such as the irradiation (G), air mass flow rate ($\dot{m}$), the inlet and outlet fluid temperatures ($T_{f,in}$ and $T_{f,out}$), hot and cold temperature of the TEC, ambient temperature (T_{amb}), voltage of the PV panel and the TEC (V), current of the PV panel and the TEC (I), and an average temperature of the PV panel surface ($T_{s,PV}$). Then, the collected data was analyzed to determine the thermal and electrical efficiency of the PV/T-TEC collector.

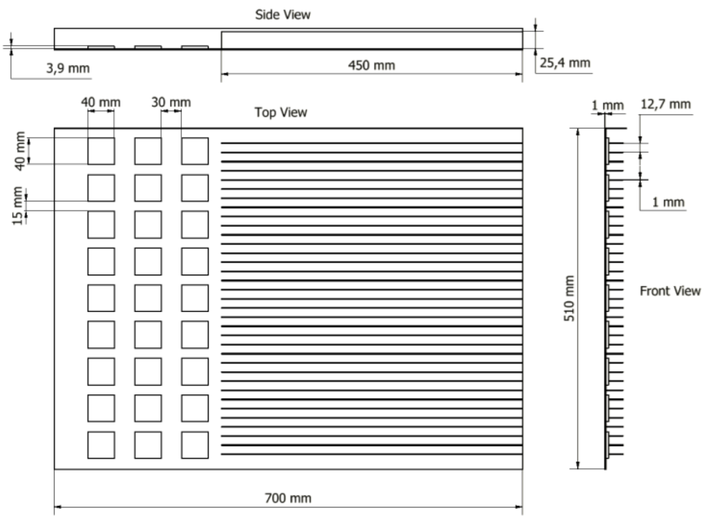
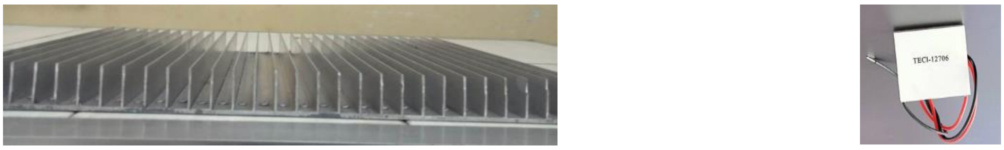


Fig. 1. Model of straight fins and TEC



(a) (b)

Fig. 2. (a) Photograph of straight fins and (b) TEC 1-12706

Table 1
The specifications of the PV panel

Items	Unit	Value
Maximum Power (P_{max})	W	50.0
Maximum Power Voltage (V_{mp})	V	17.6
Oven circuit voltage (I_{mp})	A	2.85
Short circuit current (I_{sc})	A	3.04
Nominal Operating Cell Temp (NOCT)	^oC	45±2

The experiments are conducted to find out the thermal performance of PV collectors in the form of surface and fluid temperatures. Besides, this work was also to find out the electrical efficiency.

The thermal performance is calculated through the following equation [29]

$$\eta_{th} = \frac{\dot{m}\, c_p (T_{fo} - T_{fi})}{A\, G} \quad (1)$$

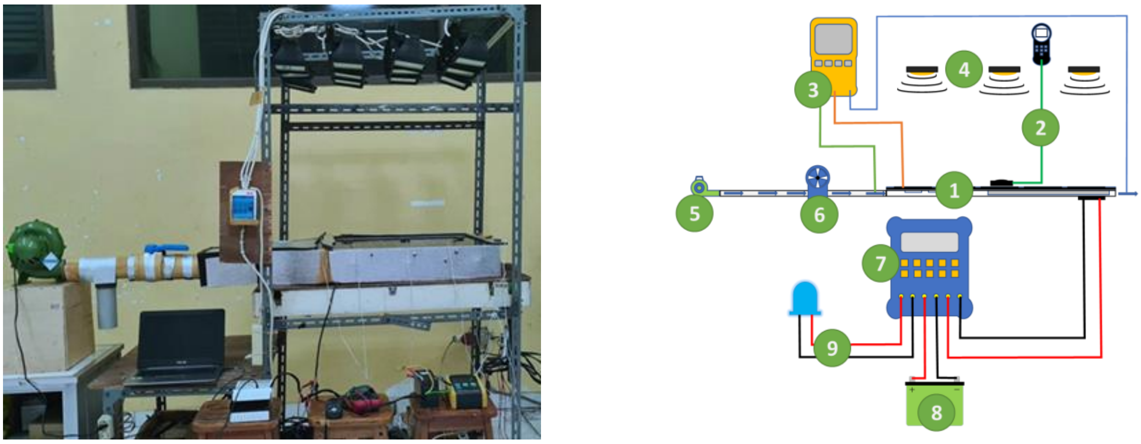
where η_{th} is the thermal efficiency (%), c_p is the air specific heat (W/m^2 ^{o}C). $T_{f,in}$ is the inlet fluid temperature (^{o}C) $T_{f,out}$ is the outlet fluid temperature (^{o}C), A is the absorber area (m^2), G is the irradiation (W/m^2), while the electrical performance is determined through the next formula

