A Review of the Reinforcement Performance of the Photovoltaic/Thermal Hybrid System

Hulya Sabah Sulaiman[1] , Ehsan Fadhil Abbas[2], Tahseen Ahmed Tahseen[3]
{hulya1993h@ntu.edu.iq [1] , ehsanfadhil@ntu.edu.iq[2], tahseen@uokirkuk.edu.iq[3]}

1 Master student at Technical Engineering College / Kirkuk - Northern Technical University,2 Department of the Power Mechanic's Techniques Engineering, Technical Engineering College / Kirkuk - Northern Technical University, 3 Mechanical Depart. College of Engineering, Kirkuk University, Email:

Corresponding author: Hulya Sabah Sulaiman, e-mail: hulya1993h@ntu.edu.iq

Co-authors: Ehsan Fadhil Abbas, e-mail: ehsanfadhil@ntu.edu.iq , Tahseen Ahmed Tahseen: e-mail: tahseen@uokirkuk.edu.iq

Received: 17-09-2021, **Accepted:** 17-10-2021, **Published online:** 28-10-2021

Abstract. Population growth and economic development in most countries of this world have increased global energy needs. The international energy agencies indicated that the increase in energy consumption in developing countries is faster than in developed countries, and it requires almost twice their current capacity to meet energy demand by 2020. It is also estimated that the total energy consumption in the world will increase by 44% from 2006 to year. 2030. Therefore, alternative energy sources must be specified to meet our energy requirements and to conserve traditional fossil fuels. Solar energy is a renewable energy source. This clean energy has the potential to meet a large amount of the world's energy demand. In the field of renewable energy and energy efficiency, it has brought stability to the negative impact of carbon emissions due to the increase in energy consumption in the world, as well as the reduction of major fossil fuel sources. Photovoltaic thermal technology (PVT) has been developed since the 1970s. PVT system generates electrical and thermal energy simultaneously. The aim of this hybrid system was to use a cooling PV panel to enhance electrical efficiency, while, at the same time, utilizing thermal energy for the heating process. Most studies on PVT systems focused on the air or water-based medium for the heat transfer. In recent years, nanofluids and phase-change materials have been used with working fluid to enhance PVT thermal performance, in addition to adding some design parameters.

Keywords: PVT collectors, electrical and thermal efficiency, hybrid PVT system

1. INTRODUCTION

The rapidly increasing demand for global energy due to an increase in population and industrial activity has pushed researchers to renewable energy to secure part of the world's energy needs, especially as it is environmentally friendly. The photovoltaic technique is one of the renewable sources used in electricity generation, but its efficiency does not exceed 20%.

Many theoretical and experimental studies have been conducted to increase photovoltaic panel efficiency since the middle of the last century. A PV panel integrated with a thermal collector system (PV/T) was used as a way to improve efficiency by using the most significant amount of solar radiation energy from the PV. Researchers have used various working fluids and storage materials in their studies to get the best one for improving the hybrid system's efficiency. With the continuation of studies in this field, the PV thermal energy system was introduced.

Which is an integrated system of photovoltaic cell system and solar collector. The photoelectric panel absorbs the solar radiation while the heat collecting system removes the heat from the photovoltaic cell to regulate the temperature of the panel, avoiding the extreme heat condition of the panel during operation. Thus, this system produces electrical and thermal energy from one integrated system. These systems are classified as follows.

Some of these studies were classified as PVT performances while using different types of nanofluids and when using Phase-change material; also, PVT studies include theoretical, experimental, and numerical studies based on energy and exergy analysis of the systems.

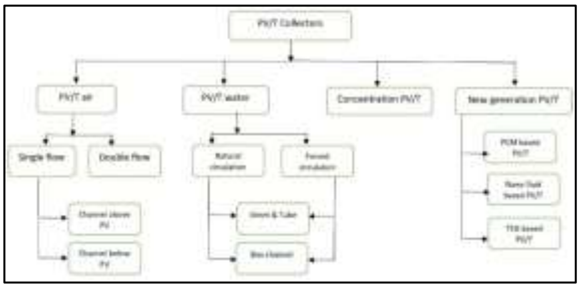

Figure1: Classification of PV / T collector.

a. Use of nanofluids in PVT collectors.

