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Selecting the Best Nanofluid Type for A Photovoltaic Thermal System Based on Reliability, Efficiency, Energy, Economic, and Environmental Criteria

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Abstract:	The foremost alternative for running a PV unit is chosen among five items using analytical hierarchy process (AHP) decision-making approach. Two items are individual PV usage and pure water based PV/T system, and three other ones are, Al_2O_3, TiO_2, and ZnO nanofluid based PV/T technologies. The experimental data gathered throughout a year for a 250W multicrystalline module is utlized to obtain the results. Energy yield, electrical and thermal efficiencies, payback period, and CO_2 reduction are the decision-making criteria while the reliability is added to them to have a broader insight from the performace. According to the results, with the gained score of 36.8 out of 100, ZnO nanofluid based PV/T system is the best alternative. It has the annual energy production, and average electrical and thermal efficiencies of 632.5 kWh, 14.65, and 47.63%, respectively. Moreover, it is able to reduce CO_2 emission by 378.3 kg and enjoy the reliability of 0.986388, which is the highest one among the alternatives. Additionally, this alternative offers a payback period of 5.12 years, which is aroud 10% lower than the main rival, i.e., TiO_2 nanofluid based PV/T system. Utilizing pure water PV/T is also found much better than Al_2O_3 one beucase of economic issues.
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Dear Editor of Journal of the Taiwan Institute of Chemical Engineers,

Enclosed is the manuscript entitled "**Selecting the Best Nanofluid Type for A Photovoltaic Thermal System Based on Reliability, Efficiency, Energy, Economic, and Environmental Criteria**" to be considered for publication in Special Issue on the Applications of Nanofluids in Renewable Energy. It is our deep pleasure to have the opportunity of submitting our work to Journal of the Taiwan Institute of Chemical Engineers, as one of the leading journals in the field.

The paper is thought to be suitable for special issue since it has the theme of Application of novel nanofluids to renewable energy systems and Techno-economics of nanofluids in renewable energy systems. They are two subjects indicated as of immediate interest of the special issue.

In addition, the paper text (including main text, references, and figure captions) is 4479 words, while number of display items (including figures, schemes, and tables) are 6 (3 Figures and 3 Tables). Both are within the range mentioned in the guide for authors of journal, which are 4500 words and 10, respectively.

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Thank you very much for taking your valuable time to read this letter and for your consideration.

Kindest Regards,

Ali Sohani

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   Yes.

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   Yes. The paper had 6 keywords, which were presented just after the abstract.

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Highlights

- ZnO nanofluid based PV/T system is chosen as the best.
- It has the annual average electrical and thermal efficiencies of 14.65 and 47.63%.
- It offers payback period and annual reliability of 5.12 years and 0.986388.
- 378.3 kg CO_2 is saved using this scenario, more than all other ones.
- Employing pure water cooling is found better than Al_2O_3 nanofluid.

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Selecting the Best Nanofluid Type for A Photovoltaic Thermal System Based on Reliability, Efficiency, Energy, Economic, and Environmental Criteria

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Abstract

The foremost alternative for running a PV unit is chosen among five items using analytical hierarchy process (AHP) decision-making approach. Two items are individual PV usage and pure water based PV/T system, and three other ones are, Al_2O_3, TiO_2, and ZnO nanofluid based PV/T technologies. The experimental data gathered throughout a year for a 250W multicrystalline module is utlized to obtain the results. Energy yield, electrical and thermal efficiencies, payback period, and CO_2 reduction are the decision-making criteria while the reliability is added to them to have a broader insight from the performace. According to the results, with the gained score of 36.8 out of 100, ZnO nanofluid based PV/T system is the best alternative. It has the annual energy production, and average electrical and thermal efficiencies of 632.5 kWh, 14.65, and 47.63%, respectively. Moreover, it is able to reduce CO_2 emission by 378.3 kg and enjoy the reliability of 0.986388, which is the highest one among the alternatives. Additionally, this alternative offers a payback period of 5.12 years, which is aroud 10% lower than the main rival, i.e., TiO_2 nanofluid based PV/T system. Utilizing pure water PV/T is also found much better than Al_2O_3 one beucase of economic issues.