$$\eta_{el} = \frac{I\, V}{A\, G} \quad (2)$$

where I is the current generated by the PV panel (A), V is the voltage of the PV panel (V), A is the PV collector area (m^2) and G is the irradiation (W/m^2). The electrical efficiency of the PV/T-TEC collector in this study is obtained through the equation below:

$$\eta_{el} = \frac{Power\ of\ PV\ panel + Power\ of\ TEC}{A\,G} \tag{3}$$

Figure 3 illustrates the photograph and flowchart of the experimental setup which consists of various research components. The solar simulator with 12-300 (Watt) halogen lamps is applied as a representation of the solar radiation. The irradiation level is varied in the range of 700-1000 W/m^2. The PV/T-TEC collector is placed perpendicular to the direction of incoming radiation. The fluid temperature and air mass flow rate are measured with a type K thermocouple and an anemometer respectively. Concerning the radiation, it is recorded with a Solar meter, while the electric current and voltage were measured with Solar Charge Controller TS-45 Tristar.



(a) (b)

Fig. 3. (a) Photograph of the experimental setup and (b) The flow chart of the experimental procedures *(1)* (PV/T-TEC collector (2) Solar power meter (3) Digital thermometer (4) Solar simulator (5) Blower (6) Anemometer (7) Solar charge controller (8) Accu (9) Lamp)

3. Results and Discussion

In the present study, the experiments were conducted to obtain the values of several parameters. The irradiation level and air mass flow rates were varied in the range of 700-1000 W/m^2 and 0.0075-0.075 kg/s, respectively. The measured data were recorded every 10 seconds. The PV/T-TEC collector was tested indoors using a solar simulator which is the representation of solar radiation.

To determine an initial time for recording data, time constant testing at constant fluid mass flow rates was carried out. As shown in Figure 4, the time constant based on the operating temperature of the PV collector is found to be 400 s. Thus, the initial time to record data is approximately 4 times the time constant value [30].