Several researchers have studied the effect of the nanofluid type on improving the thermal performance of PVT collectors. Waeli et al. (2017) [1], for example, have conducted an experimental study to verify the effect of SCI nanofluid silicon carbide particles as working fluid on the effect of 3% wt in the heat recovery system. They concluded that the addition of nanoparticles to water leads to an improvement in the physical properties of water, where the density of the fluid increased up to 0.0082% and viscosity by 1.8%; moreover, the thermal conductivity increased by 8.2% for the extent of tested temperatures from 25 °C to 60 °C. These ratios of increases in properties contributed to improved electrical and thermal efficiency up to 24.1% and 100.19%, respectively. When the nanofluid was replaced by regular water, the system's total efficiency while using nanofluid was found to be 88.9% higher than when it used the conventional compound. Sardarabadi et al. (2017) [2] conducted an experimental study to verify the energy and exergy efficiency in the PVT system on the effect of using metal oxides/hydro-fluids as a cooling system in the thermal photovoltaic system. They used Al2O3 aluminium oxide, TiO2 titanium dioxide, and diluted ZnO in deionized water at 0.2 wt. They found that the nanofluids ZnO-H2O and TiO2-H2O generate more energy and exergy efficiency than those obtained from Al2O3-H2O; as the results showed, the use of TiO2-H2O nanofluid improves electrical and thermal energy efficiency by 7.06% and 29.95%, respectively, compared to the use of pure water in cooling the system. Sardarabadi et al. (2017) [3] studied theoretically and experimentally to assess the effect of the nanofluid use simultaneously with four different concentrations of nitrogen oxide: 0.1wt, 0.2wt, 0.3wt, and 0.4 wt. and the use of paraffin wax (PCM) in the system as an experimental cooling medium. They found a 13% increase in electrical efficiency, and the results showed that the ratio of improving the efficiency of the system using the nanofluid was 5% compared to the efficiency of the system cooled with pure water, and in addition to the use of PCM enhances the efficiency of the PV panel by 9%. As for the exergy analysis results, the simultaneous use of both the nanofluid and PCM in the cooling of the unit increases the total energy efficiency of the system by 23% compared to the conventional PV/thermal system. Aberoumanda et al. (2018) [4] have experimentally investigated electrical and thermal efficiency of the PV/T collector, which was cooled with Ag-H2O nanofluid at two concentrations (2wt% and 4wt%) by three flow regimes, lamina transient and turbulent. Seven consecutive sunny days with clear skies in July were adopted in the experiments to obtain as reasonable results as possible. The results of the experiments showed that using an Ag-H2O nanofluid with a concentration of 4% at a turbulent flow has contributed to increasing the energy productivity of the solar panel by 35% and 10% compared to both cases of the PV collector, when it cools with water and without cooling, respectively. On the other hand, the use of the nanofluid with the mentioned concentration improving the energy and exergy efficiencies by 50% and 30%, when it compares to a case of water cooling, respectively. Hosseinzadeh et al. (2018) [5] conducted a theoretical and experimental study to investigate the true performance of PVT systems from the point of view of energy and exergy using the ZnO-H2O nanofluid by 0.2% as a cooler in the simulation system, while in the experimental system organic paraffin wax was used. The tests were conducted daily from 9:30 a.m. to 3:30 p.m. in August and September in Iran. The results showed that the maximum exergy output and total energy efficiency were 114.99 W/m2 and 13.61%, respectively, in addition to the relative entropy generated in both nanofluid-based PVT hybrid systems and phase-changing material compared to the traditional PV unit of about 1.59% and 3.19% respectively. Du et al. (2019) [6] have designed the hybrid PVT system, which works with a nanofluid with silica air glass. The present study aims to analyze both the energy and exergy of the system, carried out under different environmental conditions. In this study, the nanofluid flow from the bottom of the photovoltaic panel pulls the extra heat from the photovoltaic conversion and then directs the preheated nanofluid into streams above the photovoltaic panel. Also, a silica glass had been used to isolate the PV cell from the thermal path and reduce the system's thermal loss from the environment. The obtained results indicated that the current system could produce high-quality electric thermal energy in concentrated solar systems at C = 10 and improve energy production generated by 13.3% compared to the traditional PVT system. Al-Waelia and Kazem (2020) [7] studied the effect of three different types of energy storage materials such as water-based PV/T, water-based PV/T with PCM tank, nanofluid-based PV/T with nano-PCM tank and conventional PV module that were used in the PV/T collectors. Experiments have been performed simultaneously on these systems under Malaysia's local climate with an ambient temperature of 31°C, 80% humidity, and wind speed of 1 m/s during 210 hours per month on sunny days. They found that both PCM and nanofluid materials gave higher efficiency and electric power generation than water (it was about 72% and 14 kW, respectively). Moreover, the results showed that the performance of these systems was better than the conventional PV/T system.