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Keywords: *Analytical hierarchy process (AHP) decision-making; Comparative study; Experimental investigation; Nanofluids; Photovoltaic thermal (PVT) system; Reliability.*

Nomenclature

A	Area $\left(\mathrm{m}^2\right)$
c_p	Specific heat $\left(\mathrm{J.K^{-1}.kg^{-1}}\right)$
cde	CO_2 emission factor $\left(\mathrm{kg}_{CO_2}.(kWh)^{-1}\right)$
CDR	CO_2 reduction $\left(\mathrm{kg}\right)$
E	Produced energy of a solar module (kWh)
G	Solar radiation $\left(\mathrm{W.m^{-2}}\right)$
$\dot{m}$	Mass flow rate $\left(\mathrm{kg.s^{-1}}\right)$
P	Power (W)
Q	Heat (W)
R	Reliability
T	Temperature (K)
t	Time (s)
Greek symbols	
δ	Uncertainty
η	Efficiency (%)
Scripts	
elec	Electrical
end	End of the time period
in	Inlet
module	PV solar module
NF	Nanofluid
out	Outlet
start	Beginning of the time period
th	Thermal
tpp	Thermal power plant
w	Water
Abbreviation	
AEP	Annual electricity production
AHP	Analytical hierarchy process
CFD	Computational fluid dynamics
IPP	Initial purchase price
PBP	Payback period
PV	Photovoltaic
PV/T	Photovoltaic thermal

1. Introduction

Despite being taken into account as a new technology, a considerable share of electricity in the world is being supplied using photovoltaic (PV) solar power generation systems. PV technologies have the potential of being utilized in a vast range of applications and power production rates, from supplying the required energy for a traffic light on the road to providing the electricity for a household, or a town, or a city. In addition, PV systems are able to generate power with high level of reliability while they are easy to install and repair [1].

The efficiency and consequently, the amount of the generated power of a PV module has a reverse relationship with operating temperature of that. Not only the electrical performance, but also lifetime of a PV module declines when temperature of that is not controlled properly. Therefore, and considering the fact that a fraction of the received solar radiation leads to increasing the temperature of a PV module, thermal management of PV systems is extremely essential.

During the past years, using nanofluids for cooling PV modules has increasingly become popular. Nanofluids have a high heat transfer capability, which is taken into account as the biggest advantage of them. Therefore, by employing nanofluids, not only a PV module could be considerably cooled down but also a part of dissipated heat will be recovered through transferring to another working fluid like water. It leads to obtaining a better energy efficiency level because of changing the PV to photovoltaic thermal (PV/T) system.

Due to the mentioned benefits, as well as significant progress in solving the issues about non-stability of particles in the base fluid, an accelerating trend in the studies performed in the field of nanofluid PV/T systems have been observed. A brief introduction of the state of the art is presented in Table 1.

Table 1. A brief introduction of the state of the art

Study	Year	A brief description	Was reliability of the system investigated?	Was the best type of nanofluid chosen by a systematic decision-making approach?
Sardarabadi and Passandideh-Fard [2]	2016	ZnO, Al_2O_3, and TiO_2 as the three most frequent types of water-based nanofluids were studied. Both experimental and numerical results were provided. Temperature and electrical efficiency, in addition to the required size of PV to fulfill a specified demand were evaluated as the performance criteria of the system.	No	No
Khanjari et al. [3]	2016	Two types of water-based nanofluid for cooling a PV module were compared together. The comparison was made using a developed numerical model that worked based on the computational fluid dynamics (CFD) approach.	No	No
Sardarabadi et al.	2017	The recorded experimental data was employed to analyzing the performance of a nanofluid water-based system. The investigation was done from exergy and energy perspective while a brief economic discussion was also carried out.	No	No
Khanjari et al. [4]	2017	The effects of cooling by pure water and water-based Al_2O_3 were obtained and compared together for a PV system. Electrical and thermal efficiency, in addition to the heat transfer coefficient were investigated in the performed parametric study.	No	No
Ebrahimi et al. [5]	2018	Analytical network process was utilized to select the foremost PV/T system among a number of alternative. However, the decision-making only restricted to the energy and economic aspects, and did not take the environmental and reliability issues into account. In addition, only one alternative in which nanofluid was used was considered, and for that alternative nanofluid type did not change.	No	No
Hosseinzadeh et al. [6]	2018	The water-based ZnO nanofluid was chosen and by developing a numerical 3D model, the performance of that was analyzed. The impact of changing different parameters, such as the inlet fluid temperature on the thermal and electrical efficiencies of the system was studied.	No	No
Abadeh et al. [7]	2018	By conducting experiments on one sample day for each month of a year, different nanofluids were compared together from economic and environmental aspects. However, the results were limited to giving the values of performance criteria and no systematic decision-making approach was utilized to introduced the foremost fluid.	No	No
Al-Waeli et al. [8]	2019	The goal of that study was to find the foremost surfactant material for improving the suspension time of nano-particles in a nanofluid PV/T system. Based on the conducted parametric study, the solution of NH_3 and $C_{76}H_{52}O_{46}$ had a good performance. Ammonium cetyl cetyl was another surfactant which made considerable improvements in the stability of the nano-particles.	No	No
Lee et al. [9]	2019	Taking advantage of experiments, the performance of CuO and Al_2O_3 were evaluated through a comparative study. Three conditions for flow rate were examined, and the	No	No

		electrical and thermal efficiency values were obtained and compared.		
Jia et al. [10]	2020	A numerical model was developed, and the impact of changing volumetric concentration and nanofluid type on the performance indicators of a PV/T system, namely PV temperature, electrical and thermal power and efficiency values were found. Based on the conducted results obtained from the parametric study, combination of water with Al_2O_3 was found better than TiO_2.	No	No
Salari et al. [11]	2020	The combination of phase-change materials and nanofluid flow to enhance the performance of a PV system was investigated. A numerical approach was employed. Temperature counters and overall efficiency was studied as the performance criteria.	No	No