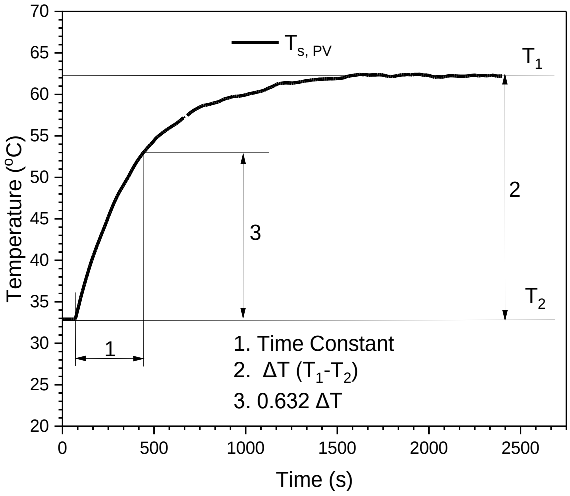


Fig. 4. Response time of PV/T-TEC collector

3.1 Thermal Performance of PV/T-TEC Collector

In this work, experiments were carried out to determine the characteristic of the PV/T-TEC collector. The performance parameters are represented by surface temperature, outlet fluid temperature, and the thermal efficiency of the PV/T-TEC collector. Figure 5 shows the relations of the air mass flow rates and the surface temperatures of the PV/T-TEC collector associated with variation of irradiation level. The air as a working fluid based on the Bandarlampung climate conditions was passed under the PV/T-TEC collector to extract the unused waste heat. While the irradiation level is provided by solar simulator since the indoor testing. Thus, ambient airflow (V = 1 m/s) was also moved over the surface of the PV/T-TEC collector to meet the requirements of testing [19]. Experiments without ambient airflow (V = 0 m/s) were also involved to see the effects on the operation temperature of the PV/T-TEC collector.

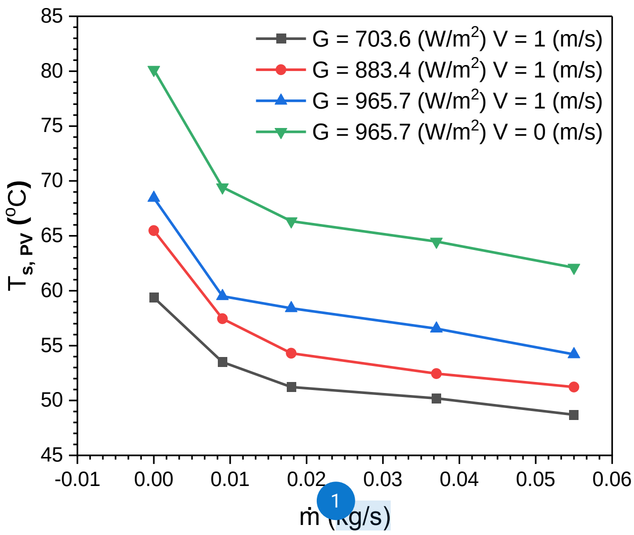


Fig. 5. Effect of the mass flow rate and irradiation level on the surface temperature

As described in Figure 5, it is seen that the higher the air mass flow rate, the lower the temperature of the PV/T-TEC surface. The higher air mass flow rate increases the heat transfer process to absorb the unused waste heat. Hence, this might be attributed to the increase in electrical efficiency as expected in the study. In the other case, there is a significant temperature difference between *with* and *without* an ambient airflow movement over the surface PV/T-TEC collector. The operating temperature of PV/T-TEC collector *without* an ambient airflow is higher about 8-12 °C than that of *with* an ambient airflow especially at irradiation level of 965.7 (W/m^2). This is because the process of heat transfer convection occurs on the PV/T-TEC collector surface. Hence, the unused waste heat is then transferred to the ambiance by flowing air over the PV/T-TEC collector surface. The airflow movement over the surface implemented here is to simulate the outdoor conditions as required by EN-12975 standard.

The effect of radiation and the mass flow rate on thermal efficiency can be seen in Figure 6. It shows that the higher the mass flow rate, the thermal efficiency is also increased. Besides, it is also obvious that there is no significant difference in thermal efficiency based on irradiation level. On the contrary to the mass flow rate, the variation of irradiation level does not significantly affect the thermal efficiency in the present study.