b. Use of phase change material (PCM) in PVT collectors.

PCM is used to improve the thermal efficiency of hybrid PVT systems; in order to do that, many studies have been conducted and can be summarized as follows:

Sardarabadi et al. (2017) [8] studied theoretically and experimentally to assess the effect of nanofluid use simultaneously with four different concentrations of nitrogen oxide: 0.1wt, 0.2wt, 0.3wt, and 0.4 wt., and the use of paraffin wax (PCM) in the system as an experimental cooling medium. They found a 13% increase in electrical efficiency, and the results showed that the ratio of improving the efficiency of the system using the nanofluid was 5% compared to the efficiency of the system cooled with pure water, in addition to the use of PCM enhancing the efficiency of the PV panel by 9%. As for the exergy analysis results, the simultaneous use of both the nanofluid and PCM in the cooling of the unit increases the total energy efficiency of the system by 23% compared to the conventional PV/T system. Sarhaddi et al. (2017) [9] studied theoretically and experimentally to compare energy and exergy efficiency between two PVT systems; one contained PCM storage. The weather data of the sunny and semi cloudy days has been used in the simulation. In general, the comparative results showed that using PCM improved energy and exergy during sunny days. Still, during the semi-cloudy days, the system's energy and exergy performance that includes a PCM covered tank was better, as the overall energy efficiency and exergy value without PCM for the average sunny day was around 76.69% and 6.53%. While on the semi cloud day in the PCM-covered tank system, it was about 74.35% and 8.59% respectively. Gaur et al. (2017) [10] conducted a numerical study on the effects of using the organic substance (OM37) as PCM on the performance of energy and exergy on PVT system for a typical day of the winter and summer and compared its results with a standard PVT unit. The numerical solution showed that electric power efficiency increased by 16.30% and 15.40%, respectively, for PVT/PCM and PVT systems in the summer. For the winter, the percentages were found to be 16.87% and 16.78%, respectively. There was no significant difference in energy usage or exergy efficiency when using the phase change material in the unit, where it was preferable to use more effective substance. Mousavi (2018) [11] performed a numerical study to investigate the effect of five types of phase-changing substances, such as paraffin C15, paraffin C18, paraffin C22, palmitic-capric acid, and sodium phosphate salt, in an integrated porous medium in the PVT system, as well as study the effects of other factors, such as mass flow rate, solar intensity, and inlet water temperature. They found that the system's highest thermal efficiency was 83% at the 0.02 kg/s flow rate, using paraffin C22 as a test material. The researchers also found that total exergy usage and energy efficiency was 16.7% and 15.6%, respectively. Hossain et al. (2018) [12] presented a design for developing the photovoltaic/thermal system using phase-changing materials to study the assessment of energy, exergy usage, and economic payback. PCM in PV/T was used in this study as the thermal energy storage medium, allowing it to store for a long time. In this system, tests were conducted using volume flow rates ranging from 0.5–4 LPM. The study results showed that the maximum thermal efficiency of the system occurred at a flow rate of 2 LPM and 87.72% and PVT-PCM 12.2% at 0.5 LPM. The maximum electrical efficiency of PV and PVT-PCM was 9.9% and 11.1% at 4 LPM, respectively, and the highest exergy efficiency was 7.1% and PVT-PCM% 12.2% at 0.5 LPM. Kazemian et al. (2020) [13] conducted a theoretical experiment to assess the effect of using a mixture of pure water and ethylene glycol (EG) 50% by mass on the performance of glazed and non-glazed thermal PV systems with a layer of phase-changing material (PVT/PCM), where the cooled liquids were (a) pure water and 100% pure EG water, and the other mix was (b) pure water and 50% pure EG. Experimental tests were conducted on sunny days in August. The results showed the low exergy efficiency of PVT in mixing water with EG compared to using pure water while contributing to improved thermal energy efficiency. The results also showed that the system's performance in the PVT/PCM case decreased when adding EG to water, where the results indicated that the energy loss decreased in a system when it was glazed and used coolant (a) and (b) by 23.3% and 48.6%, respectively, compared to unglazed systems.

