Photovoltaic Thermal (PVT) with Advanced Tube Design and Working Fluid - A Review

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Abstract – This paper reviews the state-of-the-art cooling classification methods for photovoltaic system (PVs) modules and evaluates water or nanofluid, in details, the performance of radioactive cooling method. This review also covers the future development of absorber tubes photovoltaic thermal collector PVT. Daily heat budgets of PV modules with different absorbed tubes used in solar cells to reduce the temperature of the surface were analysed. This paper provides an overview of the various solar absorber tubes of Photovoltaic thermal (PVT) collector technologies, including their efficiencies, benefits, drawbacks, and research opportunities. The results show that the shape and diameter of the tube, the mass flow rate and the working fluid improved the total efficiency for the PV cell.

Keywords Nanofluids, Photovoltaic thermal (PVT), Absorber collector, Performance, Exergy, Thermal and electrical efficiency

1. Introduction

Photovoltaic (PV) is one of the potential alternatives to current energy and environmental problems. PV modules used photoelectric converters called solar cells, which converts directly absorbed sunlight into electrical energy. Further improvement of PV conversion efficiency and cost reduction are needed to advance the deployment of PV.

Photovoltaic thermal PVT management is critical for both low and high concentration systems. The operating temperature of photovoltaic PV cells has significant impact on the overall performance of solar panels. Solar cells have an average efficiency of around 15%. The remainder of the absorbed radiation in the cell is converted to thermal energy, which later raises the temperature of the cell. With the increased of the temperature, the open circuit voltage and fill factor will decrease and the panel efficiency even more [1, 2].(one of the first who worked in this field is Martin Wolf to get the available energy input to the absorber was reduced by 10% [3], and the Akio use the combined PV and thermal hybrid collector gated the maximum thermal efficiencies 72% and 77% with using water as coolant[4].

This review paper investigates the studies on the tube design of photovoltaic thermal PVT systems using sheet and tube with many types of working fluid. The aim of this study is to summarize variety of PVT developments and novelities to improve the efficiency and maximize the usage of solar energy on order to minimize fossil fuel consumption and maintain a more sustainable environment. In this regard, the used of nanoparticles in conjunction with base fluid has been more widely discussed in separate categories. Phase change materials (PCM), - with Nano particles, heat pipes, and absorber tube have all been studied in PVT systems, and the focus of this review is about the shape and diameter for the tube.

2. Heat Pipe Photovoltaic Thermal System

The heat pipe in the PVT system is used to increase the electrical and thermal efficiency. There are many types of single heat pipes used. These include heat pipes that are integrated with and without wick and U tubes [5].
This paper reports nine heat pipes used, with mean water box to obtain heat transfer for the upper section of heat pipe (condenser section). The dimensions of pipes were Ø8 × 0.7 × 1000 mm for the evaporator and Ø24 × 1 × 120 mm for the condenser. The collector's glazing with a glass plate was joined to the back side of the plate as shown in Figure 1. The results indicated that the heat pipe photovoltaic/daily thermal efficiency 41.9% and electric efficiency 9.4%.

![Figure 1 The Heat pipe - PVT solar collector [5].](image)

3. Photovoltaic Thermal System (PVTs)

PVT system is a hybrid technology used for converting energy through combination of the PV with solar thermal that producing electricity as well as heat using a single system. The work fluids are air, water, Nano fluid, phase change material (PCM) with water based as fluid. Therefore, various design approach was aimed at investigating different cooling method and optimizing the heat generated by the system.

Bergene et al. used mathematical method in computing the thermal efficiency for the sheet and tube a system. The diameter was 0.01-0.1m, parallel space for each tube was 0.10m, while the mass flow rate (ṁ) ranged between (0.001 to 0.075) kg/s. The thermal efficiency increased by increasing the width of the absorber to tube diameter W / D mm [6].

Yu et al. reported on microencapsulated phase change material (MPCM) with water based as fluid. The system consisted of tube and sheet with five copper pipes. The outer diameter of the tube was 0.01m, weld on the copper plate with a thickness of 0.002m. The working fluid had an inlet velocity, Vin = 0.04-0.25 m/s, the condition of ambient were set as Q=1000W/m², Ta= 0°C and UA=0.5 m/s respectively. The total enhancement of the energy and exergy efficiency 8.3%, 2.23% respectively for the MPCM [7].

Yang et al. conducted a study using water-based fluid. The PVT substrate passed through functionally graded material (FGM) with copper pipe of 0.006m internal diameter. The indoor irradiation ranged between 850-1100 W/m². The Q=1100 W/m², ṁ=66 ml/min. A temperature decrease was observed from (55-35) °C. The PVT efficiency increased to 12.3% when the outlet temperature was about 35°C [8].

Tiwari et al. studied the integrated photovoltaic thermal system. (Reference) The photovoltaic with an area of 0.516 m² was used to deliver hot water with constant = 0.016 kg/s. The temperature of ambient was between (25-36) °C, while hourly variations intensity was between 486 W/m² and 852 W/m² as observed on 21/05/99 in Taiwan (This is not related to Tiwari. Please check). The overall exergy efficiency of 9.05% was obtained with flow rate at 0.012, the overall energy efficiency was 55% at the same flow rate [9].

Thinsurat et al. used the PVT collector for the domestic hot water, two types of PVT cell with and glass cover with air gap were investigated used in this study. The study tackled four water temperature target PVT with air gap as shown in Figure 2. The model was done using Fluent detailed developed by MATLAB. The PV cell was modelled for standard condition temperature 298.15 K and the Q = 1000 W/m² (no water flow) (40-100) °C. In addition, the average electricity efficiency ranged between 12.99 and 9.88. Average thermal efficiency (53.22-34.79) %, total efficiency (66.21-44.68) % and PV electricity efficiency was 12.97% [10].

![Figure 2 typical flat glass covered water PVT collector [10]](image)

In the Solar simulation laboratory at Tianjin Chengjian University, a system was designed using sheet and tube with six copper tube, aluminium plate with glazing cover and inclined angle of 20°. MATLAB was used to simulate the system. The irradiance changed (365-508) W/m² in mass flow rate 0.13L/min. The conditions, the maximum thermal and maximum overall efficiency 37.2%, 46.5% respectively [11].