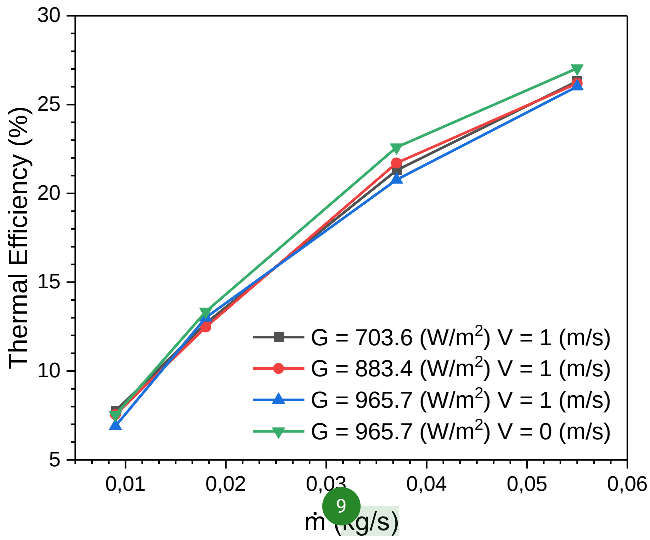


Fig. 6. Effect of the mass flow rate and irradiation level on thermal efficiency

The implementation of the working fluid based on the climate in Bandarlampung region as presented in Table 2 and Figure 7, the outlet fluid temperature increased with the increase in air mass flow rate, irradiation level and the difference between the outlet and inlet of fluid temperature. Again, the irradiation level does not affect significantly the outlet fluid temperature in comparison with the air mass flow rate. Thus, results given by applying the ambient fluid movement over the surface (with V=1 m/s and without V=0 m/s) do not also contribute significantly to the difference of the outlet fluid temperature as can be seen at G=965.7 (W/m^2).

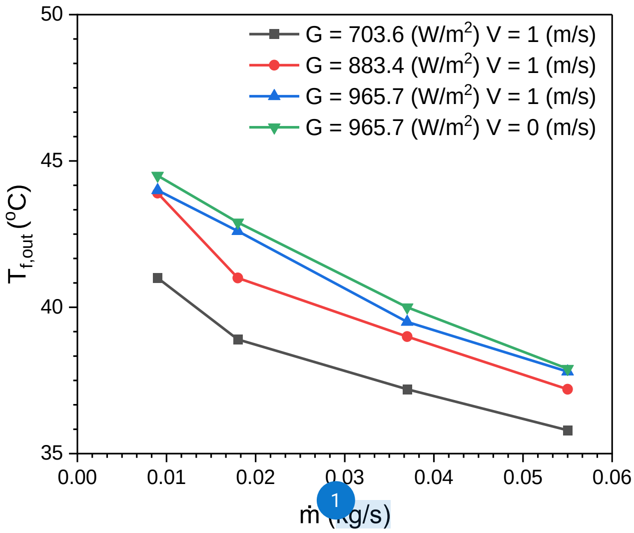


Fig. 7. Effect of the mass flow rate and irradiation level on outlet fluid temperature

Table 2
The inlet (Tf,in) and outlet (Tf,out) of fluid temperature

ṁ (kg/s)	G=703.6 (W/m²) V=1(m/s) $T_{f,i}$(°C)	$T_{f,o}$(°C)	G=883.4 (W/m²) V=1(m/s) $T_{f,i}$(°C)	$T_{f,o}$(°C)	G=965.7 (W/m²) V=1(m/s) $T_{f,i}$(°C)	$T_{f,o}$(°C)	G=965.7 (W/m²) V=0(m/s) $T_{f,i}$(°C)	$T_{f,o}$(°C)
0.009	31.1	41.0	31.8	43.9	31.9	44.1	31.3	44.6
0.018	30.8	38.9	31.0	41.0	31.2	42.6	31.2	42.9
0.037	30.4	37.2	30.3	39.1	30.4	39.5	30.1	40.1
0.055	30.2	35.8	30.2	37.2	30.2	37.8	30.0	37.9

3.2 Electrical Performance of PV/T-TEC Collector

In terms of the electrical performance tests, similar procedures as that of the thermal performance tests are performed in this work. The effects of the irradiation level and the variation of mass flow rate on the electrical efficiency are depicted in Figure 8-9. It is seen that the increase in the air mass flow rate is also followed by the increase in electrical efficiency. This is because the use of the finned absorber and TEC modules as a heat sink can absorb more unused waste heat than the conventional PV collector. Consequently, the operating temperature of the PV/T-TEC collector will be lower than the PV collector without a heat sink, and electricity production will be increased. This also agrees with the results obtained from the earlier references [2-4].