Reviewing the information given in Table 1 reveals that despite the fruitful studies which have been conducted so far, a number of gaps have been still needed to be fulfilled. As it has been highlighted by answering the questions in Table 1, to the best of authors' knowledge, two serious issues are:

- Although energy, economic, environmental, exergy, and exergoeconomic aspects have been studied in different research works, reliability has been overlooked.
- No systematic decision-making approach has been utilized to introduce the foremost nanofluid. Instead, only the values of performance indicators from different aspects have been given, and they have been compared together. In other words, selection of the best nanofluid in the studies have been based on the authors' discussion, and not a rigid systematic methodology.

Consequently, the current research work is done to address the introduced gaps. In the current investigation, the results obtained from the performance of different nanofluids by experiments during a year were utilized. Here:

- Reliability of the system throughout a year is calculated for the individual PV and different nanofluid water-based PV/T technologies, and it is employed for evaluation of the system in addition to other key performance criteria of the system.

- Analytical hierarchy process (AHP), as a systematic way to choose the best item among a number of alternatives is utilized to find the best system to run a PV unit, among individual PV, and Al_2O_3, TiO_2 and ZnO nanofluid water-based PV/T technologies. In addition to the reliability, the produced energy, the payback period, and CO_2 reduction of the system are studied as the representative of energy, economic, and environmental aspects of the system, respectively. Electrical and thermal efficiency values are also taken into account to consider the efficient energy conversation viewpoint.

In the rest of this paper, first, the information about the experiments is presented in part 2. After that, in section 3, the methodology is introduced, and next, the results are given and explained in part 4. Finally, the most significant points revealed by the study are proposed in the conclusions, i.e., section 5.

2. Experiments

This part provides details related to the experiments.

2.1. General description

In order to carry out experiments and obtain the data for power production and temperature of the systems, one sample day in each month is selected. Selecting the sample days on each month is done based on the recommendation of [12] for the average day. The experiments are done in Tehran, Iran, whose latitude and longitude are 51.4 °E and 35.7 °N, respectively.

The experimental setup is employed to gather the measured data is depicted in Figure 1. This experimental setup is similar to the one previously utilized by Abadeh et al. [7] for experimental measurement of a nanofluid PVT system.

Five conditions are considered here, which are individual PV, pure water cooling PV/T system, and Al_2O_3, TiO_2 and ZnO nanofluid water-based PV/T technologies. For the three employed nanofluids, the concentration of suspended particles during the experiments were two-tenths of weight fraction.