Li et al. conducted a study using four case glass covers added before for two modules PVTs and solar thermal system STs collectors. The cases were unglazed PVTs module and ST collector, PVTs glazed module, ST collector unglazed, and PVT unglazed and ST collector unglazed. The PVTs and ST. The diameter of the tube was 0.01m with parallel space between each maintained at 0.1m. The absorber plate was 0.035 m with incline angle for the collectors at 30°. The highest total energy of 41.51% and exergy efficiency of 17.63 % were obtained from the glazed PVT and glazed ST, respectively. Highest outlet temperature of 97 °C was observed with the parameters [12, 13].
In the Mediterranean region of Greece, Athens, Cyprus, Nicosia, and Alexandria of Egypt are the three cities in study. The chillers, sheet and tube with a class cover were used. The total cooling capacity of the system is 14.7 KW, and the overall efficiency of energy was used on the solar collector (21.7%) for Nicosia's climate conditions of July. When the PVT solar collector was used without cover the total exergy efficacy was maximized (11.25%) [14].

In university of Patras, the hybrid photovoltaic thermal PVT solar collector was used to provide electrical power and hot water preparation. The - TRNSYS simulation was used for 45 types for domestic hot water in three cites Nicosia, Athens, and Madison, used flat plat collector glazing. The diameter of the pipe was increased by 15 mm, the diameter of a header pipe was 28 mm. The plates thickness was (0.5 mm), while the material was isolated. The thickness of the Fiber Wool was 40 mm. As the water flows, the rate of absorption of raised to 4.9 l/h m² and the solar contribution was (222-532) kwh of electric energy and ranges (29%-72%). The percentage of the solar hot water load decides the solar contribution [15].

A flat box aluminium alloy PV and water heating system intended for natural movement has been developed. In the PVT hybrid system for power and hot water production, in a moderate climate environment, an outdoor test was carried out to develop the prototype. The heat-collecting area of the hot water load per unit exceeded 80 kg/m². The Batten, 1380 x 85 x 12 mm had three channel cross-sections, each 20 x 110 mm. The prototype collector was experimented at the University of Science and Technology of China (3153N, 117 to 101E), 35 tilt angle, with the daily thermal efficiency of 60% and 70% respectively [16].

In a study conducted using the Iran climate conditions, the MATLAB simulation was used in combination with TRNSYS program. Three cities of Tabriz, Shiraz and Esfahan were identified for the study. A solution of 30% glycol was added to water in Tabriz avoid the fluid from freezing. Exergy efficiency of 9.7%, 9.6% and 9.6% were obtained at Tabriz, Esfahan, and Shiraz respectively [17].

Ibrahim et al. used the building integrated photovoltaic thermal system in Malaysia weather condition. The system was made of sheet and tube with single plate cover for polycrystalline silicon as shown in Figure 3. The water work fluid medium as absorber in the single channel stainless steel metal with dimension 12.7×12.7 mm. The inlet=0.027kg/s was obtained when the Ta= 20°C. The average outlet temperature of 34°C and 43°C with 690 W/m² respectively. Increase in PVT energy efficiency from 55 to 62 % was observed and was higher than 12 to 14 % PVT exergy efficiency [18].

In the study conducted at Tianjin Chengjian University, a new PVT system for solar energy collection (IFTP) was designed. The system consists of iron filled pipe plates PVT system (IFTP). It has efficiently increased the heat transfer the PV and the working fluid channel as shown in Figure 4. The radiation intensity ranged between 400-800W/m² with 4.2 kg and the water tank volume was 60 L. When the mass flowrate was 0.9 m3/h, the overall efficiency and the filled system was from 31.8-62.4% at 400 W/m². The (IFTP) system will improve the average thermal and electrical efficiency 45.6-56.2% and 10.5-16.7% respectively [19].

Figure 4 Sectional drawing of PVT collector [19]

In the advanced center solar garden in University of Malaya, a novel PV / T was used with different volume flow rate of (0.5-4) L/min. The new parallel serpentine pipe flow, the sheet and tube, a (76.2-101.6) mm space between tube and 177.8 mm space for the two parallel sides of sheet were used in the glass plate photovoltaic model as show in Figure 5.

Figure 5 layout of PVT thermal collector [20]

The Solar Garden's geopolitical location was 3.11° North and 101.66° East. The irradiation level increased to a higher level of 975 W/m² at after noon. The maximum change in cell temperature between PV and panels was 6.16 °C. The PVT system showed maximal thermal efficiency in 2 LPM, as 76.58%. photovoltaic and photovoltaic thermal-only 9.89 % and 10.46 % of electrical efficiencies were observed, respectively [20].

Huide et al. used three systems consisting of the PVT natural circulation, the PV pump and PV, the third system was incorporated with conventional DC brushless pump direct coupling as shown in Figure 6. A series of day long
The performance of the system was observed to deliver thermal and electrical efficiency approaching the results of the current showed that the outlet water temperature was high. The experiment with the use of China’s climate zone during the summer day was from 8:00 AM to 4:00 PM. The angle of inclination was set at 35°, with the channel dimensions at 1.4×0.02×0.001 m. Number of channels was 42 and the total water in collector was 0.012m³. Assumption of daily performance in January revealed there was an electrical efficiency ranging between 11.7-12.3 %. Heat gained by the water was 130.2-134.8 MJ. Thermal efficiency was 37.6-39.0 % and solar radiation daily of 346MJ and the Electricity gain was from 20.6MJ to 21.3 MJ [22].

Al-Hrari et al. used the concentrated photovoltaic in thermal application, in Sep. and Oct. at the EDL, Karabuk Univ., Turkey in 2018. The average $T_a=18°$ C and the average daily solar radiation was 881 W/m². The water temperature inlet and outlet were 23° C and 55° C, while the mass flow rate ranged between (3-1.8) L/m²h. The overall thermal efficiency of 71% and the average electrical efficiency 18.2% were delivered by the system [25].

Figure 6 Test rigs of the three PVT systems [21]

Figure 7 Constituent layers of the PVT collector [22].

María et al. used sheet and tube with working fluid water. The model consisting of 6×4 mm channels, two 10×10 mm channel and one 20×10 mm flat box structure channel was presented on COMSOL. The mass flow rate ranged between 10–50 L/h with ambient condition having overall incident solar irradiance of 1000W/m², mains water temperature of 20°C and $T_a=289.15$ K (with an optical efficiency 4% higher and a linear coefficient of heat loss 15 % lower), while the weight of the collector (about 9%) and investment costs (about 21%) were also decreased. The structural analytics have shown that the maximum of stress von Mises in the PC float-box collector absorbed-exchanger was substantially lower than the maximum from the copper sheet-and-tube (< 13% vs. 64%) [26].

Evangelos et al. did simulation and experimental study using sheet and tube. The 8 pipes used had diameter of 6 mm each with the Peach between raisers set at 12 mm. The work fluid was water and the mass flow rate between (60-95) kg/h was adopted. The collector temperature variations of the RMS were estimated to be 0.66% for weather condition stable and 4.22% for very intermittent weather conditions with occasional showers at the University of West Attica (2356.52°24' E, 3803.84°05' N). However, the gap between power generation sources stands at 5.05 and 14.91%. About 2.060% deviation for water outlet 4.151% deviation for energy generation were observed [27].