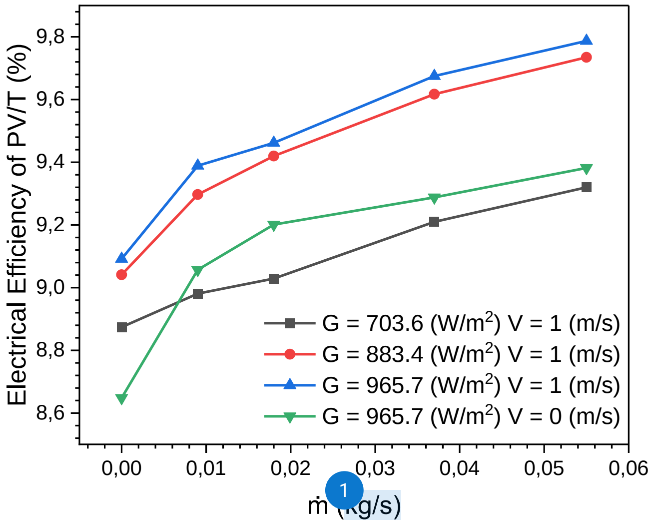


Fig. 8. Effect of the mass flow rate and irradiation level on electrical efficiency of the PV/T collector

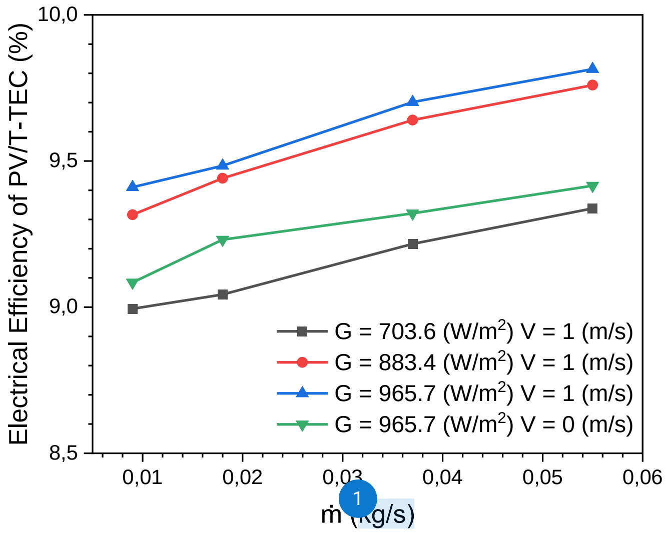


Fig. 9. Effect of the mass flow rate and irradiation level on electrical efficiency of the PV/T-TEC collector

Besides, the higher the irradiation level, the higher the temperature of the TEC hot side, and consequently, the temperature difference (ΔT) between the two sides of TEC is increased as seen in Table 3. Therefore, in this case, the output power of the TEC and the total output power of the PV/T-TEC system are increased as well.

Table 3
The temperature differences of the TEC

ṁ (kg/s)	G=703.6 (W/m^2) V=1(m/s) ΔT (°C)	G=883.4 (W/m2) V=1(m/s) ΔT (°C)	G=965.7(W/m2) V=1(m/s) ΔT (°C)	G=965.7(W/m2) V=0(m/s) ΔT (°C)
0.009	1.65	1.86	1.91	2.17
0.018	1.50	1.71	1.86	2.02
0.037	1.38	1.55	1.73	1.76
0.055	1.20	1.40	1.61	1.65

Concerning working fluid applied in the present study, since the air has low density, small heat conductivity, and small volumetric heat capacity, so the temperature difference obtained from the two sides of the TEC based on the climate in Bandarlampung is found to be less than 2.2 °C as shown in Table 3. Thus, Figure 10 presents the comparison results for electrical efficiency of PV/T collector *with* and *without* implementing TEC modules. Hence, there is a 0.3 % increase in electrical power for only 12 % of the PV panel surface covered by the TEC modules. It implies that the beneficial use of TEC for increasing electrical power exists in tropical regions.