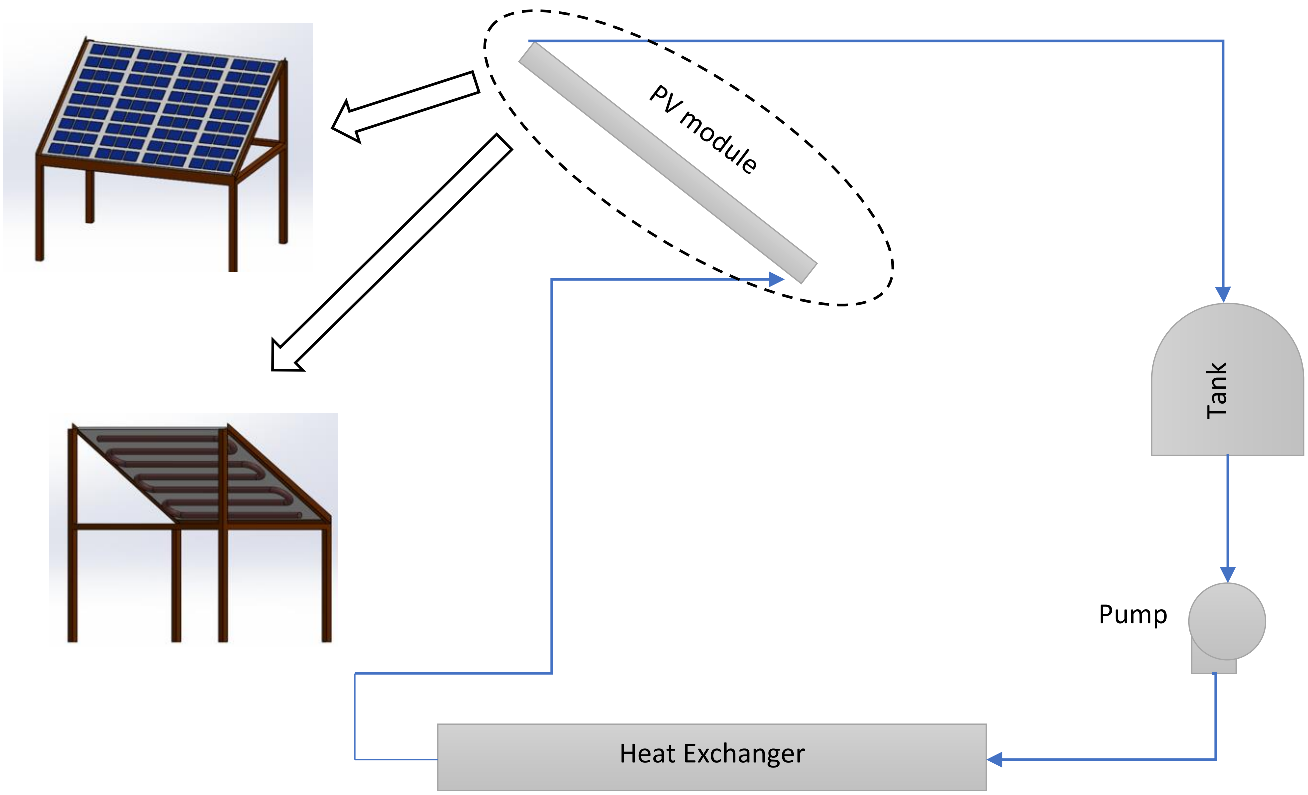

Figure 1. Schematic description of the investigated system

A 250W multicrystalline solar module that had been produced by Yingly company was chosen as the studied module (The information about this module is found in the catalogue of that, which could be found on [13]), and recording the experimental data is done by the time resolution of 10 minutes on the selected sample days with a number of the measurement equipment. Most of the measurement devices are the ones which are employed in the previous studies of the research team, like [14]. In addition to those introduced for measuring a PV system in the recent relevant investigation of the research team, LZB-10 rotary flow meter and K-type thermocouples are employed to record the data for fluid flow rate and temperature of different streams. Moreover, the solar module was installed on a frame which is made of steel while the tilt angle of that was adjusted to the recommended value of Mainzer et al. [15], i.e., longitude of the location, which is 35.7 °.

2.2. Uncertainty estimation

Estimating uncertainty for parameters measured throughout an experiment is vital to get confident they have enough accuracy. If a parameter is directly determined by a measurement device, the reported value in the catalogue could be employed. Nonetheless, for the ones which are functions of the measured parameters, or a combination of the measured and computed ones, the rule of propagation of uncertainty is used [16]:

$$\delta_h = \sqrt{(\frac{\partial h}{\partial \alpha})^2 \delta_\alpha^2 + (\frac{\partial h}{\partial \beta})^2 \delta_\beta^2 + ...} \tag{1}$$

In Eq. (1), h is the parameter whose uncertainty (δ_h) is going to be found. α and β are the input arguments for the function h, which have uncertainty values of δ_α and δ_β, and partial derivatives of $(\frac{\partial h}{\partial \alpha})$, and $(\frac{\partial h}{\partial \beta})$, respectively.

3. Methodology

The utilized methodology of this research work is explained here.

3.1. The investigated performance criteria

The investigated performance criteria of the system which are considered as the decision criteria are introduced, and the way to calculate them is described.

3.1.1. The energy production

The produced energy of a solar module (*E*) is obtained from Eq. (2) [14].

$$E = \int_{t_{start}}^{t_{end}} P dt \quad (2)$$

In Eq. (2), *P* is the power of a module. Moreover, t denotes time, and subscripts 'start' and 'end' represent the beginning and end of the time period in which *E* is going to be computed. Considering the point that power in were measured every 10 minutes, which means that the values are available in the discrete form, the trapezoidal rule is used to compute the answer of the integral [17].

3.1.2. The efficiency

In general, the ratio of the desirable output to the given input is called the efficiency. Two types of efficiency are usually defined for a nanofluid PVT system, which are electrical and thermal efficiencies. The given input for both efficiencies is the same, which is the received solar radiation. Nonetheless, the desirable outputs are not identical. As the name indicates, the produced power is the desirable output for electrical efficiency (Eq. (3)), while for the thermal efficiency, it is the usable part of heat absorbed by the nanofluid (Eq. (4)):

$$\eta_{elec} = \frac{P}{GA} \quad (3)$$

$$\eta_{th} = \frac{Q_{NF,useable}}{GA} = \frac{\dot{m}_w c_{P,w} (T_{w,out} - T_{w,in})}{GA} \quad (4)$$

η, P, G, A, Q, $\dot{m}$, and T represent efficiency, power, solar radiation, module area, heat, mass flow rate, and temperature respectively. c_P is also the isobaric heat capacity. Moreover, subscripts 'elec', 'th', 'NF', 'useable', 'w', 'out', and 'in' denote electrical, thermal, nanofluid, usable, water, outlet, and inlet, respectively.