c. The effect of glazing on the performance of the hybrid PVT.

Some of the researchers' studies have interest in the effect of glazing on hybrid PVT systems' efficiency Kasaeian et al. (2013) [14] presented the theoretical model for evaluating the overall performance of the earthair hybrid PVT system on two sets of non-glazed and glazed PVT under the climatic conditions of Kerman, Iran. They found that the glazed compound's thermal and overall energy efficiency was higher than that of the non-glazed compound. The results indicated that the total energy efficiency of glazed and non-glazed systems was 66% and 52%, respectively, while the total exergy efficiency for glazed and non-glazed systems ranged from 11.2% to 11.6% and from 10.5% to 11.1%, respectively. Agrawal and Tiwari (2013) [15] have studied theoretically and practically to analyze and compare different types of hybrid PV/thermal systems to verify the energy and exergy and carbon emission ratios for glazed and non-glazed collectors under the climatic conditions of the Indian city of Srinagar. The researchers concluded that CO_2 emissions decreased annually on the basis of the total thermal energy acquisition of glazed and non-glazed hybrid PVT by 62.3% and 59.7%, respectively, which were increased percentages compared to the traditional hybrid air collector The total gain of exergy was 27.7% and 22.7%, respectively, for the glazed and non-glazed PVT, and this is likely because of the glass cover in the glazed collector, which reduces thermal loss from the compound to the outer environment.

d.Studies which deal with an evaluation comparative of the PVT system's efficiency by energy and exergy.