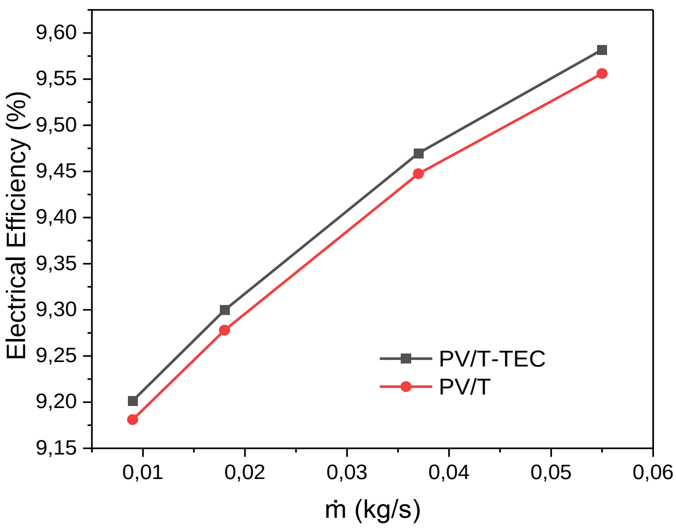


Fig. 10. Comparison of average electrical efficiency between the PV/T and PV/T-TEC collector

4. Conclusions

In the present study, the experiments were carried out to analyze the performance of PV/T-TEC collectors for the tropical climate of Bandarlampung, Indonesia. The results show that the increases in both the air mass flow rate and irradiation level enhance the thermal and electrical efficiency of the PV/T-TEC collector due to the utilization of the straight fins and TEC modules. Furthermore, the increase in irradiation level causes the temperature of the hot side of TEC modules to increase, so the temperature difference between the two sides of TEC (cold and hot sides) will be higher than before. Then, the electricity power TEC will be increased as well. The increase in the air mass flow rate (at the same irradiation level) reduces the operating temperatures, consequently, the temperature difference between the two sides of TEC (cool and hot sides) will be lower than before, so the electricity power TEC will be decreased. In general, however, the total amount of electrical efficiency of the PV/T-TEC collector is still increasing due to the decrease in operating temperature.

In terms of performance values, the highest thermal and electrical efficiency are found to be 26.3 % and 9.8 % respectively at a mass flow rate of 0.055 kg/s and irradiation level of 965.7 W/m^2. The temperature difference between the two sides of the TEC is less than 2.2 °C and there is a 0.3% increase in the total electric power generated from the TEC modules which cover 12 % of the PV collector surface. Thus, the results lead to the implication of PV/T-TEC collectors and could be beneficial use in the tropical regions. While several improvements are still required especially in terms of other configurations, quantities, types of both TEC and fins.

Acknowledgment
This research was funded by a grant from the Ministry of Research and Technology/National Research and Innovation Agency of Republic Indonesia-*Fundamental Research/PDUPT* (Grant No. 120/E4.1/AK.04.PT/2021).