3.1.3. Payback period

Payback period (PBP) is an economic indicator which shows that for an improvement plan, in how much time the initial investment is returned by the added profit. PBP is determined by solving Eq. (5) [7]:

$$\left[\sum_{k=1}^{PBP}(AEP)\times c_{elec}\times(1+y_{O\&M})^{PBP-k}\right]-IPP\times(1+y_{O\&M})^{PBP-1}\times(1+z)^{PBP-1}=0 \qquad (5)$$

AEP is the annual electricity production of the system. In order to calculate AEP, the values measured on the sample day in each month is multiplied by number of days in that month. Then, the impact of cloudy days is considered by a coefficient, which is 0.80 for October, November, December, January, and February, 0.85 for September and March, 0.90 for April and May, and 0.95 for June, July, and August.

Moreover, IPP denotes the initial purchase price of the system. IPP is determined by employing the information about cost of each component. The summation of IPP of all parts except for nanofluids are 750 $ while for nanofluids, IPP is obtained from [18].

3.1.4. Reliability

In this study, reliability (R) is defined according to Eq. (6):

$$R = \frac{\int_{t_{start}}^{t_{end}} dt_{T_{modolue} \leq 75\,°C}}{\int_{t_{start}}^{t_{end}} dt} \qquad (6)$$

In the catalogue, the temperature of 85 °C is indicated as the maximum allowable value of T_{module} [13]. Therefore, and by considering a safety margin of 10 °C, the value of 75 °C is chosen as the highest permissible T_{module} in this study. In other words, if T_{module} exceeds 75 °C, the module does not work.

3.1.5. CO_2 reduction

In order to calculate CO_2 reduction, briefly called CDR, it is assumed that using PV solar module is accompanied by decreasing the power generation in a thermal power plant. Therefore, the amount of CDR could be calculated based on Eq. (7) [19]:

$$CDR = cde_{elec,tpp} \times AEP \qquad (7)$$

Where $cde_{elec,tpp}$ is CO_2 emission per unit of the produced electricity in a thermal power plant, which is considered 0.598 $kg_{CO_2}.(kWh)^{-1}$ [19].

3.2. Decision-making

Decision-making is done using AHP, which has been completely introduced in the previous studies of the research team, as well as the original reference, i.e., [20]. The matrix of pairwise comparison of the criteria is presented in Table 2.

Table 2. Pairwise comparison of decision criteria

	AEP	**PBP**	**η_{el}**	**η_{th}**	**R**	**CO_2 reduction**

AEP	1	1/2	1	2	3	2
PBP	2	1	2	4	5	4
η_{el}	1	1/2	1	2	3	2
η_{th}	1/2	1/4	1/2	1	2	1
R	1/3	1/5	1/3	1/2	1	1/2
CO_2 reduction	1/2	1/4	1/2	1	2	1

4. Results and discussion

This part gives the obtained results of this work and has a discussion about them.

4.1. Accuracy of the experiments

For all the measured parameters, average relative uncertainty values are calculated and reported in Table 3. The values presented in this table is in the same order of magnitude as the works done in the field of investigating PV and PV/T systems like [17] and [21], which verifies the accuracy of the conducted experiments.

Table 3. The values of average relative uncertainty for the parameters measured throughout the experiments

Parameter	Average relative uncertainty (%)
Current	0.944
Inlet water temperature	0.336
Outlet water temperature	0.308
Voltage	0.617
Solar radiation	0.035
Flow rate	0.709

4.2. Finding the foremost alternative

The annual energy yield values of different systems are compared together in Figure 2a. As observed in this figure, with 420.1 kWh, the individual PV system has the lowest annual energy production among different alternatives. By employing cooling, the produced energy throughout the year increases significantly so that cooling by pure water makes it 37.0% more. Using Al_2O_3 nanofluid leads to only 11.4 kWh raise in the energy generation of the system, whereas by utilizing TiO_2 and ZnO nanofluids the obtained improvement compared to the pure water get 4.43 and 5.00 times bigger. As shown in Figure 2a, when TiO_2 and ZnO are employed, the annual energy yield reaches 632.5 and 626.0 kWh, respectively.

Moreover, according to Figure 2b, the increment in the electrical efficiency of the systems when cooling is employed is not as high as the enhancement in the power production. However, the values are still significant. The base PV has the annual average efficiency of 13.54% while it is 14.27, 14.34, 14.56, and 14.65% for pure water, Al_2O_3, TiO_2 and ZnO nanofluids, respectively. This means 5.39, 5.90, 7.53, and 8.19% growth in the electrical energy conversion efficiency, which is a remarkable outcome.