In a simulation study by Mangesh et al., 8 mm copper and 95 mm of space were used for mass flow rate 0.02
kg/s. The study was done using Mumbai (19170.00000 N, 72480.00000 E) and significant decreases both in the collector (10% in residential and 7% in the industrial) and in storage volume (66% in residential and 23% in industrial cases) were obtained [28].

Sun et al. did a study on simulation and indoor experimental using 10 copper tube. The diameter of the tube was 20 mm, with water as the work fluid having a mass flow rate 0.04 kg/s, in Hong Kong. Series connection electricity decreased by 2%, thermal energy increased by 11.4 % and total energy increased by 5.4 %, it was noted [29].

Blessy et al., combined both simulation and experimental study using copper pipe and the diameter 13 mm. The study was done at Amal Jyothi College of Engineering in Kottayam, India research Centre. Water and ethylene glycol (EG) were the working fluid, the mass flow rate (8-2) g/s (9320.00000 N and 76490.00000 E). Increase in average output energy and electrical efficiency were 14.15 and 1.21 % respectively. The combined output of the PVT water collator and 30:70 combination PVT water collator were 56.94% and 38.72%, respectively[30].

Al - Shamani et al. studied the sheet and tube with a rectangle shape of 15x20 mm. The work fluid was water with SiO2, TiO2 and SiC. The mass flow rate ranged from 0.068kg/s to 0.17 kg/s. An 81.73% thermal (PVT) efficiency and 13.52% PVT electrical efficiency were recorded with the highest total energy (COE) of 0.93 [31].

The study by Huan-Liang Tsai used R134a, while the model includes sheet and tube water heater PVT assisted heat pump. The solar power of roof top PVT system can supply the compressors in the heat transfer water heater HPWH system power consumption. Considering the mutual exchange of energy between PVT and HPWH [32].

Milad et al. used the working fluid that was water and mass flow rate of (0.05-0.025) kg/s, in a silicon monocrystalline photovoltaic module. Sufficient reflectors were used to increase insolation at the location in Maragheh city (37230.00000 N, 46130.00000 E). The PV / T final reflective electric efficiency had an average of 11.9 % in order, that is 1.1 %, in relation to a simple PV module) [33].

Fudholi et al. did an experimental study conducted indoor using a rectangle shape of 12.7mm x 12.7mm. This parameter was used in fabricating three different types of water collector PVT, as show in Figure 8. The system worked with mass flow rates from 0.011 kg/s to 0.041 kg/s. In each case, the efficiency of PVT was 68.4%, PV efficiency was 13.8% and 54.6% thermal efficiency has been observed. It also achieved an efficiency of primary energy savings of 79% to 91% [34].

Figure 8 (a) Web flow absorber (b) direct flow absorber (c) spiral flow absorber [34]

Santbergen et al. used sheet and tube type of absorber in conducting an experimental study. The diameter and the space for the tube were 10mm, 95 mm a piece. The working fluid was water and mass flow rate of 10 kg/m²h. The PVT collector were around 15 % lower than the separate traditional PV and conventional thermal collector systems [35].

Ibrahim et al. did a simulation study using many models formed with sheet and tube (direct, serpentine, oscillatory, web, spiral, parallel, serpentine, modified serpentine parallel) flow, and the mass flow rate for water was 0.01kg/ s. The comparative study found that the bast configuration for spiral flow was the 50.12% thermal efficiency and 11.98% corresponding cell efficiency [36].

Mohd et al. conducted experimental research using mass flow rate as 1.0 L/min, with working fluid water, (avg) by 4.6 % at the University of Malaya. The result suggested that the cooling system applied to the PV system was responsible for the reduction temperature for PV cell and
increase in the power output of the PV. Developed photovoltaic thermal water collector PVTw modules were capable of collecting thermal energy and had about 23% efficient [37].

Kadhim et al. performed an experimental test using working fluid was water and mass flow rate 0.045 kg/s. The study was done at Universiti Kebangsaan Malaysia when the ambient temperature was ranged between (28.6-33.55) °C. The solar radiation range (700-800) W/m². 65.8% combined PVT efficiency and 11.4% electrical efficiency [38].

Ibrahim et al. did an experimental study that includes used water as the work fluid with used three mass flow rates at (0.034,0.039 and 0.041) kg/s. The results show that combined efficiency of PVT was 65% and electricity was 12% [39].

Several dynamical and static simulation models were presented in the PVT water collector as shown in Figure 9. The first un-optimized Combi-Panel system was built using a 3D dynamic model and a stable 1D, 2D, and 3D model. The simple 1D standard-state model showed a result that was very close and comparable with the much longer 3D dynamic model for the daily output calculation. The researchers concluded that the composite panel requires 2D and 3D models for further optimization [40].

Figure 9 The combi panel collector [40]

The study by Zondag et al. used several water-based PVT absorbers in the design studied. The models showed the concept of PVT collector sheet and tube. PVT, free flow PVT, and two PVT collector absorbed were linked as shown in Figure 10. respectively. They achieved an unveiled PVT collector with 52% thermal efficiencies and a single cover design of 58%. Analysis from all design concepts showed the optimum design with significantly easier production process was the single cover sheet and tube collector [41]. This paper presents a detailed single diode based computational PV model for organic photovoltaic (OPV) cells. These cells employ organic semiconductor materials and are cheaper and lighter than conventional PV cell [42].

Figure 10 (A) sheet-and-tube PVT, (B) channel PVT, (C) free flow PVT, (D) two-absorber PVT [40]

4. Phase Change Material

Increasing the thermal capacitance is a good technique to keep temperature rises to a minimum. The use of phase change material PCM at a desired temperature is one effective method of increasing thermal capacitance and controlling temperature. Paraffin comes in a variety of melting points. Organic paraffin, for example, is non-hazardous and inexpensive. It also has a phase change temperature and its thermo-physical properties do not change after many freeze/melt cycles. As a result, organic paraffin can be used to cool mechanical systems. The PCM not only keeps the cells cool, but it also stores the solar energy for later use. During the working period of solar power systems, this feature ensures a consistent and uniform thermal output. Several experimental, analytical, and numerical studies to integrate photovoltaic modules with PCM system have been conducted in recent years.