References

[1] Tous, Loic. "Nickel/Copper Plated Contacts as an Alternative to Silver Screen Printing for the Front Side Metallization of Industrial High Efficiency Silicon Solar Cells (Elektrochemisch gedeponeerde nikkel/koper contacten als alternatief voor zilver zeefdruk voor metallisatie van de voorzijde van hoog-efficiënte industriële silicium zonnecellen)." (2014).
[2] Hassan, Zulkurnain, Mohd Suffian Misaran, Nancy Julius Siambun, Ag Sufiyan Abd Hamid, and Mohd Amran Madlan. "Feasibility of using Solar PV Waste Heat to Regenerate Liquid Desiccant in Solar Liquid Desiccant Air Conditioning System." *Journal of Advanced Research in Experimental Fluid Mechanics and Heat Transfer* 2, no. 1 (2020): 10-16.
[3] Das, Biplab, Behnaz Rezaie, Prabhakar Jha, and Rajat Gupta. "Performance analysis of single glazed solar PVT air collector in the climatic condition of NE India." *Multidisciplinary Digital Publishing Institute Proceedings* 2, no. 4 (2017): 171. https://doi.org/10.3390/ecea-4-05021
[4] Moharram, Khaled A., M. S. Abd-Elhady, H. A. Kandil, and H. El-Sherif. "Enhancing the performance of photovoltaic panels by water cooling." *Ain Shams Engineering Journal* 4, no. 4 (2013): 869-877. https://doi.org/10.1016/j.asej.2013.03.005
[5] Herrando, María, and Christos N. Markides. "Hybrid PV and solar-thermal systems for domestic heat and power provision in the UK: Techno-economic considerations." *Applied energy* 161 (2016): 512-532. https://doi.org/10.1016/j.apenergy.2015.09.025
[6] Chow, Tin Tai. "A review on photovoltaic/thermal hybrid solar technology." *Applied energy* 87, no. 2 (2010): 365-379. https://doi.org/10.1016/j.apenergy.2009.06.037
[7] Amrizal, N., D. Chemisana, J. I. Rosell, and Jérôme Barrau. "A dynamic model based on the piston flow concept for the thermal characterization of solar collectors." *Applied energy* 94 (2012): 244-250. https://doi.org/10.1016/j.apenergy.2012.01.071
[8] Amrizal, N., D. Chemisana, and J. I. Rosell. "Hybrid photovoltaic–thermal solar collectors dynamic modeling." *Applied energy* 101 (2013): 797-807. https://doi.org/10.1016/j.apenergy.2012.08.020
[9] Abdalla, Abakar Yousif, Zwalnan Selfa Johnson, Shanmugam Anandan, Chan Andy Tak-Yee, and Su Yuehong. "A Numerical Evaluation of the Effect of Building Thermal Load on the Overall Performance Characteristic of a Grid-Coupled PV/T Energy System." *Journal of Advanced Research in Numerical Heat Transfer* 4, no. 1 (2021): 32-43.
[10] Kazem, Hussein A. "Evaluation and analysis of water-based photovoltaic/thermal (PV/T) system." *Case Studies in Thermal Engineering* 13 (2019): 100401. https://doi.org/10.1016/j.csite.2019.100401
[11] Irsyad, Muhammad, Muhammad Akmal, and M. D. Susila. "Heat Transfer Characteristics of Paraffin in Staggered Fins Heat Exchanger for the Cooling Process to Room Cooling Applications." In *IOP Conference Series: Earth and Environmental Science*, vol. 520, no. 1, p. 012009. IOP Publishing, 2020. https://doi.org/10.1088/1755-1315/520/1/012009
[12] Japar, Wan Mohd Arif Aziz, Nor Azwadi Che Sidik, Natrah Kamaruzaman, Yutaka Asako, and Nura Mu'az Muhammad. "Hydrothermal performance in the Hydrodynamic Entrance Region of Rectangular Microchannel Heat Sink." *Journal of Advanced Research in Numerical Heat Transfer* 1, no. 1 (2020): 22-31.
[13] Bashir, Muhammad Anser, Hafiz Muhammad Ali, Shahid Khalil, Muzaffar Ali, and Aysha Maryam Siddiqui. "Comparison of performance measurements of photovoltaic modules during winter months in Taxila, Pakistan." *International Journal of Photoenergy* 2014 (2014). https://doi.org/10.1155/2014/898414

[14] Ali, Hafiz Muhammad, Mubashar Mahmood, Muhammad Anser Bashir, Muzaffar Ali, and Aysha Maryam Siddiqui. "Outdoor testing of photovoltaic modules during summer in Taxila, Pakistan." *Thermal Science* 20, no. 1 (2016): 165-173. https://doi.org/10.2298/TSCI131216025A

[15] D'Antoni, Matteo, and O. Saro. "Energy potential of a Massive Solar-Thermal Collector design in European climates." *Solar energy* 93 (2013): 195-208. DOI:10.1016/j.solener.2013.04.011

[16] Narkwatchara, Piya, Chavalit Ratanatamskul, and Achara Chandrachai. "Effects of particulate matters and climate condition on photovoltaic system efficiency in tropical climate region." *Energy Reports* 6 (2020): 2577-2586. https://doi.org/10.1016/j.egyr.2020.09.016

[17] Misha, Simulation, Amira Lateef Abdullah, N. Tamaldin, M. A. M. Rosli, and F. A. Sachit. "Simulation CFD and experimental investigation of PVT water system under natural Malaysian weather conditions." *Energy Reports* 6 (2020): 28-44. https://doi.org/10.1016/j.egyr.2019.11.162

[18] Nesarajah, Marco, and Georg Frey. "Thermoelectric power generation: Peltier element versus thermoelectric generator." In *IECON 2016-42nd Annual Conference of the IEEE Industrial Electronics Society*, pp. 4252-4257. IEEE, 2016. https://doi.org/10.1109/IECON.2016.7793029

[19] Alghanima, Yasser Abdulrazak, Osama Mesalhy, and Ahmed Farouk Abdel Gawad. "Effect Of Position and Design Parameters of a Fan-Cooled Cold Side Heat Sink of a Thermoelectric Cooling-Module on The Performance of a Hybrid Refrigerator." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 85, no. 2 (2021): 66-79. https://doi.org/10.37934/arfmts.85.2.6679

[20] Chottirapong, Kittikun, Supatra Manatrinon, Prachumpong Dangsakul, and Natavut Kwankeow. "Design of energy harvesting thermoelectric generator with wireless sensors in organic fertilizer plant." In *2015 6th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES)*, pp. 1-6. IEEE, 2015. https://doi.org/10.1109/ICTEmSys.2015.7110823

[21] Diwania, Sourav, Sanjay Agrawal, Anwar S. Siddiqui, and Sonveer Singh. "Photovoltaic–thermal (PV/T) technology: a comprehensive review on applications and its advancement." *International Journal of Energy and Environmental Engineering* 11, no. 1 (2020): 33-54. https://doi.org/10.1007/s40095-019-00327-y

[22] Saleh, Umar Abubakar, Muhammad Akmal Johar, Siti Amely Binti Jumaat, Muhammad Nazri Rejab, and Wan Akashah Wan Jamaludin. "Evaluation of a PV-TEG Hybrid System Configuration for an Improved Energy Output: A Review." *International Journal of Renewable Energy Development* 10, no. 2 (2021): 385-400. https://doi.org/10.14710/ijred.2021.33917

[23] Park, Yoonbeom, Kyoungah Cho, Seunggen Yang, Taeho Park, Sungeun Park, Hee-eun Song, Soo Min Kim, and Sangsig Kim. "Performance of Hybrid Energy Devices Consisting of Photovoltaic Cells and Thermoelectric Generators." *ACS Applied Materials & Interfaces* 12, no. 7 (2020): 8124-8129. https://doi.org/10.1021/acsami.9b18652

[24] Khan, Muhammad Ahsan Iqbal, Muhammad Irfan Khan, Ali Hussain Kazim, Aqsa Shabir, Fahid Riaz, Nauman Mustafa, Hassan Javed, Ali Raza, Mohsin Hussain, and Chaudhary Awais Salman. "An Experimental and Comparative Performance Evaluation of a Hybrid Photovoltaic-Thermoelectric System." *Frontiers in Energy Research* 9 (2021): 722514. https://doi.org/10.3389/fenrg.2021.722514

[25] Lv, Song, Wei He, Zhongting Hu, Minghou Liu, Minghui Qin, Sheng Shen, and Wei Gong. "High-performance terrestrial solar thermoelectric generators without optical concentration for residential and commercial rooftops." *Energy conversion and management* 196 (2019): 69-76. https://doi.org/10.1016/j.enconman.2019.05.089

[26] Zhang, Jia, Han Zhai, Zihua Wu, Yuanyuan Wang, Huaqing Xie, and Mengjun Zhang. "Enhanced performance of photovoltaic–thermoelectric coupling devices with thermal interface materials." *Energy Reports* 6 (2020): 116-122. https://doi.org/10.1016/j.egyr.2019.12.001

[27] Soltani, Shohreh, Alibakhsh Kasaeian, Tahmineh Sokhansefat, and Mohammad Behshad Shafii. "Performance investigation of a hybrid photovoltaic/thermoelectric system integrated with parabolic trough collector." *Energy Conversion and Management* 159 (2018): 371-380. https://doi.org/10.1016/j.enconman.2017.12.091

[28] Dimri, Neha, Arvind Tiwari, and G. N. Tiwari. "Comparative study of photovoltaic thermal (PVT) integrated thermoelectric cooler (TEC) fluid collectors." *Renewable Energy* 134 (2019): 343-356. https://doi.org/10.1016/j.renene.2018.10.105

[29] Duffie, John A., William A. Beckman, and Nathan Blair. *Solar engineering of thermal processes, photovoltaics and wind*. John Wiley & Sons, 2020.

[30] European Standard EN 12975. "CEN European Committee for Standardisation." (2006).

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