By converting the individual PV system to a PV/T unit not only the electrical efficiency of the system goes up, but also a part of the dissipated heat is recovered. The recovered fraction for different investigated PV/T technologies are compared in Figure 2c. Based on Figure 2c, for all cases, more than one -third of the dissipated heat is recovered on average in a year. Furthermore, since the heat absorption capacity of pure water and Al_2O_3 is lower than two other nanofluids they offer a lower level of thermal efficiency. In addition, the difference between the values of ZnO and TiO_2 are more compared to the two previously studied cases, where the first mentioned nanofluid provides 3.66% greater annual average thermal efficiency than the second mentioned ones.

Additionally, PBP values for the five studied technologies are presented in Figure 2d. The obtained values in Figure 2d demonstrate that the individual PV system and PV/T technology with ZnO nanofluid have the best PBP among all alternatives. For the first rank, i.e., the individual PV, the shorter PBP originates from the lower imposed initial purchased price, whereas for ZnO nanofluid PV/T system, it comes from the higher electricity production during the lifespan. TiO_2 is in the third place by around 10% longer PBP than ZnO. Such difference between the PBP of TiO_2 and ZnO have three reasons, which are the lower electrical, worse thermal efficiency, and higher imposed cost of TiO_2 in comparison to ZnO. Al_2O_3 nanofluid based PV/T system is also the worst system from PBP point of view, after pure water PV/T unit.

Considering the definition, reliability of the systems has a direct relationship with the average module's temperature during a year, and for that reason, the working fluid which makes the highest heat removal from the module, i.e., ZnO enjoys the highest reliability level among all the alternatives. According to the information presented in Figure 2e, the annual reliability of ZnO nanofluid based PV/T system is 0.986388. This value is 1.98% higher than the individual system, which is a significant improvement in a reliability value of the system. The reliability of ZnO nanofluid based PV/T is also 0.38% bigger than the main rival, i.e., TiO_2 nanofluid based PV/T technology.

Based on the definitions of this investigation, the higher a renewable energy system generates energy, the less CO_2 other fossil fuel burning power plants produce. Therefore, utilizing the system with the highest energy production during a year, i.e., ZnO nanofluid based PV/T technology is accompanied by the greatest CO_2 reduction compared to the other cases. As Figure 2f reveals, taking advantage of ZnO nanofluid based PV/T unit leads to 378.3 kg decrease in CO_2 production, which is almost 50% better than the individual PV system, and taken into account as a significant outcome. With 374.4, 350.9, and 344.1 kg decrement in CO_2 emission, TiO_2, Al_2O_3, and pure water based PV/T systems are in the second, third, and fourth places, respectively.