Mousavia et al. conducted on a PVT with working fluid water cooling and five different PCMs. The system includes a glass covered PV panel with a copper plate having a thickness of 0.02m and the 20-copper tube of diameter 0.01m as shown if Figure 11. The optimum mass flow rate was 0.02 kg/s, while paraffin wax type (C22) was used as the storage material. The maximum thermal efficiency was reported to be 83% when it showed that the PVT module exergy efficiency with PCM-filled metal foam was 16.7% [43].

Figure 11 Schematics of the model [43]
In a study conducted at UKM, (2.9021N, 101.7830 E), three models were demonstrated using water flowing in pipes and water tank, water flowing in pipes with PCM tank and Nano fluid flowing in pipes with Nano PCM tank. The weather condition the wind speed, ambient temperature and humidity were 1 m/s, 304.15 K and 80% respectively. The constant mass flow rate was 0.175 kg/s; the operating efficiency 13.53% with an average electrical energy efficiency of 12.05 % for Nano-PCM tanks with Nano fluid [44].

Babayan et al. studied an enhancement of the thermal and electrical efficiency in the Proton Exchanger Membrane with the PCM with the aim of producing hydrogen in a hydrogen fuel station. The test was done on the 16 Aug. 2018 used PV type mono crystalline semitransparent. The 120kg of RT 50, RT 44, RT 35 and RT 28 PCM types were used, the mass flow rate used 0.14 kg/s for three hours morning after the temperature reached 60.5°C; the maximum mass flow rate reached 0.20kg/s. The maximum energy efficiency was 35.4% and the maximum daily exergy efficiency 15.17 % were obtained [45].

Hossaina et al. studied PVT with PCM using sheet and tube. The system was positioned using a tilt angle of 15°. The diameter of the tube was 12.7 mm with working fluid water and mass flow rate form 0.5L/min to 4 L/min. The size of nanoparticle was 10nm on the base fluid deionized water and surfactant concentration 1 wt. %. The constant 30 kg/hour mass flow rate was used by adding silver (Ag) nanoparticle. The fluid was used by adding ZnO/water Nano fluid for PCM with Nano particle mass fraction (0.1wt%, 0.2wt% and 0.4 wt %). The tilt-angle was 30° in the Aug. and September. The mass flow rate of working fluid was 30 kg/h. According to the exergy analysis results, the PVT water/Nano fluid-based system with PCM, recorded an increase of more than 23% above the overall exergy eff. for system when compared against the conventional PVs. While the overall exergy for the three cases of (water, 1 wt % SiO2/water, 3 wt % SiO2/water) increased by 19.36%,22.61% and 24.31% respectively [50]. The same author and location in Ferdowsi University of Mashhad, a model fabricated using sheet and tube. The tube was made using 16 copper tube with 10 mm diameter in three models of PV, PVT, PVT/PCM coolant mediums. The work fluid was ZnO/water Nano fluid for PCM with Nano particle mass fraction (0.1wt%, 0.2wt% and 0.4 wt %). The tilt-angle was 30° in the Aug. and September. The mass flow rate of working fluid was 30 kg/h. According to the exergy analysis results, the PVT water/Nano fluid-based system with PCM, recorded an increase of more than 23% above the overall exergy eff. for system when compared against the conventional PVs. While the overall exergy for the three cases of (water, 1 wt % SiO2/water, 3 wt % SiO2/water) increased by 19.36%,22.61% and 24.31% respectively [50].

In the study conducted by Ali Al-Waeli, 0.084–0.583 kg/s was the working fluid mass flow rate of Nano concentrate. The study was conducted at Bangi, Selangor, Malaysia using a combination of experimental and mathematical research. The findings of experimental and quantitative simulations show that the performance of the thermal and electrical simulations was 72.0% and 13.20%, is 71.30%, respectively, 13.70%. In addition, (39.92, 41.2, 38.8 and 36.5) °C were observed in respect of the temperature of PV cell, glass, PCM and Nano fluid [48].

Mohammad et al., did an experimental study using sheet and tube. The study was conducted in FUM, Iran (Lati. 36° and Long. 59°). The model used nano fluid PV/T PCM, in a nano fluid of ZnO/water having 0.2 wt %. The PCM was made from organic paraffin wax and mass flow rate was 30 kg/house. The combined total performance of the Nano fluid-based PVT / PCM and PVTs systems had total exergy eff. were 13.16% and 114.99 W/m² respectively. The duo were reduced by approximately 1.59 and 3.19 % respectively, compared to the classical PV module [49].

5. PVT with Nano Fluid

In the study conducted by Fum et al. Iran (Lati. 36° and Long. 59°), the tilt-angle tracking system was 32° in the months of July and August. A sheet and tube model were used in this study. The average ambient condition was with a temperature of 33 0.5 °C and the average total incident radiation was about 921 W/m². Two different work fluids were used. The first was water and SiO2/water Nano fluid 1%, while the second fluid contain 3% by weight (wt.%). In the experiments, the mass flow rate (20,30 and 40) LP/H were utilized. The thermal efficiency of the PV/T collector for the two cases of SiO2/water Nano fluids increase 7.60% and 12.80%. The overall exergy for the three cases of (water, 1 wt % SiO2/water, 3 wt % SiO2/water) increased by 19.36%,22.61% and 24.31% respectively [50]. The same author and location in Ferdowsi University of Mashhad, a model fabricated using sheet and tube. The tube was made using 16 copper tube with 10 mm diameter in three models of PV, PVT, PVT/PCM coolant mediums. The work fluid was ZnO/water Nano fluid for PCM with Nano particle mass fraction (0.1wt%, 0.2wt% and 0.4 wt %). The tilt-angle was 30° in the Aug. and September. The mass flow rate of working fluid was 30 kg/h. According to the exergy analysis results, the PVT water/Nano fluid-based system with PCM, recorded an increase of more than 23% above the overall exergy eff. for system when compared against the conventional PVs. While maintaining the same condition, three types of Nano metal water was used with the basic fluid containing 0.2 wt%. The constant 30 kg/hour mass flow rate was used. In the four PVT / water, PVT / TiO2, PVT / Al2O3 and PVT / ZnO cases the overall exergy efficiencies were increased by 12.33 %, 15.95 % and 18.27 respectively and 15.45 % [51, 52].

In a study conducted at Dhafran, Saudi Arabia, the Nano fluid was used by adding silver (Ag) nanoparticle. The size of nanoparticle was 10nm on the base fluid deionized water and surfactant concentration 1 wt. %. The maximum power 275 W and the PV dimension was 1640 × 800 W/m² based. The ambient condition was 800 W / m² solar radiation, temperature was 20°C, wind speed was 1 m/s and mass flow rate were 0.022kg/s.m² per area of the collector. The system was positioned at 26° tilt angle. Panel from 7 AM to 4 PM on 16th (Feb. and Aug.). The PV panel temperature was higher in the warmer month (Aug.) with temperature up to 56.0°C. The results show that the PVT and PV
system electricity output increased by 8.5%. Apparently, the thermal efficiency of the Nano-fluid-cooled PVTs increased by 13% over the PVTs with a water-cooled system [53].