Several theoretical and experimental studies have been conducted on the performance (energy and exergy) of PVT collectors, some of them illustrated. Joshi et al. (2000) [16] have studied the performance of the PVT hybrid air systems by verifying the factors for improving the efficiency of thermal and exergy efficiency. The present study includes two methods, practical and experimental. The experiments have been conducted from 9 a.m. to 4 p.m. on March 27, 2006, in India. They found that the theoretical and experimental thermal efficiencies ranged from 33% to 45%, respectively, while the exergy efficiency varied from 11% to 16%, respectively. Clearly, there is ample room for improvement of the current system where solar radiation is used at 11–16% of the solar energy. Joshi and Tiwari (2007) [17] studied theoretically and experimentally through the parallel-panelled PVT air collector's design. It consists of two panels made of polyvinyl fluoride, known as Tedlar, a non-corrosive material. The tests were carried out in India's cold weather conditions, and the air was used as a thermal energy carrier in the tests, with an effective thermal pool area of about 0.61 m^2 The energy and exergy to the hybrid system were analyzed, and the results showed that the free energy and exergy efficiency to a heater ranged from 55–65% to 12–15%. The results suggest a marked increase in efficiency compared to the conventional compound because polyvinyl fluoride has a flammability reduction characteristic and is classified as an insulating thermoplastic. Chow et al. (2009) [18] prepared a practical and theoretical study to determine the suitability of the glass cover of the PVT collector system with a cell area of about 0.81 m2 and left a distance of 25 mm between the glass cover and the photovoltaic panel and the filling factor 0.60 during winter. The results of the study showed that by comparing the numerical solution with the practical results, there was a consensus between them that the use of a glass cover in the PVT system helps to increase the energy efficiency and exergy, and this is likely to reduce the heat loss to the environment of the collector, especially in cold weather. Agrawal and Tiwari (2011) [19] presented an experimental and theoretical study to evaluate the thermal efficiency of a hybrid PVT system, and it includes a small canal of 0.12 m in length and 0.12 m in width, an effective solar panel area of 0.0144 m^2 and a channel of 500 µm depth. The experiments were conducted under actual Indian weather conditions on sunny days. The results showed that the current hybrid PVT system contributed to increased energy gain and exergy increase by 59.7 and 22.7%, respectively. Aoun et al. (2014) [20] conducted an experimental study of monocrystalline PV panels' performance in terms of energy, exergy, and capacity efficiency. Data for outdoor experimental tests were collected for three typical days (21–23 March 2013) in Algeria. The researchers found that the system efficiency for a cloudy day was 22.3% energy efficiency, exergy efficiency (12%), and capacity efficiency (16%). However, the same efficiency was 22.1%, 15.5%, and 16.8%, respectively, on clear days. Debbarma et al. (2014) [21] prepared a theoretical and experimental study on the thermal and electrical properties of the hybrid air PV/T under climatic conditions in India. The tests took place in May 2014 from 10:00 a.m. to 5:00 p.m. with using air as a cooler in the system at a constant mass flow rate of 0.0142 kg/s. They found that the system's total efficiency ranged from 30% to 60% and found that the maximum exergy efficiency was about 9.72%. The daily electrical efficiency was about 4.86% and estimated the daily thermal efficiency was approximately 44.3%. In comparison, the overall efficiency of the system exceeded 56%. Kumar et al. (2015) [22] presented a theoretical and practical study on assessing the performance of the thermal PV unit in terms of energy, exergy, and power efficiency. The researchers found that the two efficiencies' highest value is relatively obtained in the morning and evening in February. The average energy efficiency of the system was between 19.0% to 52.0%. Higher power conversion and exergy efficiency in some months (February, May, June, September, October, and December) were higher than power conversion efficiency, while this trend was reflected in the rest of the months. Srimanickam et al. (2015) [23] studied a theoretical and experimental to analyzing energy in the PVT photovoltaic system, using modified electrical efficiency to estimate electrical output and PVT performance. Simulation data was based on a clear day, from 9 am to 5 pm. The experiments were conducted at different hours for a typical day of May in climatic conditions in Chennai. The researchers observed that the highest temperature difference of air flowing into the PV panel was about 6.5°C at 12:00 noon, and the panel surface temperature reached 52.9°C. The results showed that the system's maximum and minimum electrical efficiency was estimated at 9.78% at 5:00 p.m. and 5.71% at 12:00 p.m. Additionally, it showed that electrical efficiency, thermal efficiency and electrical, efficiency, total energy, and exergy efficiency to the system were about 9.8%, 24.2%, 27.2%, 44.8%, and 11.3%, respectively. Fudholi et al. (2016) [24] studied a theoretical and experimental to evaluate the energy and exergy analysis of the Hybrid Solar Drying System (HSDS), wherein the system was designed based on indirect forced thermal. The system consists of a PVT with a v-groove, a diesel stove, fans, a rotary shelf drying room, and six clusters of a thermal photovoltaic collector, connected in a series with a total area of about 13.8 m2. The results showed that the solar and dried compound systems' efficiency was about 41% and 23% respectively, while the exergy efficiency ranged from 17% to 44%. Rekha et al. (2016) [25] conducted a theoretical and practical study of the performance of the hybrid PVT system, focusing on the analysis of the PVT hybrid composite system for a typical residential application with an electrical power demand of 3 kWh/day and a 100 LPD hot water request. In the current work, the thermal, electrical, and exergy performance of the PVT system enhanced by the Flat Panel Collector (FPC) is analyzed for a typical local application. The 2 m2 flat solar collector can deliver about 100 LPD of hot water at about 80°C. The system is a combination of PVT with a 4 m2 area and a 2 m2 flat solar panel collector that meets the typical home's thermal and electrical requirements. The researchers found that the system gave an average electrical efficiency of 11% and total exergy efficiency of 15%, while total energy efficiency was 56%. Tripathi et al. (2017] [26] completed a theoretical and experimental study of the energy consumed by the PV system, which was partially covered with water and DMDP dimethyl-diphenyl silicone fluid as working fluid and had 25% of the compound area covered by the PV unit. The receiver and aperture areas were about 2 m2 and 4 m2, and the area of the semi-transparent PV unit (glass to glass) was 0.5 m2. The compound parabolic concentrator (CPC) used PVT thermal energy to improve the entry of solar radiation into the system and obtain the highest temperature, as this procedure increased the temperature to 190°C at the mass flow rate 0.06 kg/s. The results showed the annual net profit for electrical gain, overall thermal energy, and exergy electricity were 12.4 kWh, 304.5 kWh, and 50.6 kWh, respectively.

Shbailat and Jassim (2018) [27] conducted an experimental study on three thermal PVT systems containing a double channel with a V-shaped corrugated slab. Air flows into both the absorbent panel's upper and lower channels to increase the heat transfer coefficient and improve thermal performance. The experimental results of the V shaped plate system are compared to the flat double-channel system. The tests were conducted under the environmental conditions of the city of Baghdad, using different values of mass flow rates of 0.021 kg/s, 0.027 kg/s, and 0.32 kg/s in each model they used absorbent panels made of black-plated copper with three different thicknesses of 0.9 m, 0.7 m, and 0.6 m. Plain transparent glass with 6 mm thickness was used as a transparent cover. A 2800 rpm air blower (0.5 hp) was used to equip the compounds with the required flow. They found from the results of tests that the thermal efficiency of a double channel with a corrugated absorbent panel is 39% higher than that of the flat panel and increases efficiency by increasing the rates of mass flow; moreover, the results of the analysis of the exergy of the compound flat-panel showed that it has the greatest irreversibility (exergy losses) in it, and the double-channel integrator with a wavy absorbent plate has the highest exergy efficiency.

Gürtürk et al. (2018) [28] presented an experimental study using a chemical solution and hand tools in the process of cleaning dust-induced damage during wind gusts to find out the relationship between chemical cleaning materials and tools on the outputs of both energy and exergy. The results showed that the worst cleaning tool is a rubber mop, which causes a decrease in energy, exergy efficiency, and power by 17.87%, 19.37%, and 19.62%, respectively, due to both wind and dust decreasing the energy, exergy, and capacity by 13% at the angle between 40° and 90°. Khosravi et al. (2018) [29] A theoretical and practical analysis was performed to examine the energy, exergy, and economic cost of a hybrid PVT system under the climatic conditions in southern Iran between April and August and from 9:00 a.m. to 14:00 p.m. The results showed that the average exergy and exergy efficiency was around 12% and 16%, respectively. On the other hand, researchers found that the total destruction of external energy is around 65%, and economic assessments confirmed that an energy storage system expects 50% of the total system investment. Fudholi et al. (2018) [30] have done a theoretical and practical analysis that has been carried out with a mathematical model to estimate the thermal efficiency of the ∇-groove PVT collector. The unit was designed at 1.2 m length and 0.35 m wide and tested at 30°C environmental temperature and a mass flow rate of (0.007 and 0.07) Kg/S at sun rays from (385 to 850) W/m2, respectively. The comparison results illustrate that the mathematical model is compatible with experimental results at about 94%, and the study results also showed average energy efficiency PVT 65.52% and 66.73%, respectively, for studies. In contrast, the average exergy efficiency was between 12.69% and 12.66%, respectively.

Mahdavi (2018) [31] prepared a theoretical analysis to assess the energy efficiency of the collector and the energy of the heat exchanger/photoelectric heat exchanger for the solar greenhouse (PVT-EAHE). The results showed that PVT was not largely able to heat the air, but in summer and winter, respectively, this PVT–EAHE hybrid system appears to be promising for greenhouse air cooling down to 9°C and 8°C.

Jassim and Shbailat (2018) [32] studied the comparison of the theoretical and experimental results on the rate of improvement in the efficiency of five models of solar collectors that can be achieved by improving heat transfer and reducing heat loss. For this, five types of solar collector devices were designed and built as follows: model (A) contains a standard channel with a flat absorption panel; model (b) contains a double channel with a flat absorption panel; model (C) contains a double channel with a wavy and perforated absorption panel; model (D) contains a double channel with an absorbent panel and a metal mesh; and model (E) contains a double channel with a beehive-shaped absorbent. The experimental tests were conducted from December (2016) to February (2017) and from 8:30 a.m. to 3:00 p.m. on sunny days and with three airflow rates of 0.0217, 0.0271, and 0.0375 kg/s. The results showed that the average thermal efficiency was 72.2% for model A, 40.2% for model B, 51.6% for model C, 65.1% for model D, and 59.7% for model E. Additionally, an analysis of the exergy to PVT was conducted. The results showed that the standard channel model enjoyed greater deferral losses and that the dual-channel model enjoyed the greatest exergy efficiency. Kandilli (2019) [33] prepared a theoretical and practical study by evaluating the efficiency of PVT systems by using natural zeolite as a heat storage material with systems that work with paraffin and fatty acid in different climatic conditions. All the results of the above cases were compared with the efficiency of the standard PVT system. They found that the general average energy efficiency values for these cases are 33% for paraffin, 37% for fatty acid, 40% zeolite, and 32% for standard PVT systems, as well as the recovery period of PVT using paraffin, zeolite, fatty acid and traditional as 10, 8, 9 and 9 years respectively.

The results concluded that natural zeolite is a highly effectively elevated substance for heat management in the PVT system for any climatic environment. Natural zeolite has a high speed in the absorption of liquids, gases, and steam. Rad et al. (2019) [34] presented an experimental study on the solar thermal photovoltaic system to analyze the energy and exergy efficiency of the multi-channel PV/thermal system (MCPV/T), where this system consists of the integration of PV/T thermal PV plate and two multi-channel heat exchangers. Total electrical efficiencies, exergy and energy at the extreme airflow rate at 0.005 kg/s, when the intensity of solar radiation is about 926 w/m2 to be 9.35%, 10.40%, and 65.10% respectively. Simulation sought for the same system and showed the results of the simulation, which took into account the validation of the experiments as the increase in the airflow rate increased the total energy efficiency to a maximum of 80%. However, its maximum energy efficiency at the optimum spot point was 13.46% with a fluid flow rate of 0.024 kg/s, similarly with increased channel heights and reduced total energy efficiency to 70% and maximum energy efficiency at the optimum spot point of 13.64% when the channel was at the height of 0.011 m.

2.CONCLUSION

By reviewing studies dealing with the development in different models of PVT hybrid collectors that focused on analyzing energy and exergy efficiency from 2000 to 2020. Simulation studies included several optimization methods in hybrid PVT systems, using different nanoparticles, phase change materials, and glass cover effect. These papers showed that the improving percentage to energy and exergy by using the mentioned enhancements in performance of PVT systems ranges from 13% to 87.7% and 7.06% to 44%, respectively. It was noted from the results that the use of a phase change material gives the best performance among others. The researchers [8] were able to achieve good results through the dual use of phase change material and nanofluid, where they obtained maximum PVT system thermal efficiency among mentioned studies about 87.7%Meanwhile, the use of phase change materials alone in the hybrid system has given a thermal efficiency of 74.4% and a good result, it compares with other material used to improve system efficiency. As for the use of nanofluids in PVT hybrid systems, results showed that the maximum thermal efficiency of 35%, when using Ag-H2O nanofluid (2wt% and 4wt%) as a coolant working medium by three flow regimes, lamina transient and turbulent. In addition, other modifications to the system, such as the addition of a fan or fins, have contributed to the increase of the heat transfer area. Therefore, the low temperatures that occur on the surface of the PV panel will increase the efficiency of the panel. Not only that, but the climatic conditions and the difference between summer and winter had greater impacts than previously mentioned. In the clear, sunny days, the difference in energy and exergy efficiency was about 16% and 12% respectively, compared to cloudy days. The study on increasing the exergy is limited even nowadays, and further expansion is recommended in order to obtain more useful energy generation by the system, especially since we have a need for alternative energy to save the planet from global warming.

Table.1 Displays results from studies on performances of PVT system

Reference no.	type of the study	Working condition	Result	
			Energy	Exergy
[1]	experimental	SCI nanofluid 3% wt as working fluid	24.1%	10.19%
[2]	experimental	Using Al_2O_3,TiO2 and ZnO in deionized water as 0.2%wt	29.95%	7.06%
[3]	theoretical and experimental	Using nitrogen oxide with four different concentrations 0.1%wt, 0.2%wt, 0.3%wt, and 0.4% wt	13%	9%
[4]	experimental	Using Ag-H_2O nanofluid (2wt % and 4wt %) as cooler by three flow regimes, lamina transient and turbulent	35 %	10 %
[5]	theoretical and experimental	Using ZnO-H2O nanofluid by 0.2% as a cooler in the system	13.61%	11.49%
[6]	experimental	design hybrid PVT system, which works with a nanofluid with silica air glass	13.3%	Non
[7]	theoretical and experimental	Using different types of energy storage materials, water-based PV/T, water-based PV/T with PCM tank, nanofluid-based PV/T with nano-PCM tank	Non	Non
[8]	theoretical and experimental	PCM used as thermal energy storage media	87.72%	12.2%
[9]	theoretical and experimental	Using PCM storage (Paraffin wax)	74.35%	8.59%
[10]	numerical	Using the organic substance (OM37) as PCM	16.30%	15.40%
[11]	numerical	Using Paraffin C22 as PCM	16.7%	15.6%
[13]	theoretical and experimental	Using a mixture of pure water and ethylene glycol by a 50%	23.3% 48.6%	Non
[14]	theoretical	hybrid PVT system on two sets of non-glazed and glazed PVT under the climatic conditions of Kerman, Iran	Glaze 66% Non-glaze 52%	Glaze11.2%- 11.6% Non-glaze 10.5% -11.1%
[15]	theoretical and experimental	glazed and non-glazed PVT under the climatic conditions of the Indian city of Srinagar	Glaze 62.3% Non-glaze 59.7 %	Glaze 27.7 % Non-glaze 22.7 %
[16]	theoretical and experimental	Under climatic conditions of India on March 27	33%-45 %	11%-16 %
[17]	theoretical and experimental	Under India's cold weather conditions	55%-65%	12%-15%
[18]	theoretical and experimental	Using glass cover PV/T system under cold weather .	Non	Non
[19]	theoretical and experimental	Under actual Indian weather on sunny days	59.7%	22.7%
[20]	theoretical and experimental	Using small fan	Non	Non
[21]	experimental	Using monocrystalline PV panel under Algeria climatic condition	22.1%	15.5%
[22]	theoretical and experimental	Under climatic conditions of India in May 2014	44.3%	9.72%
[23]	theoretical and experimental	Under climatic condition of Iran in February	19.0%-52.0%	Non
[24]	theoretical and experimental	typical day of May under climatic conditions in Chennai	44.8%	11.3%
[25]	theoretical and experimental	Using Hybrid Solar Drying System (HSDS)	Non	17%-44%
[26]	theoretical and experimental	Using PVT hybrid composite system for a typical residential application	56%	11%
[27]	theoretical and experimental	Using dimethyl-diphenyl silicone fluid as working fluid	304.5 kWh	50.6 kWh
[29]	experimental	Using chemical solution and hand tools in the cleaning process	17.87%	19.37%

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