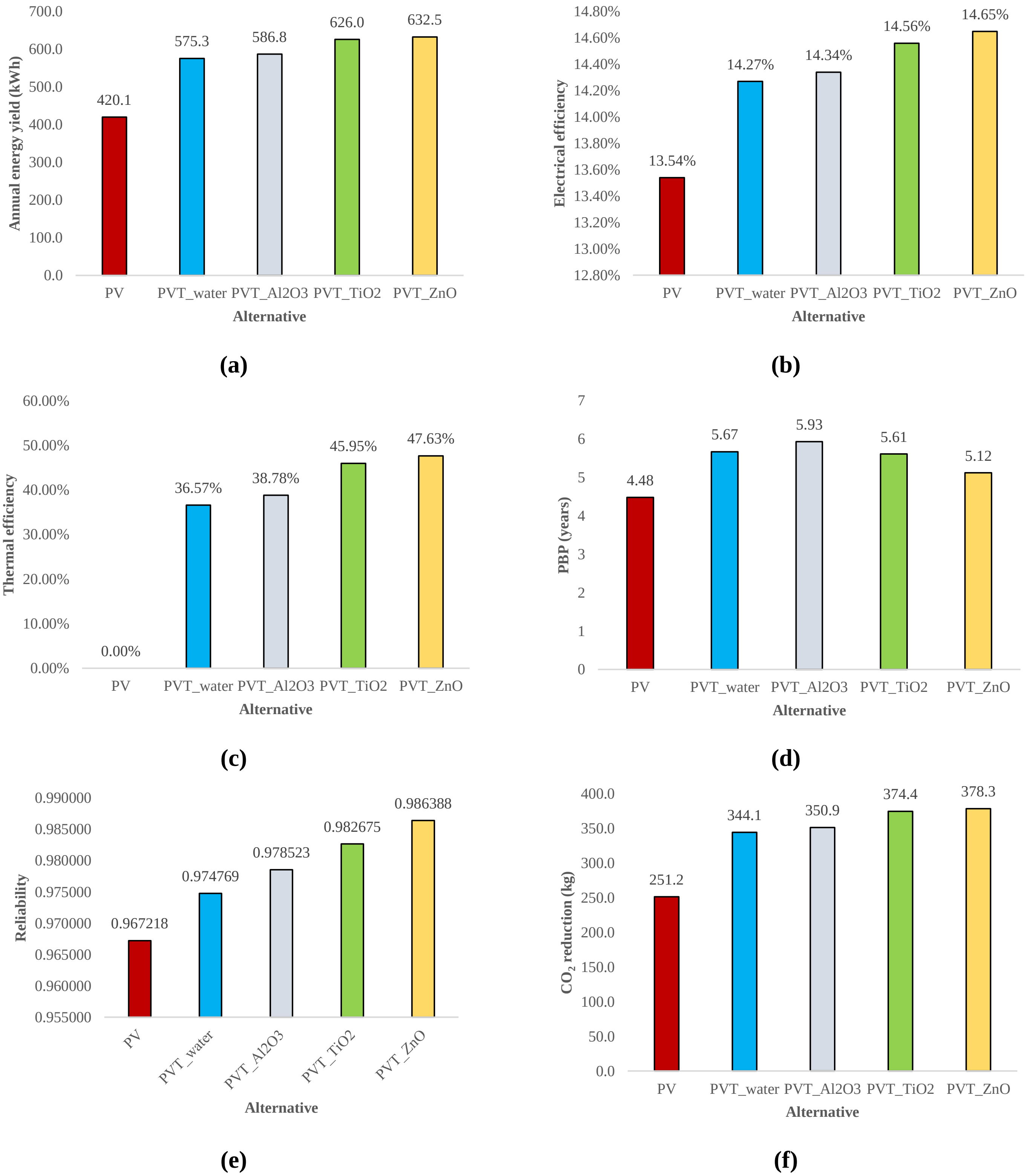

Figure 2. Comparing the criteria of the five alternatives together; (a) Annual energy yield; (b) Annual average electrical efficiency; (c) Annual average thermal efficiency; (d) Payback period; (e) Reliability; (f) CO_2 reduction.

The score each alternative achieves in AHP is also presented in the pie-diagram of Figure 3. Figure 3 demonstrates that among all the alternatives, utilizing ZnO nanofluid based PV/T technologies bring the most benefits, and it is the foremost item among the considered alternatives. It gains the score of 36.8 out of 100. Using TiO_2 is in the second-rank, by the score of 22.7 and a large part of the difference between its score and ZnO nanofluid PV/T unit comes from the higher PBP compared to that. Pure water-based PV/T technology is in the third rank, with the score of 18.9, and most of its superiority to two worse ones, i.e., individual PV and Al_2O_3 nanofluid based PV/T comes from the higher energy and efficiency, and better economic condition, respectively.