CATIA software used the numerical investigation obtained using computational fluid dynamics (CFD) for the development of the model and then imported to ANSYS workbench. The simulation used three working fluids consisting of water, Ag/water Nano fluid and Al2O3 / water Nano fluid. The volumetric fractions of the nanoparticle were between 0% to 12%. The sheet and tube used five tubes each of 2m length, 0.01 m outer diameter and 0.001m tube thickness. A spacing of 0.2m was maintained between center using a copper material. The number of cells was 60. Solar radiation absorbed 570 W/m², temperature inlet 30 °C, 0.05-0.23 m/s inlet velocity, the maximum rise in the heat transfer coefficient for Ag and Al2O3/ water Nano fluid was 43.0 % and 12.0% [54, 55].

Al-Waeli et al. generated the new idea proposed to be used in Bangi, Selangor Malaysia where the weather condition was 31 °C, wind speed was 10 Km/h and the humidity approximate of 66.0%. The four-model used were the conventional PV, PVT cooling with water flows in pipe, PVT cooling with water flows in pipe and PCM. The last model was PVT cooling and the tank failed with PCM/SiC and Nano fluid water /SiC. The mass fraction was 0%,0.1%,0.5%,1%,2%,3% and 4% as shown in Figure 12. The tilt angle was 14° and the 0.084-0.583kg/s mass flow rate was utilized during the study. The electrical efficiency ranged (7.10%-13.70), while the thermal efficiency up to 72.0% [56]. Another study used same location and three models of PV, PVT (sheet and tube) and PVT / PCM, the mass flow rate was 0.1kg/ s. The PVT water angle was steeper than PVT/ PCM Water. The high tilt was suggested to give more intensity exposure to changes in thermal exergies because of the angle. The graph of the Y - intercept showed a PVT PCM water was higher value. The implication was that electrical energy reached 35.90 until [57].

The 1200 WP roof top Grid Connected Photovoltaic Thermal System (GCPVT) with Nano fluid SiC. In March, at University Kebangsaan Malaysia, GCPV reported an efficiency range of 8.77 per cent, a 77.14 % efficiency ratio, a 10.57 kWh/kWP (kWP is the peak power of a PV system) monthly array yield and 100.53 kWh/kWP final output. Similarly, GCPVT with Nano Fluid reported 13.52 % PV array efficiency, 95.72% PR, 0.17 kg / s mass flow rate, 14 % PV module electrical efficiency and 42° C Nominal Operating Cell Temperature [58].

The study by Al-Waeli et al. used 3 wt.% volume fractions of SiC Nano fluid in tests that were performed with 0.068-0.170 kg / s mass flow rate, 14° tilt angle, and the ambient temperature used was 297K. The experiment was done in University Kebangsaan Malaysia. The result showed increased in the electrical efficiency reach to 24.1%, the overall efficiency was about 88.9% [59].

Senthilraja et al. used 10.26 mm diameter tube in experimental study. The study was done in the Institute of Science and Technology Chennai, India on May 5th, 2018. The maximum electrical and thermal efficiency for PV T solar collector with a water-based flow rate of 33.8 % was observed at mass flow rate of (0.008,0.010 and 0.011) kg/s with an average solar radiation of 700W/m² [60].

Obalanlege et al. used a system with external diameter sheet and tube of 8 mm, 14 copper pipes (PVT) by a heat pump PVT tank. The ambient conditions were 14°C ambient temperature and solar radiation [250 – 1000] W/m². The temperature increased abut (12-30) °C in PVT (that is 150%) in the panel temperature. This change in temperature resulted in a decreased electrical efficiency of the PVT from 16% to 14.50%. the overall efficiency of PVT electrical and thermal improved from 16.0% to 64.50% with increased water flow rate though the panel PVT from 3 to 17 LPM. Increased the PVT tank size from 1 L to 100 L has improved PVT’s overall efficiencies by 6.5 % [61].

Eisapour et al. used the PV / T system with wave tubes for numerical investigation, while using different coolant. For instance, fluids with used water, Ag / water Nano fluid, and microencapsulated PCM Nano slurry were used. The diameter was 8 mm, 0.05 to 0.25 m/s mass flow rate. With these conditions, the exergy efficiency and thermal exergy to pure water were 13.25% and 69.39% respectively. The MPCM Nano-Slurry had 13.26% as shown in Figure 13. the pressure decreased and the that absorbed by heat transfer fluid improved due to lower wavelength and amplitude. PVT had the lowest amplitude and wavelength, by extending the lowest average panel temperature, resulting in higher overall performance [62].

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**Figure 12** Schematic diagram of PVT water and PVT/PCM water [56].
Figure 13 The schematic of the proposed PVT system with the wave tube front view [62]

Lee et al. performed the experimental work using glass plate - in conjunction with Nano fluid (CuO / water, Al2O3 / water). The apparatus was tilt at an angle of 45°, while the three-mass flow rate were (1,2 and 4) LPM as shown in Figure 14. The PVTs used Al2O3 / water as a Nano fluid that increased thermal efficiency by 15.14%, but there was no difference in electrical efficiency between water and Al2O3 / water systems. Results showed that the PVT system’s thermal and electrical efficiencies using CuO / water as a Nano fluid increased by 21.30% and 0.07% [63, 64].

Figure 14 Schematic diagram of a PVT system [63]

Kirti et al. used a photovoltaic thermal (PVT) non-metallic water heater solar (PVNMSWH), and the diameter of the pipe was 0.01 m. The model used 10 tubes with mass flow rate 0.02 kg/s. Maximum thermal efficiencies were found to be 43.9% and 38.3% in the month of April and December respectively at 13:00hr. The electrical efficiency was found to vary between 11-12.5% [65].

Fudholi et al. research was a combination of theoretical and experimental indoor strategies of the PVT model. The system had unglazed plate and work fluid was TiO2 / water Nano fluid with (0.5wt% and 1wt%) TiO2. 0.012-0.025kg/s mass flow rate. TiO2 Nano fluid-based PVT collector energy output of 1wt.% was 85 – 89 % compared to 60 – 76 % for water-based collector at 0.0255 kg/s. the exergy efficiency gain of 1wt.% TiO2 was 6.02% compared to water based collector at a mass flow rate of 0.0255 kg/s [66].

6. Passive Cooling

Chandrasekar et al. used the passive cooling with cotton wick structure water in comparison. The total dimensions of the PV panel were (60×60) cm with an arrangement of 18 rows and 4 columns silicon cell as show in fig 16. There are three types of work fluid gas, Al2O3 / gas, and CuO / water Nano fluid. The Nano fluid had a 0.1 percent volume concentration, the tilt angle was 15° with reference horizontal, and the latitude of position 10 normal as shown in Figure 16. The cotton wick has a diameter of 7 mm. Between 9:00 AM to 5:00 PM in April 2012 for 8 hours, the temperature was around 45 hp with cooling and 65 hp without cooling., a maximum efficiency of 10.4 % was achieved using wick structures in conjunction with water. Nonetheless, the performance without cooling system was the least at a value of 9% [67].

Figure 15 front and back sides of PV models [67]

7. Air Flow Cooling

Fudholi et al. used the V groove absorber, located on the back of panel of 80 W PV. The 13 V-groove units was deployed with the dimension of groove at 1.140 m. each corner of the rod was 60° per vertex, the temperature of PV for mass flow rate 0.007-0.07 kg/s as show in Figure 16 was between 62.9-51.1 C°. During the experiment, the solar radiation was 820, the average PVT exergy efficiency of 12.66% and the average PVT energy efficiency of 66.73% were observed [68].

Figure 16 (V-grooved absorber model) [68]
<table>
<thead>
<tr>
<th>Author</th>
<th>Type of study</th>
<th>Diameter D, Space S</th>
<th>model type</th>
<th>work fluid</th>
<th>location</th>
<th>mass flow rate</th>
<th>conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gang, 2011[5]</td>
<td>Exp.</td>
<td>D=80</td>
<td>the collector glazing with glass plate</td>
<td>water</td>
<td></td>
<td></td>
<td></td>
<td>the daily results the thermal efficiency 41.9% and the electrical efficiency 9.4%</td>
</tr>
<tr>
<td>Fudholi 2018 [68]</td>
<td>Exp.</td>
<td>V=60°</td>
<td>air</td>
<td></td>
<td>0.007-0.07 kg/s</td>
<td></td>
<td></td>
<td>the average PVT energy efficiency 66.73% and the average PVT exergy efficiency 12.66%</td>
</tr>
<tr>
<td>Yu, Q., 2019 [7]</td>
<td>Exp.</td>
<td>D=100</td>
<td>MPCM /water</td>
<td>(0.04-0.25) m/s</td>
<td>I=1000 W/m²</td>
<td>Ta=273 K Ua=0.5m/s</td>
<td></td>
<td>The maximum enhancement in energy efficiency provided by the MPCM was 8.3%, exergy efficiency was 3.23%</td>
</tr>
<tr>
<td>Yang, 2012 [8]</td>
<td>Exp.</td>
<td>D=60</td>
<td>water</td>
<td>66 ml/min</td>
<td>I=1 W/m²</td>
<td>850-1100</td>
<td></td>
<td>The efficiency of the PV increased to 12.3%</td>
</tr>
<tr>
<td>Tiwari, 2009 [9]</td>
<td>Exp.</td>
<td></td>
<td>Integrated PV/T system (IPVTS)</td>
<td>Taiwan</td>
<td>0.016 kg/s</td>
<td>I=486-852 W/m²</td>
<td>Ta=25-36 °C</td>
<td>The overall exergy efficiency 9.05%, the overall energy efficiency 55%</td>
</tr>
<tr>
<td>Thinsur2 019 [10]</td>
<td>Sim.</td>
<td></td>
<td>P VT cell with and glass cover with air gape</td>
<td>I=1000 W/m²</td>
<td>Ta=25 °C</td>
<td>T=364 W/m²</td>
<td></td>
<td>electricity efficiency (12.99-9.88) Ave. thermal efficiency (53.22-34.79) %, total efficiency (66.21-44.68)%, PVT electricity efficiency 12.97%</td>
</tr>
<tr>
<td>Qi Shi, 2017 [11]</td>
<td>Exp. indoor</td>
<td>T No.=6</td>
<td>aluminum plat glazing cover and</td>
<td>water</td>
<td>Tianjin</td>
<td>Chengjian University</td>
<td>0.13L/min</td>
<td>Tilt angle=20°, the maximum for the thermal and electrical efficiencies 37.2% and 46.5% respectively.</td>
</tr>
<tr>
<td>Li, M., 2020 [12]</td>
<td>Exp.</td>
<td>D=10 P S=100 mm</td>
<td>PVT, ST collector, Unglazed PVT, glassed ST</td>
<td>water</td>
<td></td>
<td></td>
<td></td>
<td>glassed PVT, glassed ST collector was the best overall exergy and energy efficiency 17.63%and 41.51%, respectively.</td>
</tr>
<tr>
<td>Korona 2016 [14]</td>
<td>Exp.</td>
<td></td>
<td>water</td>
<td>Greece</td>
<td></td>
<td></td>
<td></td>
<td>the overall exergy efficiency was 11.35% for without cover PVT, Overall energy efficiency 21.7%</td>
</tr>
<tr>
<td>Kalogir 2006 [15]</td>
<td>Sim.</td>
<td>D=150</td>
<td>flat plat collector glazing</td>
<td>water</td>
<td>Nicosia</td>
<td>Athens Madison</td>
<td>4.9 l/h</td>
<td>the electrical energy 222-532 kWh</td>
</tr>
<tr>
<td>Ji, J., et al 2007</td>
<td>Exp.</td>
<td>20=10</td>
<td>flat box Aluminum</td>
<td>water</td>
<td>(HeFei,AnHui Province, PRC,31530: N, 117150: E),</td>
<td>80 kg/m²</td>
<td>T=20 °C, the thermal efficiency was 50%, the daily primary energy saving 70%</td>
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<tr>
<td>Jabrom20 15 [17]</td>
<td>Sim.</td>
<td></td>
<td>30%gl yeol/w ater</td>
<td>Tabriz</td>
<td>Shiraz</td>
<td>Esfahan</td>
<td></td>
<td>Exergy efficiency is obtained to be 9.6%,9.7% and 9.6% for the three cites Shiraz, Tabriz and Esfahan, respectively.</td>
</tr>
<tr>
<td>Ibrahim 2014 [18]</td>
<td>Exp.</td>
<td></td>
<td>Building integrated photovoltaic thermal</td>
<td>Malaysia</td>
<td></td>
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<td>55-62 % PVT energy efficiency is higher than 12-14 % PVT exergy efficiency.</td>
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<tr>
<td>Huo, 2019 [19]</td>
<td>Exp. indoor</td>
<td></td>
<td>iron filling filled tube plate PVT system</td>
<td>water</td>
<td>Tianjin</td>
<td>Chengjian University</td>
<td>0.9 m³/h</td>
<td>1=400-800 W/m²</td>
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<tr>
<td>Hossain, 2019 [20]</td>
<td>Exp.</td>
<td>SP=76.2-101.6</td>
<td>water</td>
<td>Latitude 3.11 ° north and 101.66 ° east</td>
<td>0.5-4 L/min</td>
<td>I=975 W/m²</td>
<td></td>
<td>the max. of thermal efficiency for PVTs at 2L/min was 76%. Electrical eff. Of PV and PVT was</td>
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<tr>
<td>Study</td>
<td>Methodology</td>
<td>System Description</td>
<td>Location</td>
<td>Water Temperature</td>
<td>Exergy Efficiency</td>
<td>System Performance</td>
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<tr>
<td>Fu, et al., 2019</td>
<td>Exp.</td>
<td>PVT natural circulation, direct coupled PV pump and third system PV</td>
<td>China</td>
<td>20°C</td>
<td>3.2%</td>
<td>Electricity gain (20.6 MJ), thermal efficiency (37.6%)</td>
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<td>Chow, 2006</td>
<td>Exp.</td>
<td>An aluminum flat box type PVT</td>
<td>China</td>
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<td>Total energy efficiency 12.48%</td>
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<td>Chaabane, 2015</td>
<td>Sim.</td>
<td>T No.=2 to 6</td>
<td>Italy</td>
<td>20°C</td>
<td>30 LPM</td>
<td>The thermal efficiency 11.7-12.3%</td>
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<td>glazed the roll ond flat plate adsorber</td>
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<td>20°C</td>
<td>0.066 kg/s</td>
<td>Tilt angle=30°</td>
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<td>Al-Hrari, 2020</td>
<td>Exp.</td>
<td>Concentrated Photovoltaic/Thermal system (CPV/T)</td>
<td>Turkey</td>
<td>20°C</td>
<td>0.02 kg/s</td>
<td>Average electrical efficiency 18.2% and the overall thermal efficiency 71%</td>
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<td>Sopian, 2020</td>
<td>Sim.</td>
<td>D=100, T No.=20</td>
<td>Malaysia</td>
<td>20°C</td>
<td>Humidity=80% U=1 m/s</td>
<td>The proposed system’s daily exergy efficiency averages around 13.53% for the Nano-PCM Nano-Fluid tank, mean electrical exergy efficiencies 12.05%</td>
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<td>Babayan, 2019</td>
<td>Exp.</td>
<td>water</td>
<td>Iran</td>
<td>20°C</td>
<td>0.14-0.20 kg/s</td>
<td>The maximum energy efficiency obtained 35.4% and the maximum daily exergy efficiency 15.17%</td>
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<td>Sardarabadi et al., 2014</td>
<td>Exp.</td>
<td>(SiO2)/water</td>
<td>Iran</td>
<td>20°C</td>
<td>33 0.5 C</td>
<td>For the two cases of silica/water Nano fluids are increased by 7.6% and 12.8%, the total exergy eff. for cases pure water 19.36%, nano fluid 1 wt % was 22.61% and nano fluid with 3wt% was 24.31 %.</td>
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<td>Electricity output for PVT-cooled and PVT-systems is up 8.5%, thermal efficiency of a Nano-cooled PVTs is increased by 13% over water-cooled PVT-system</td>
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</table>
| Khanjari, et al. 2016 [54] | Simulation | D=100 Ø S P =20 T No.=5 | Alumina – water | 0.05 m/s | 0.23 m/s | The four-model used conventional PV, PVT cooling water – SiC | Bangi, Selangor Malaysia | Hum.=66 % | T=31°C | U∞=10 km/h | Tilt angle=14° | The electrical eff. (7.10% - 13.70%) thermal eff. reached 72.0% | Al Weali, A.H.A., et al. 2019 [57] | Exp. | PV, PVT and PVT / PCM | water | 0.1 kg/s | The PVT PCM water was best, the electric exergy reaches 35.9 $/MJ for the PVs, and its output is about 478,275 $/MJ | Al Weali, et al. 2017 [56] | Exp. | Photovoltaic Thermal Connected Grid | SiC/water | National University of Malaysia UKM | 0.17 kg/s | 13.52% of efficiency, 95.72% of PR at m=0.1 kg/s, 14% of the electric module photovoltaic efficiency, Nominal operating system temperature 42°C | Chandra, M., et al 2013 [67] | Exp. | Passive cooling with cotton wick structure in combination with water | Al2O3/water CuO/water | Institute of Science and Research Tech., Chennai; | 0.008, 0.01 and 0.011 kg/s | I=700W/m2 | Max. thermal eff. and electrical eff. of 33.80% and 8.50% observed for PVT solar collector used water. | Al-Waeli, et al. 2020 [60] | Exp. | D=10.26 Ø | Panel (PVT) to a heat pump by means of a PVT water tank. | 3L/min to 17L/min | I=250-1000 W/m2 T=r=14°C | This increase in temperatures leads to a reduction in PVT's elec. output, from 16.0% to 14.5%, the increased the mass flow rate of from 3LPM to 17 LPM through the PVT panel increases PVT's total output (electric + thermal) from 61-64.5%. | Obalan,ge, M.A., et al. 2020 [61] | Sim. | D=80 Ø T No.=14 | Water tubing PV / T system is numerically examined with different coolant fluids | water, Ag/water | 0.05to 0.25 m/s | T=r=273.15, I=0.5 m/s, l=1000W/m2 | The exergy efficiency and thermal exergy to pure water 13.25%+69.39% respectively and MPCM Nano-Slurry 13.26%. The pressure decreases and the heat absorbed by the increased heat transfer as result lower wavelength and amplitude. | Eisaipoor, M., et al 2020 [62] | Sim. | D=8 Ø | Flat plate PVT with class cover | CuO/water, Al2O3/water | 127°C and 37°C | I=713-931.7W/m2 U∞=0.18(m/s) T=25.7-34°C | l=995 W/m2 | The exergy efficiency and thermal efficiencies using Cu/water improved by 21.30% 0.07% | Lee, J.H., S.G. Hwang, 2019 [63] | Exp. | Flat-plate PVT with class cover | (CuO/water, Al2O3/water) | 1, 2, and 4 L/min | I=713-931.7W/m2 U∞=0.18(m/s) T=25.7-34°C | Al2O3/water PVT system increased thermal eff. by 15.14%, but there was no difference electrical eff. between water and Al2O3/water. PVT thermal and electrical efficiencies using Cu/water improved by 21.30% 0.07% | Kirit Tewari 2019 [65] | Sim. | D=100 Ø T No.=10 | a photovoltaic thermal (PVT) non-metallic solar water heater (PVNMSWH) | Alahhabad, Allahhabad, U.P India (latitude 25°27’N and longitude 81°44’). | 0.02kg/s | Tilt angle=25° | Maximum thermal efficiencies have been found to be 43.9% and 38.3% in the month of April and December respectively at 13:00hr and electrical efficiency is found to vary between 11-12.5%. | M.S. Hossaina, et al. 2019 [46] | Exp. | 12.70 | (PV/T-PCM) | water | University of Malaya | 0.5-4 liter per minute | I=995 W/m2 | Tilt angle= 15° | PVT PCM collector’s max. thermal eff. was 87.72% at 2 L/min. Max. electrical eff. of PV and PVT PCM systems was 9.88% and 11.08% 4 L/min resp. the PV and PVT PCM
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Methodology</th>
<th>Collector</th>
<th>Fluid</th>
<th>Temperature</th>
<th>Electrical Efficiency</th>
<th>Thermal Efficiency</th>
<th>Exergy Efficiency</th>
<th>Economic Efficiency</th>
</tr>
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<tbody>
<tr>
<td>Maria Herrando et al. 2019</td>
<td>Sim.</td>
<td>10-10</td>
<td>water</td>
<td>25°C</td>
<td>10.1 t 50 LPH</td>
<td>1000 W/m²</td>
<td>Tilt angle=35°</td>
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<td>Ahmad Foolad et al. 2019</td>
<td>Theo. and exp.</td>
<td>flat plate</td>
<td>TiO2/water</td>
<td>0</td>
<td>0.012-0.025 kg/s</td>
<td>500,700 W/m²</td>
<td>Tilt angle=5°</td>
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<td>Thiermos et al. 2019</td>
<td>Num.</td>
<td>1x1.7</td>
<td>PVT with heat pipe</td>
<td>R-134a, water</td>
<td>200 to 800 W/m²</td>
<td>66%</td>
<td>Tilt angle=14°</td>
<td></td>
</tr>
<tr>
<td>Ali H.A. et al. 2019</td>
<td>Expe. and math.</td>
<td>Water/Nano</td>
<td>UKM, Malaysia</td>
<td>2.9021N and 101.7830 E</td>
<td>0.084-0.583 kg/s</td>
<td>Ta=29-31°C</td>
<td>Ua=10 km/h</td>
<td></td>
</tr>
<tr>
<td>Evangelos Sakellariou 2018</td>
<td>Sim. and Exp.</td>
<td>D=6, P=12</td>
<td>University of West Attica</td>
<td>water</td>
<td>60 to 95 kg/h</td>
<td>Tilt angle=10°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mohammad Hosseinadad 2017</td>
<td>Exp.</td>
<td>8</td>
<td>PVT/PCM</td>
<td>ZnO/water</td>
<td>FUM Iran, Lat. 36° and Long. 59°</td>
<td>30 kg/hr</td>
<td>I= (976.52, 847.07, 602.36) W/m²</td>
<td></td>
</tr>
<tr>
<td>Mangesh S 2016</td>
<td>Sim.</td>
<td>8</td>
<td>water</td>
<td>Mumbai (19°170N, 72°480E)</td>
<td>0.02 kg/s</td>
<td>Tilt angle=45°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.L. Sun et al. 2016</td>
<td>Sim. and exp. indoor</td>
<td>20 Ø</td>
<td>water</td>
<td>Hong Kong, Thus</td>
<td>0.04 kg/s</td>
<td>Tilt angle=20-40°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blessy Joy 2016</td>
<td>Sim. and exp.</td>
<td>13 Ø</td>
<td>Water/ethylene glycol (EG)</td>
<td>Amal Jyothi Engineering College, Kottayam, India (9°320N and 76°400E)</td>
<td>8 g/s 2 g/s</td>
<td>I= 727.4 W/m²</td>
<td>Tilt angle=15°</td>
<td></td>
</tr>
<tr>
<td>Shamsani, 2016</td>
<td>Sim. and exp.</td>
<td>15x20</td>
<td>water</td>
<td>National University of Malaysia UKM</td>
<td>0.068-0.170 kg/s</td>
<td>I= 400-1000 w/m²</td>
<td>Ta=297 k</td>
<td></td>
</tr>
<tr>
<td>Huan-Liang Tsai</td>
<td>Exp.</td>
<td>SP=12</td>
<td>photovoltaic/thermal assisted heat pump</td>
<td>R134a</td>
<td>Tilt angle=23.5°</td>
<td></td>
<td>Solar electricity from rooftop PVT systems is capable of supplying</td>
<td></td>
</tr>
</tbody>
</table>
### 8. Conclusion

Many researchers are currently working on the use and proper use of sustainable because of global challenges such as global climate change, increased curd oil and gases piece and predictions of an end to non-renewable resources. Working on photovoltaic and thermal hybrid systems, driven by the need to analyse environmental impact and energy sources. This paper analyses the application results of photovoltaic hybrid pipe and fluid and nano fluid systems as well as various other systems. The geometries and the different fluids were analysed. The overview of results for PVT systems is as follows:

1. In contrast with panels, PVT-PCBM systems improve the electrical output by 15-23 % and increase the electrical efficiency by cooling phase material compared to single and dual fluid cooling.

2. Improved electricity output by 20.5% by 37.67% and 27 % using Nano fluids as PVT coolers for direct channels, spiral channels, and micro channels respectively.

3. Increase energy efficiency of PVT system by glazing PV.

4. The thermal efficiency was measured at 63 % to be 55 % and 66%, respectively of the reflector, spiral and double fluid flow PVT system.

5. The thermal efficiency of PVT PCM system of Nano fluid/Nano PCM (Organic Paraffin wax PCM and many Nano particles) was measured at 72%.

6. Tube number and the shape has direct relation to PVT system thermal efficiency.

7. Improved thermal efficiency, increasing channel output.

8. Using PCM Nano fluid increased the difference in voltage, power output and thermal efficiency by about twice.

9. In the absorbed tube (sheet and tube) the range of diameter was 6-20 mm.

### Acknowledgements

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[37] M.F. Mohammed and N.A. Rahim, Comparative Study on Photovoltaic (PV) and Photovoltaic thermal water collector (PVTw). 2014.


[62] M. Eisapour, A.H. Eisapour, M.J. Hosseini, and P. Talebizadehsardari, Exergy and energy analysis of wavy tubes photovoltaic-thermal systems using microencapsulated PCM nano-