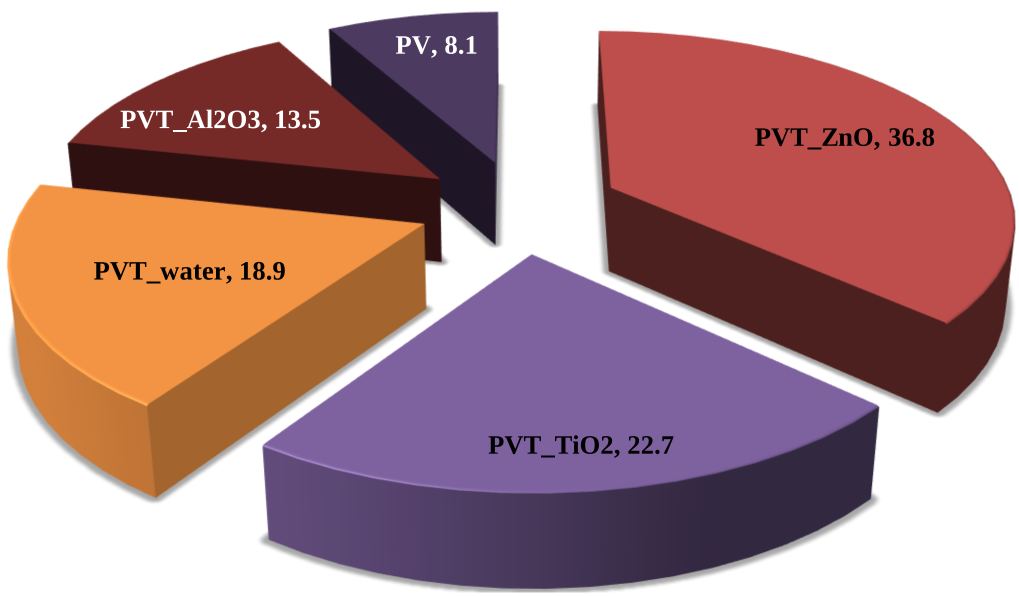

Figure 3. The gained score of each alternative, obtained by AHP

5. Conclusions

The performance of different alternative for using a PV module, including individual PV, pure water-based, Al_2O_3, TiO_2 and ZnO based nanofluid PV/T technologies were investigated and compared together in details here, and the best alternative was selected based on a systematic way for this purpose, which was analytical hierarchy process (AHP) decision-making approach. The experimental data gathered throughout a year was utilized for a 250W multicrystalline PV module to obtain the results, while in addition to electrical and thermal efficiency, energy production of the system, payback period, and CO_2 reduction, reliability of the system, as a new important performance criterion was also taken into account.

Based on the obtained results, ZnO nanofluid based PV/T system was chosen as the foremost item. In the investigated condition, this alternative had a slightly better electrical and thermal efficiency, as well as energy yield, reliability and CO_2 reduction compared to the main rival, i.e., TiO_2 nanofluid based PV/T technology. However, the substantial superiority originated from the much lower PBP of that. Moreover, decision-making revealed that pure water-based system was in the third place and better than the individual PV and Al_2O_3 nanofluid based PV/T systems because of better energy and economic performance, respectively. This alternative had a moderate level of reliability compared to the other alternatives.

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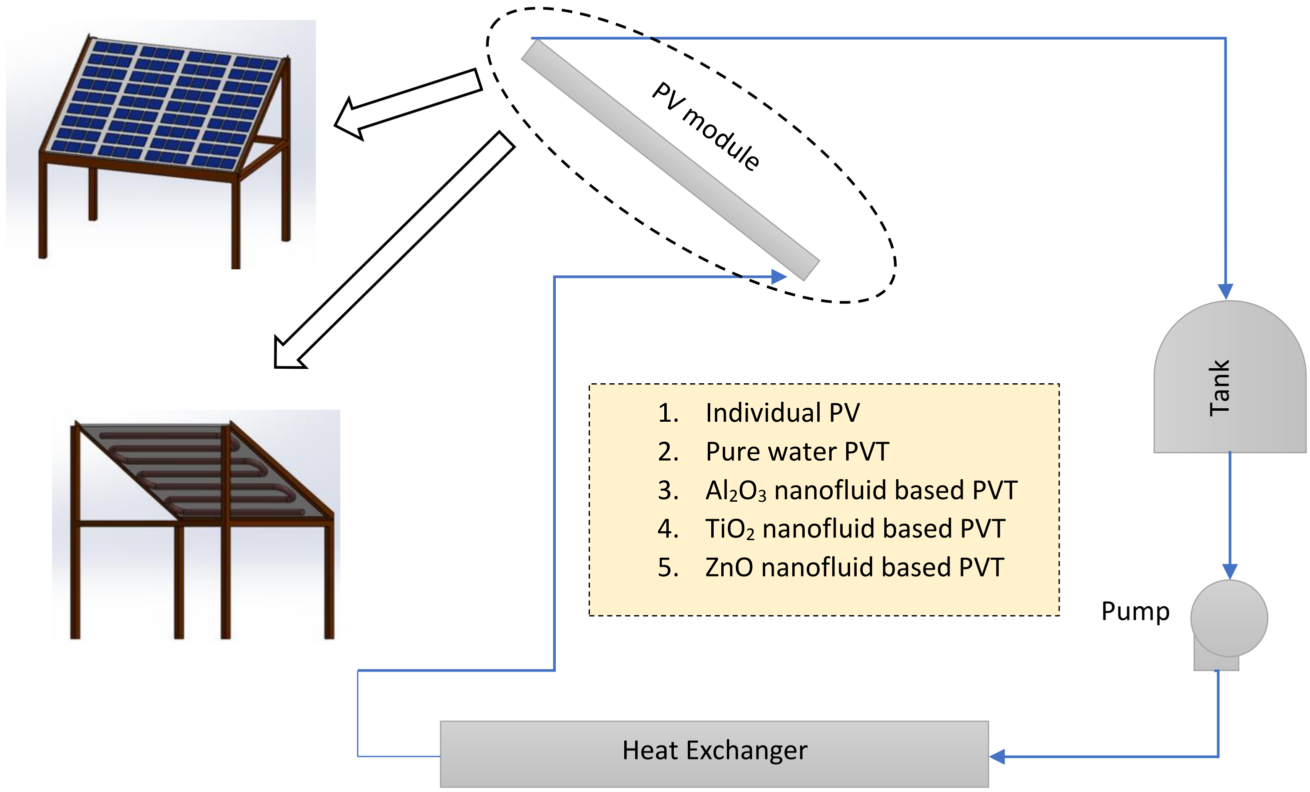
Graphical abstract



Declaration of interests

■ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: