OPTIMIZATION OF PHOTOVOLTAIC COOLING SYSTEM PERFORMANCE: A COMPARISON REVIEW OF ACTIVE, PASSIVE AND COMBINED METHODS

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Abstract

Photovoltaic modules play a crucial role in the generation of renewable energy. However, their performance is highly sensitive to temperature changes, as excessive heat can significantly reduce photovoltaic efficiency and electrical output. To counteract this issue, an effective cooling system is essential to maintain the optimal operating temperature of PV modules. Therefore, a cooling system is needed to maintain the optimal temperature and increase the output. This paper compares various cooling approaches categorized into three main types: active, passive, and hybrid (combined) cooling methods. Active cooling methods, such as forced air cooling and water circulation systems, are capable of significantly reducing the temperature of photovoltaics. However, they often require external power sources, which can reduce overall energy efficiency. Passive cooling techniques, including heat sinks, phase change materials (PCMs), and natural convection, offer energy-efficient alternatives that do not require external power, although their cooling capacity may be limited. Hybrid cooling methods, which integrate active and passive elements, have demonstrated superior performance by balancing energy consumption and cooling effectiveness. Effective cooling not only improves performance but also extends the life of the system. Cooling technology should focus on cost-effective, eco-friendly solutions to enhance solar module performance and support efficient renewable energy use.

Keywords: Renewable energy, solar photovoltaic, active cooling, passive cooling, energy efficiency

Abstrak

Panel surya berperan penting dalam menghasilkan energi terbarukan. Namun, kinerjanya sangat dipengaruhi oleh suhu. Ketika suhu terlalu tinggi, efisiensi panel menurun dan output listrik berkurang. Oleh karena itu, sistem pendinginan diperlukan untuk menjaga suhu operasi tetap optimal dan mendukung kinerja panel. Penelitian ini membahas tiga jenis sistem pendinginan utama: aktif, pasif, dan hibrida. Sistem aktif, seperti pendingin air atau kipas, efektif dalam menurunkan suhu secara cepat, tetapi membutuhkan energi tambahan yang dapat menurunkan efisiensi keseluruhan. Sementara itu, metode pasif misalnya penggunaan sirip pendingin, bahan perubahan fasa (PCM), dan konveksi alami lebih hemat energi karena tidak memerlukan daya tambahan, meski kapasitas pendinginannya terbatas. Metode hibrida yang menggabungkan teknik aktif dan pasif menunjukkan hasil terbaik dalam menyeimbangkan efektivitas pendinginan dan efisiensi energi. Selain meningkatkan performa, sistem pendinginan juga dapat memperpanjang usia pakai panel surya. Pengembangan teknologi pendinginan yang hemat biaya dan ramah lingkungan sangat penting untuk mendukung efisiensi sistem fotovoltaik dan memperkuat pemanfaatan energi terbarukan secara berkelanjutan.

Keywords: Energi terbaharukan, panel surya, pendingin aktif, pendingin pasif, efisiensi energy

1. Introduction

Along with the increasing number of global energy demand and environmental problems, making renewable energy sources very important [1], [2]. Renewable energy is an alternative energy that comes from renewable sources, namely the sun, water, wind, geothermal and biomass to replace energy from fossils [3], [4]. Of the several renewable energy sources available, solar energy is the most economical and environmentally friendly. Sunlight is available in every climate zone, but each region has different levels of irradiation. Where tropical areas have the highest levels of global irradiation throughout the year [5]. Generally, photovoltaic systems are made of semiconductor materials, where the semiconductor itself is one part of the relatively small energy of the electrons. Electrons can be generated from valence band photons to the conduction band [6], [7]. Basically, photovoltaic cells are composed of light absorbers that only absorb photons from the sun above a certain minimum photon energy [8], [9].

Through the photovoltaic system, solar radiation will be converted into electrical energy [10]. The conversion process is through photovoltaic cells that function to capture the energy produced by the sun by utilizing the photoelectric effect [11]. However, the level of irradiation that can be converted is only 5-20% of the total amount of irradiation received, and the rest will be distributed to the environment, causing an increase in operational temperature, significantly reducing system performance [12], [13]. In several studies, photovoltaic can work optimally at a temperature range of 25^0 C to 35^0 C [14]. If the temperature produced exceeds the ideal range and then reaches a maximum limit at a temperature of around 45^0 C or more, it can cause efficiency to drop significantly [15]. In addition, the side effect of every 1^0 C increase in temperature above 25^0 C will reduce the panel's output power by 0.5% [16]. Several factors that can affect the performance of photovoltaic are solar radiation, which has a direct influence on the output power produced by the photovoltaic, where the higher the solar radiation, the higher the panel output power [17], [18], environmental temperature, angle of incidence of light, panel surface temperature, weather, and wind speed [19]–[22].

Temperature is a major factor that can affect the power output generated by the panel. Panel efficiency will decrease along with the increase in the operational temperature on the panel surface [23], [24]. Therefore, a cooling system is needed that can lower the operational temperature so that the efficiency of the photovoltaic increases [25]–[27]. In its integration, active, passive and combined passive-active cooling systems are used to overcome the challenges arising from the high operational temperature of the photovoltaic system [28]. In passive cooling systems such as the use of phase change materials (PCM), heat pipes, air ducts, thermosyphons that do not require additional power [29]. While for active cooling, namely water spray cooling, water flow cooling, thermoelectrics, heatsinks that require energy consumption in system operation [30]. Where the power required in the active cooling system is reduced from the power generated by the photovoltaic which results in reduced output power [31]. For example, water cooling can significantly reduce the operational temperature of the panel surface so as to avoid panel damage due to excessive heat [32]. This research aims to gather relevant literature and perform a comparative assessment of how different cooling approaches influence the efficiency of photovoltaic (PV) systems in enhancing power output. The analysis is grounded in a review of existing research on various cooling techniques and their effects on PV performance. In particular, the study focuses on evaluating passive, active, and hybrid cooling methods by examining their capabilities in lowering module temperature, improving energy output, managing energy consumption, associated costs, and practicality of implementation. By outlining the strengths and weaknesses of each method, this research offers valuable perspectives on selecting the most effective cooling strategy for optimizing PV system performance across varying environmental and operational contexts.

2. Research Methods

The research method used in this article follows the Preferred Reporting Items for Systematic Reviews and Meta Analyses guidelines or commonly called (PRISMA). Using this approach in cooling system research is useful as a structured and systematic framework, an effort to improve the quality of a study and as a comparison between studies conducted.

Literature review is a strategy used in the review process. In a literature review in the form of an investigation to identify, evaluate, discuss, group and present it based on the problems of a study. This is needed to compare current research which includes what is researched and not researched through validity, increasing accuracy and transparency [33].

2.1. Determining Research Questions and Objectives

In order to determine a systematic method in the search process and also analyze literature, the first thing to do is to determine the questions and objectives of the research being conducted, so that the research being conducted is in accordance with the topic being researched.

2.2. Literature Search and Selection Methods

In this process, it is done by selecting keywords related to the research topic being studied. In this case, keywords are used to facilitate the process of identifying papers with topics that are in line with the research being conducted. Furthermore, keywords are implemented on online websites such as science direct and google scholar which provide facilities for researchers to obtain references. This study uses references from journals, books, and articles published in the period 2015 to 2025.

2.3. Information Extraction

In this information extraction process, data or information that is in line with the research topic will be analyzed. This aims to determine the advantages, disadvantages, methods and results of existing research. Additional information such as publication sources, institutions or organizations, countries of origin and authors are collected.

2.4. Evaluation and Interpretation of Results

Grouping the papers or articles obtained into sections is the main objective in the literature collection process. The papers will be grouped in the form of tables according to their significance so that they can be examined effectively. Furthermore, an in-depth analysis is carried out to obtain a brief overview of the findings. In the process by integrating and managing the findings of each article or paper, so that a certain arrangement is created that is related to the issue being analyzed which can provide a unique and comprehensive perspective.

3. Results and Discussion

This section will discuss the importance of the cooling system on photovoltaic, factors that affect the performance of the cooling system, an overview of the cooling system and the methods used in the photovoltaic cooling process.

3.1. The Importance of the Cooling System on Photovoltaic

Solar energy is the largest renewable energy source [34]. In addition, solar energy is known for its unlimited and inexhaustible amount [35], it is estimated that in 2050 the world will experience energy consumption of 45% which is obtained from the sun [36]. In its utilization, solar energy uses photovoltaic cells to capture solar irradiation and convert it into electrical energy [37]. Of the total amount of irradiation received, photovoltaic cells can only convert about 15% and the rest becomes heat which can cause panel efficiency to decrease along with increasing photovoltaic cell temperature [38]. Photovoltaic cells will work optimally when the temperature obtained is constant, namely 25^0 C. If the temperature obtained is more than 25^0 C, the open circuit voltage or (Voc) will decrease [39]. And for each photovoltaic cell experiencing a temperature increase of 1^0 C from 25^0 C, this will reduce the output power by about 0.5% [40].

3.2. Factors Affecting Cooling Performance

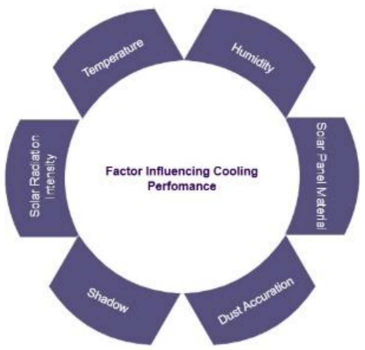

Figure 1. Cooling performance factor

Several factors that can affect the panel cooling system as an effort to increase the efficiency of photovoltaic production [41]. Some of these factors include the level of solar radiation, photovoltaic material, shadows, temperature, humidity and dust accumulation [42]. Photovoltaic are very sensitive to higher temperatures, which can cause decreased efficiency of photovoltaic [43]. Thus, a cooling system is needed to lower the temperature of the photovoltaic so that the optimal temperature can be maintained and increase the efficiency and service life of the photovoltaic [44]. Other factors such as dust accumulation on the surface of the panel can cause a decrease in the level of absorption of sunlight by the panel. With a cooling system that can be used as a panel cleaner so that there is no dust buildup [45]. The most important factor is the type of material used in construction. Where this type of material will affect the rate of heat transfer or energy conversion, the effectiveness and durability of the cooling system [46]. In addition, there is long-term performance that must also be considered, such as the following factors, namely, dirt, material degradation, and wear that can affect the system so that it requires maintenance from time to time. By carrying out routine maintenance and monitoring, problems can be reduced and the reliability of the system can be ensured in the long term [47].

3.3. Overview of Cooling System

A variety of cooling techniques are used in an effort to cool photovoltaic both actively and passively, such as natural radiation, convection and also cooling by spraying water [48], [49]. In the process of selecting the cooling system method to be used based on several things such as certain photovoltaic technology, environmental conditions and also the design of the system used [50]. The photovoltaic cooling system is very important as an effort to prevent a decrease in system performance, increase output power and maintain photovoltaic efficiency [51].

3.4. Photovoltaic Cooling System Method

Increased temperature can result in decreased electrical energy production, so that the efficiency of energy conversion that occurs will decrease along with the increasing temperature of the solar module [52]. In its implementation, an adequate cooling system can reduce the temperature of the solar module and efficiency, this makes the cooling system an important factor in order to improve the overall performance of the system [53]. Cooling methods can be divided into three types with several subsections [54].

3.4.1. Active Cooling

Active cooling method is a cooling that requires external power source as supply [5]. This method is superior compared to passive cooling method in terms of continuous heat transfer mechanism combined with real cooling [55]. In addition, some of the research conducted with active method can show effectiveness compared to passive system which is limited in number.

Table 1.Research On Active Cooling Systems

No	Author (year)	Cooling Type	Normal Power	Power With Cooler	Temperature Decrease	Power Increase	Efficiency Increase
1	Taqwa (2020) [32]	Water flow	19.0 W	21.9 W	9.9^{0}C	15.26%	0.4%
2	Amelia (2016) [58]	Air flow	42.53 W	48.02 W	4.120 C	30.40%	-
3	Sajjad (2019) [59]	Air flow	25 W	35 W	-	40%	7.2%
4	Laksana (2022) [25]	Water spray	7.39 W	10.52 W	-	42.52%	-
5	Miftahhul (2021) [17]	Water spray	568.75 W	617.6 W	16.4^{0}C	22%	4%
6	Alqahtani (2024) [1]	Water flow	100 W	-	7%	14%	0.35%
7	Zubeer (2021) [63]	Water flow (force), reflectors	-	-	30-35^0 C	18.5%	8%

3.4.1.1. Water Flow Cooling

Using water cooling system can increase the efficiency of solar module so that it can reduce excess heat generated effectively. In the study conducted in order to cool solar module on polycrystalline panel using water flowing on the module surface and heat exchanger on the back side of the module, it was shown that using solar module cooling system can increase the output power generated [29], [56]. In the research conducted by [32] using water flow cooling, power increase was obtained by 2.9 W with efficiency becoming 3.4%.

3.4.1.2. Air Flow Cooling

Air is the main cooling system in an air-based active cooling system that uses forced air circulation to lower the temperature of the solar module [57]. In a study conducted by [58] it can be seen that energy is needed to drive direct current fans. In the study it was found that the use of one fan increased electricity generation by 12.93% then to 37.17% with two fans, 41.28% three fans and 44.34% with 4 fans. To improve the performance of solar modules in producing electrical energy [59] comparing with uncooled solar modules showed PVCE was 7.2% higher with a power increase of 6%.

3.4.1.3. Water Spray Cooling

The mechanism in this method is to break water into small droplets with a large surface ratio. This method offers superior cooling benefits and increased consistency of the surface temperature of solar modules in a wider area. In addition, this method aims to increase heat transfer to the surrounding environment to reduce the temperature of the solar module so that it can increase PVCE [30].

3.4.1.4. Heatsink Airflow Cooling

In this method, air is not used directly to cool the solar module, but uses active air cooling with a heatsink. Several studies have been conducted to obtain the arrangement and placement of heatsinks that can work optimally to increase the efficiency of solar modules and cool them [60]. In his research [61] has investigated the ideal layout of fins, baffles and channels with various fin and channel configurations. Then it can be seen that combining elongated fins with angular baffles will get the best results. With an increase in output power of 6%.

3.4.2. Passive Cooling

Efforts to regulate the temperature of solar modules to ensure optimal solar module performance with a long service life. Passive cooling method is one of the techniques to cool solar modules without using or consuming energy, where the heat stored in the solar module will be transferred through radiation, evaporation, spectrum separation and natural convection with the smallest impact [12]. Several passive cooling methods such as floating PV, heat pipes, submerged phase changers (PCM), and thermoelectrics will be discussed in this paper.

3.4.2.1. Floating PV Cooling

Floating solar modules are a good solution as an effort to cool solar power plants with increased efficiency. Floating solar modules show 10% higher efficiency compared to conventional cooling systems or those installed on land [64]. In terms of economy, the cost of installing floating solar modules is 15% more expensive than installing solar modules on land, but floating solar modules have lower operational costs compared to conventional ones [65]. The environmental impact of installing floating solar modules on water bodies such as reservoirs, lakes, dams, and ponds has been shown to reduce water evaporation by up to 70%

[66]. In addition, using this cooling system can reduce algae growth and reduce water contamination in water bodies [67]. In floating infrastructure, there are several environmental risks that can be harmful to the long-term performance of solar power plants, namely, major storms, tsunamis, earthquakes and fluctuations in water levels, even so, with the strong performance and reliability of the floating system, it can convince many countries to show interest in this system [68].

3.4.2.2. Heat Pipe Cooling

The heat pipe contains a liquid that will flow at a low temperature [47]. In a study conducted by Tang with the name Novel Micro Heat Pipe Array, where in the study the heat pipe transfers the heat generated by the solar module to the air or water, thereby increasing the efficiency of the solar module by 2.6% [32]. Combining heat pipes with solar modules is a breakthrough in passive cooling systems with the highest recommendation level in areas with winter or high latitudes [69].

3.4.2.3. Natural Ventilation Cooling

The cooling method with natural ventilation using water or air is the cheapest and easiest method to implement. By applying this method to the rear channel of the solar module, the temperature can be reduced, thereby increasing the power output produced [70]. In a study conducted by [71] by analyzing the solar module cooling system using fins and planar reflectors located at the National University of Malaysia. In this study, two different heatsink configurations were used, namely lapping fins and longitudinal fins which function as passive coolers. With a solar radiation level of 1000 W/m^2 and an ambient temperature of 33^0 C. In the use of lapping fin cooling, the average temperature of the solar module is 24.6^0 C, with an efficiency of 10.68% and an output power of 37.1 W, it is determined as the best performance. It requires an energy return period of 4.2 years for longitudinal solar modules, 5 years for lapping fins and 8.4 years for bare.

3.4.2.5. PCM Cooling

The PCM cooling system or phase change material is a substance that can be used to change its physical state to absorb heat. This plays an important role as an effort to improve overall performance reliability [76]. Based on several studies that have been conducted, PCM as a solar module cooling medium has a good and beneficial impact so that it can increase efficiency by reducing the temperature on the surface of the solar module [77]–[79]. Using PCM on solar modules can provide the advantage of a high level of heat transfer, no maintenance costs, passive heat exchange. However, besides these advantages, PCM has several disadvantages including corrosion problems, high costs, flammability and toxicity [80].

3.4.3. Combined Cooling

By combining different cooling methods, a more effective and efficient heat reduction system can be achieved on solar modules, as each method can complement the limitations of the others—resulting in superior thermal management, enhanced energy conversion efficiency, and extended operational lifespan of the solar panels.

3.4.3.1. Active Combination

Research on forced convection cooling systems is a scientific interest, as an effort to increase system durability and effectiveness. In a study conducted by [81] in order to test the impact of using a heat exchanger other than the front of the water cooling system on the rear surface of the solar module in the cooling process. It can be seen that there is a substantial increase in efficiency of 13.9%.

Table 2. Research On Passive Cooling Systems

No	Author (year)	Cooling Type	Normal Power	Power With Cooler	Temperature Decrease	Power Increase	Efficiency Increase
1	Chandavar (2020) [13]	Solar air heater with chimney	-	-	13%	6%	35%
2	Nazaar (2022) [62]	Heatsink	14.36 W	17.54 W	2.73 ^{0}C	0.94 W	0.16%
3	Babu (2018) [72]	Termoelectric generator	170 W	225 W	-	5%	6%
4	Praveenkumar (2022) [73]	CPU Heat pipe	9.73 W	11.39 W	6.72 ^{0}C	1.66 W	2.98%
5	Elminshawy (2022) [74]	Floating	-	-	9.6 ^{0}C	7.66 W	2.61%
6	Gad (2023) [75]	Nano-emulsions PCM	-	-	8.7 ^{0}C	-	5.3%
7	Gupta (2019) [76]	Water evaporation, capillary action, and burlap fabric	-	-	20 ^{0}C	-	14.7%
8	Emam (2018) [77]	Foam (AMF), PCM	-	-	7.4%	3.38%	-
9	Sutanto (2022) [78]	Thermosiphon FPVS	-	-	2.6 ^{0}C	-	7.86%
10	Chen (2023) [79]	Transparent silk radiative cooling films	-	-	14 ^{0}C	-	7%
11	Liu (2024) [80]	Silica gel for cooling and water collection	-	-	16.18 ^{0}C	-	8.78

Table 3. Research On Combined Cooling Systems

No	Author (year)	Cooling Type	Normal Power	Power With Cooler	Temperature Decrease	Power Increase	Efficiency Increase
1	Dewi (2023) [85]	Water spray and coconut fiber	60 W	72 W	-	20%	-
2	Zhang (2023) [86]	Chimney and ventilator	-	-	15^0 C	-	46.54%
3	Salehi (2023) [87]	Heatsink and nanofluid	69 W	-	13%	13.7%	1.7%
4	H S (2024) [88]	Jute cloth with floating solar fountain	22.85 W	27.5 W	16.3%	15.7%	1%
5	Nižetić (2021) [89]	PV-PCM-TE system	-	-	22.33^0 C	-	17.57%
6	Ahmed (2022) [82]	Heat pipe radiative	-	-	12.86^0 C	-	7.25%
7	Lebbi (2021) [90]	Force air water flow	-	-	15^0 C	-	5.7%
8	Fakouriyan (2024) [91]	Water flow radiative	-	-	12.86^0 C	-	9.1%

3.4.3.2. Passive Combination

By combining several passive cooling systems that can provide new solutions in efforts to improve temperature control on solar modules, so that maximum benefits are obtained in terms of efficiency. In its implementation, the combined passive cooling system can eliminate active components and increase the power generated. In a study conducted by [82], combining radiation cooling and heat pipes can produce a temperature drop of $12{,}86^0$ C with a PVCE of 7.25%. According to [83] by combining heatsinks and phase change materials can efficiently absorb excess heat in the hot period so that the temperature difference on the surface of the solar module can be reduced.

3.4.3.3. Active and Passive Combination

By combining active and passive solar module cooling methods can potentially reduce energy consumption and system complexity so that efficiency increases. The cooling system that has been developed by [83] using a layer of silicon dioxide as radiation cooling and water flow through an aluminum tube placed at the bottom of the solar module. Solar modules connected to a diesel water heat exchanger using TEG together with air cooling can provide findings that using various combined cooling methods can produce a good photoelectric performance system. With a reduction in the surface temperature of the solar module by 23% and providing an increase in power generated by more than 15%, as well as an increase in PVCE by 3% [84].

4. Conclusion

This paper emphasizes that solar module cooling is an important aspect in efforts to increase the output power and efficiency of photovoltaic systems. From various cooling methods that have been compared, both active, passive and combined methods have been studied and proven to be able to reduce the surface temperature of solar modules, so that the efficiency of converting solar energy into electricity can be increased. Active cooling such as air and water flow shows a significant increase in output power but requires additional energy sources to operate. Meanwhile, passive cooling methods such as heat pipes and PCM are more energy efficient but have limitations in heat absorption. In using the combined method, it offers the best solution by optimizing the advantages of each system which can produce higher efficiency and increased output power in various environmental conditions. Based on the paper, the most efficient and best cooling system to use is the combined method, namely active and passive at the same time. Where this system has been proven to be able to reduce panel temperature more effectively, can increase output power and efficiency and extend the life of photovoltaic. The use of appropriate cooling technology is very important, especially in areas with high sunlight intensity and quite extreme environmental temperatures.
For the future, it is recommended that the development of cooling systems not only focus on increasing efficiency, but also be cost-effective and environmentally friendly. Automatic cooling technology that does not require much additional energy is very helpful in making the system more practical and sustainable.

References

[1]. M. N. Alqahtani and H. F. Shatnawi, "Exploring the Impact of Diverse Cooling Duct Configurations on Photovoltaic Panel Performance," *J. Adv. Res. Fluid Mech. Therm. Sci.*, vol. 116, no. 1, pp. 116–129, 2024, doi: 10.37934/arfmts.116.1.116129.

[2]. Z. Zapałowicz and W. Zeńczak, "Seawater cooling of PV modules mounted on ships in Świnoujście/Poland harbour," *Heliyon*, vol. 8, no. 8, pp. 1–7, 2022, doi: 10.1016/j.heliyon.2022.e10078.

[3]. R. P. Dewi, S. Rahmat, and A. A. Musyafiq, "Implementasi Sistem Pendingin Panel Surya Untuk Mempertahankan Suhu Permukaan Panel," *Pros. Semin. Nas. Wijayakusuma Natl. Conf.*, vol. 3, no. 1, pp. 75–82, 2022.

[4]. P. Studi, T. Dirgantara, S. Tinggi, and T. Kedirgantaraan, "Pengujian Sistem Pendingin Panel Surya Berbentuk Tubular Cooler Dengan Solar Simulator Untuk Menguji Daya Keluaran Panel Surya," vol. 7, no. 1, pp. 10–16, 2021.

[5]. A. Malvika, U. C. Arunachala, and K. Varun, "Sustainable passive cooling strategy for photovoltaic module using burlap fabric-gravity assisted flow: A comparative Energy, exergy, economic, and enviroeconomic analysis," *Appl. Energy*, vol. 326, no. September, pp. 1–17, 2022, doi: 10.1016/j.apenergy.2022.120036.

[6]. C. J. Chen, *Physics Of Solar Energy*. Canada: simultaneously, 2015.

[7]. D. Hendrawati *et al.*, "Design and Performance Evaluation of Analytic-Tuning Pid on Boost Converter for 200 Wp Photovoltaic," *J. Eng. Sci. Technol.*, vol. 18, no. 4, pp. 1–16, 2023, [Online]. Available: https://www.scopus.com/record/display.uri?eid=2-s2.0-85174285670&origin=resultslist&sort=plf-f&src=s&sid=096276bf4bcc127109bbaf34753d8b49&sot=b&sdt=b&s=FIRSTAUTH%28Hendrawati%29&sl=17&sessionSearchId=096276bf4bcc127109bbaf34753d8b49&relpos=5

[8]. N. S. Lewis and G. Crabtree, *Basic Research Needs for Solar Energy Utilization*. Renée M. Nault, Argonne National Laboratory, 2015.

[9]. D. Hendrawati *et al.*, "Modified Maximum Power Point Tracking on Models of a 400 Wp Wind Power Plant," *Jaict*, vol. 7, no. 2, pp. 125–129, 2022, doi: 10.32497/jaict.v7i2.3917.

[10]. G. Setyono, N. Kholili, and Y. Rakhmadanu, "The Impact of Utilization The Solar-Panels With a Cooling-Water System as a Source of Micro-Power Generation," vol. 13, no. 01, pp. 87–92, 2022, doi: 10.35970/infotekmesin.v13i1.1001.

[11]. J. S. P. Parulian Siagian, Nita Suleman, S. E. W. Asrim, Tambi, and R. A. Wa Ode Zulia Prihatini, Andi Budirohmi, *Energi Baru Terbarukan Sebagai Energi Alternatif*. Yayasan Kita Menulis, 2023.

[12]. R. B, S. CK, and K. Sudhakar, "Sustainable passive cooling strategy for PV module: A comparative analysis," *Case Stud. Therm. Eng.*, vol. 27, no. July, pp. 1–10, 2021, doi: 10.1016/j.csite.2021.101317.

[13]. A. U. Chandavar, "Quantifying the performance advantage of using passive solar air heater with chimney for photovoltaic module cooling," no. June, pp. 7–9, 2020, doi: 10.1002/er.5782.

[14]. P. K. Tiyas and M. Widyartono, "Pengaruh Efek Suhu Terhadap Kinerja Panel Surya," vol. 9, no. 1, p. 871876, 2020.

[15]. Z. Genge, M. S. Misaran, Z. Zhang, M. A. Radzali, and M. A. Ismail, "Solar Photovoltaic Surface Cooling Using Hybrid Solar Chimney-Collector with Wavy Fins," vol. 1, no. 1, pp. 46–58, 2024.

[16]. A. Jatmiko, G. Marausna, and F. Setiawan, "Rancangan Sistem Pendingin Panel Surya Jenis Box Dengan Arah Aliran Horizontal," vol. 9, no. 1, pp. 181–188, 2023.

[17]. N. Miftahhul and D. Adi, "Analisis Karakteristik Modul Panel Surya Dengan Sistem Pendingin Air," vol. 06, no. 01, pp. 37–42, 2021.

[18]. B. W. Dionova, D. J. Vresdian, D. Nugraha, A. Janeul, A. Oktaviani, and M. N. Mohammed, "The Efficiency of MPPT in Mitigating the Effects of Partial Shading on Power Stability through the MPNO Method," *J. Nas. Tek. Elektro*, 2025.

[19]. A. I. I. Widodo PS, Sunarso, Ahmad Faizal, Eri Widianto, "Analisis Computational Fluid Dynamics Suhu Permukaan Panel Surya Akibat Pengaruh Intensitas Radiasi Matahari , Kecepatan Angin Dan Suhu Udara," *Din. J. Ilm. Tek. Mesin*, vol. 10, no. 1, pp. 55–62, 2018.

[20]. E. P. Aji, P. Wibowo, and J. Windarta, "Kinerja Pembangkit Listrik Tenaga Surya (PLTS) dengan Sistem On Grid di BPR BKK Mandiraja Cabang Wanayasa Kabupaten Banjarnegara," *J. Energi Baru dan Terbarukan*, vol. 3, no. 1, pp. 15–27, 2022, doi: 10.14710/jebt.2022.13158.

[21]. I. B. G. Widiantara and N. Sugiartha, "Pengaruh Penggunaan Pendingin Air Terhadap Output Panel Surya Pada Sistem Tertutup," *Matrix J. Manaj. Teknol. dan Inform.*, vol. 9, no. 3, pp. 110–115, 2019, doi: 10.31940/matrix.v9i3.1582.

[22]. A. Asrori and E. Yudiyanto, "Kajian Karakteristik Temperatur Permukaan Panel terhadap Performansi Instalasi Panel Surya Tipe Mono dan Polikristal," *FLYWHEEL J. Tek. Mesin Untirta*, vol. 1, no. 1, p. 68, 2019, doi: 10.36055/fwl.v1i1.7134.

[23]. I. Baihaqi, E. Tridianto, and A. Ghani, "Studi Eksperimen Pengaruh Ketetebalan Lapisan Air Pendingin Terhadap Daya Keluaran Modul Photovoltaic Monocrystalline," pp. 46–51, 2017.

[24]. B. W. Dionova, R. J. P. S, D. J. Vresdian, and L. P. Pratama, "Evaluation of 300 WP Solar Photovoltaic Panel Performance for Electric Vehicle Charging Station," vol. 19, no. 03, pp. 80–84, 2023, [Online]. Available: http://dx.doi.org/10.32497/eksergi.v19i03.5008

[25]. E. P. Laksana, O. Sanjaya, Sujono, S. Broto, and N. Fath, "Sistem Pendinginan Panel Surya dengan Metode Penyemprotan Air dan Pengontrolan Suhu Air menggunakan Peltier," vol. 10, no. 3, pp. 652–663, 2022.

[26]. M. P. Putra *et al.*, "Sistem Pendingin Menggunakan Air Untuk Optimasi Kinerja Panel Surya," vol. 3, no. 1, pp. 40–47, 2021.

[27]. D. Almanda and D. Bhaskara, "Studi Pemilihan Sistem Pendingin pada Panel Surya Menggunakan Water Cooler , Air Mineral dan Air Laut," vol. 1, no. 2.

[28]. M. A. Elias, R. M. Jais, N. Muda, and N. E. H. Hassan, "Advances of Solar PV System Output Improvement through Cooling Technologies in Malaysia," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 884, no. 1, pp. 1–7, 2020, doi: 10.1088/1757-899X/884/1/012076.

[29]. C. Y. Mah, B. H. Lim, C. W. Wong, M. H. Tan, K. K. Chong, and A. C. Lai, "Investigating the Performance Improvement of a Photovoltaic System in a Tropical Climate using Water Cooling Method," *Energy Procedia*, vol. 159, pp. 78–83, 2019, doi: 10.1016/j.egypro.2018.12.022.

[30]. A. Sohail, M. S. Rusdi, M. Waseem, M. Z. Abdullah, F. Pallonetto, and S. M. Sultan, "Cutting-edge developments in active and passive photovoltaic cooling for reduced temperature operation," *Results Eng.*, vol. 23, no. July, p. 102662, 2024, doi: 10.1016/j.rineng.2024.102662.

[31]. M. Sharaf, M. S. Yousef, and A. S. Huzayyin, "Review of cooling techniques used to enhance the efficiency of photovoltaic power systems," *Environ. Sci. Pollut. Res.*, vol. 29, no. 18, pp. 26131–26159, 2022, doi: 10.1007/s11356-022-18719-9.

[32]. A. Taqwa, T. Dewi, R. D. Kusumanto, C. R. Sitompul, and Rusdianasari, "Automatic Cooling of a PV System to Overcome Overheated PV Surface in Palembang," *J. Phys. Conf. Ser.*, vol. 1500, no. 1, pp. 1–10, 2020, doi: 10.1088/1742-6596/1500/1/012013.

[33]. S. K. Pathak, P. O. Sharma, V. Goel, S. Bhattacharyya, H. Ş. Aybar, and J. P. Meyer, "A detailed review on the performance of photovoltaic/thermal system using various cooling methods," *Sustain. Energy Technol. Assessments*, vol. 51, no. june, pp. 101–844, 2022, doi: https://doi.org/10.1016/j.seta.2021.101844.

[34]. B. Widodo, "Peningkatan Energi Listrik Serta Daya Keluaran Pada Panel Surya Dengan Penambahan Sistem Pendingin Heatsink Dan Reflektor Alluminium Foil," vol. 9, no. 03, pp. 1–4, 2022.

[35]. A. N. Hidayanti, P. Handayani, and I. Chandra, "Pemanfaatan Metode Single Axis Tracker dan Maximum Power Point Tracker (MPPT) PID untuk Mengoptimalkan Daya Keluaran Panel Surya," *Pros. Ind. Res. Work. Natl. Semin.*, pp. 149–154, 2019.

[36]. Y. S. Gaos *et al.*, "The performance of solar collector CPC (compound parabolic concentrator) type with three pipes covered by glass tubes," *AIP Conf. Proc.*, vol. 1826, no. March, pp. 1–10, 2017, doi: 10.1063/1.4979238.

[37]. A. I. Ramadhan, E. Diniardi, and S. H. Mukti, "Analisis Desain Sistem Pembangkit Listrik Tenaga Surya Kapasitas 50 WP," *Tek. 37 (2), 2016, 59-63*, vol. 11, no. 2, pp. 61–78, 2016, doi: 10.14710/teknik.v37n2.9011.

[38]. B. H. Purwoto, J. Jatmiko, M. A. Fadilah, and I. F. Huda, "Efisiensi Penggunaan Panel Surya sebagai Sumber Energi Alternatif," *Emit. J. Tek. Elektro*, vol. 18, no. 1, pp. 10–14, 2018, doi: 10.23917/emitor.v18i01.6251.

[39]. H. A. S and M. Bastomi, "Analisis Pengaruh Perubahan Temperatur Panel Terhadap Daya Dan Efisiensi Keluaran Sel Surya Poycrystalline," *Din. J. Ilm. Tek. Mesin*, vol. 11, no. 1, p. 33, 2019, doi: 10.33772/djitm.v11i1.9285.

[40]. A. Warsito, E. Adriono, M. Y. Nugroho, and B. Winardi, "Dipo Pv Cooler, Penggunaan Sistem Pendingin Temperatur Heatsink Fan Pada Panel Sel Surya (Photovolatic) Sebagai Peningkat Kerja Eergi Listrik Baru Terbarukan Metode.," *Tek. Elektro*, vol. 2, no. 3, pp. 1–5, 2016.

[41]. C. O. Rusănescu, M. Rusănescu, I. A. Istrate, G. A. Constantin, and M. Begea, "The Effect of Dust Deposition on the Performance of Photovoltaic Panels," *Energies*, vol. 16, no. 19, pp. 1–20, 2023, doi: 10.3390/en16196794.

[42]. A. Maleki, A. Haghighi, M. El Haj Assad, I. Mahariq, and M. Alhuyi Nazari, "A review on the approaches employed for cooling PV cells," *Sol. Energy*, vol. 209, no. October, pp. 170–185, 2020, doi: https://doi.org/10.1016/j.solener.2020.08.083.

[43]. K. Hasan, S. B. Yousuf, M. S. H. K. Tushar, B. K. Das, P. Das, and M. S. Islam, "Effects of different environmental and operational factors on the PV performance: A comprehensive review," *Energy Sci. Eng.*, vol. 10, no. 2, pp. 656–675, 2022, doi: 10.1002/ese3.1043.

[44]. M. S. Loegimin, B. Sumantri, M. A. B. Nugroho, H. Hasnira, and N. A. Windarko, "Sistem Pendinginan Air Untuk Panel Surya Dengan Metode Fuzzy Logic," *J. Integr.*, vol. 12, no. 1, pp. 21–30, 2020, doi: 10.30871/ji.v12i1.1698.

[45]. W. Gunawan, A. Sumardiono, and P. N. Cilacap, "Prototipe Sistem Pendingin Dan Penghilang Kotoran Pada Panel Surya," vol. 05, no. 01, pp. 43–48, 2023.

[46]. A. Febrina, J. C. Siahaan, and S. Siahaan, "Analisis Sistem Pendingin Bearing Turbin Francis Horizontal Unit 1 Dengan Daya 6,7 Mw Dan Putaran 750 Rpm Di Plta Pakkat Pt. Energi Sakti Sentosa," *SINERGI POLMED J. Ilm. Tek. Mesin*, vol. 3, no. 1, pp. 1–12, 2022, doi: 10.51510/sinergipolmed.v3i1.699.

[47]. R. Rauf *et al.*, *Matahari Sebagai Energi Masa Depan*. Yayasan Kita Menulis, 2023.

[48]. N. Manoj, U. Subramaniam, M. Mathew, A. Ajitha, and D. J. Almakhles, "Case Studies in Thermal Engineering Exergy analysis of thin-film solar PV module in ground-mount , floating and submerged installation methods," *Case Stud. Therm. Eng.*, vol. 21, no. May, p. 100686, 2020, doi: 10.1016/j.csite.2020.100686.

[49]. Z. Kaneesamkandi, M. J. Almalki, A. Sayeed, and Z. A. Haidar, "Passive Cooling of PV Modules Using Heat Pipe Thermosiphon with Acetone: Experimental and Theoretical Study," *Appl. Sci.*, vol. 13, no. 3, 2023, doi: 10.3390/app13031457.

[50]. Y. E. Ahmed, M. R. Maghami, J. Pasupuleti, S. H. Danook, and F. Basim Ismail, "Overview of Recent Solar Photovoltaic Cooling System Approach," *Technologies*, vol. 12, no. 9, pp. 1–27, 2024, doi: 10.3390/technologies12090171.

[51]. J. Ariksa, A. S. S. Forestico, Y. Setiawan, S. Saparin, and E. S. Wijianti, "Pengaruh Pendinginan Panel Surya Terhadap Efisiensi Daya Keluaran," *Mach. J. Tek. Mesin*, vol. 10, no. 1, pp. 36–40, 2024, doi: 10.33019/jm.v10i1.5055.

[52]. P. Harahap, "Pengaruh Temperatur Permukaan Panel Surya Terhadap Daya Yang Dihasilkan Dari Berbagai Jenis Sel Surya," *RELE (Rekayasa Elektr. dan Energi) J. Tek. Elektro*, vol. 2, no. 2, pp. 73–80, 2020, doi: 10.30596/rele.v2i2.4420.

[53]. A. Govindasamy, Dhanusiya Kumar, "Experimental analysis of solar panel efficiency improvement with composite phase change materials," *Renew. Energy*, vol. 212, no. agustus, pp. 175–184, 2023, doi: https://doi.org/10.1016/j.renene.2023.05.028.

[54]. R. Youssef, T. Kalogiannis, H. Behi, A. Pirooz, J. Van Mierlo, and M. Berecibar, "A comprehensive review of novel cooling techniques and heat transfer coolant mediums investigated for battery thermal management systems in electric vehicles," *Energy Reports*, vol. 10, pp. 1041–1068, 2023, doi: 10.1016/j.egyr.2023.07.041.

[55]. M. Dida, S. Boughali, D. Bechki, and H. Bouguettaia, "Experimental investigation of a passive cooling system for photovoltaic modules efficiency improvement in hot and arid regions," *Energy Convers. Manag.*, vol. 243, no. September, p. 114328, 2021, doi: https://doi.org/10.1016/j.enconman.2021.114328.

[56]. I. Valiente-Blanco *et al.*, "Efficiency Improvement of Photovoltaic Solar Modules by Cooling Using an Underground Heat Exchanger," *Sol. Energy*, vol. 144, no. 6, pp. 1–11, 2022, doi: https://doi.org/10.1115/1.4055299.

[57]. K. Bilen and İ. Erdoğan, "Effects of cooling on performance of photovoltaic/thermal (PV/T) solar panels: A comprehensive review," *Sol. Energy*, vol. 262, no. September, p. 111829, 2023, doi: https://doi.org/10.1016/j.solener.2023.111829.

[58]. A. R. Amelia *et al.*, "Cooling on Photovoltaic Panel Using Forced Air Convection Induced by DC Fan," *Int. J. Electr. Comput. Eng.*, vol. 6, no. 2, p. 526, 2016, doi: 10.11591/ijece.v6i2.9118.

[59]. U. Sajjad, M. Amer, H. M. Ali, A. Dahiya, and N. Abbas, "Cost effective cooling of photovoltaic modules to improve efficiency," *Case Stud. Therm. Eng.*, vol. 14, no. March, p. 100420, 2019, doi: 10.1016/j.csite.2019.100420.

[60]. K. Mankani, H. Nasarullah, Chaudhry, and J. K. Calautit, "Optimization of an air-cooled heat sink for cooling of a solar photovoltaic panel: A computational study," *Energy Build.*, vol. 270, no. September, p. 112274, 2022, doi: https://doi.org/10.1016/j.enbuild.2022.112274 Get rights and content.

[61]. S. Anurag *et al.*, "A study on the effects of forced air-cooling enhancements on a 150 W solar photovoltaic thermal collector for green cities," *Sustain. Energy Technol. Assessments*, vol. 49, no. February, p. 101782, 2022, doi: https://doi.org/10.1016/j.seta.2021.101782.

[62]. A. A. Nazaar, "MENGGUNAKAN HEATSINK - FAN SEBAGAI," 2022.

[63]. S. A. Zubeer and O. M. Ali, "Performance analysis and electrical production of photovoltaic modules using active cooling system and reflectors," *Ain Shams Eng. J.*, vol. 12, no. 2, pp. 2009–2016, 2021, doi: 10.1016/j.asej.2020.09.022.

[64]. Patil (Desai) Sujay S, Wagh M. M., and Shinde N. N., "A Review on Floating Solar Photovoltaic Power Plants," *Int. J. Sci. Eng. Res.*, vol. 8, no. 6, p. 6, 2017.

[65]. P. Ranjbaran, H. Yousefi, G. B. Gharehpetian, and F. R. Astaraei, "A review on floating photovoltaic (FPV)power generation units," *Renew. Sustain. Energy Rev.*, vol. 110, no. April 2018, pp. 332–347, 2019, doi: 10.1016/j.rser.2019.05.015.

[66]. H. D. M. R. Perera, "Designing of 3MW Floating Photovoltaic Power System and its Benefits over Other PV Technologies," *Int. J. Adv. Sci. Res. Eng.*, vol. 06, no. 04, pp. 37–48, 2020, doi: 10.31695/ijasre.2020.33782.

[67]. T. Thumma and S. R. Sheri, "Unsteady MHD Free Convection Flow past a Vertical Porous Plate Considering Radiation and Volume Fraction Effects in a Nanofluid," *Int. Adv. Res. J. Sci. Eng. Technol.*, vol. 2, no. 2, pp. 197–205, 2015, doi: 10.17148/IARJSET.

[68]. H. Pouran, M. Padilha Campos Lopes, H. Ziar, D. Alves Castelo Branco, and Y. Sheng, "Evaluating floating photovoltaics (FPVs) potential in providing clean energy and supporting agricultural growth in Vietnam," *Renew. Sustain. Energy Rev.*, vol. 169, pp. 1–4, 2022, doi: 10.1016/j.rser.2022.112925.

[69]. T. Zhang, Z. W. Yan, L. Xiao, H. D. Fu, G. Pei, and J. Ji, "Experimental, study and design sensitivity analysis of a heat pipe photovoltaic/thermal system," *Appl. Therm. Eng.*, vol. 162, no. January, 2019, doi: 10.1016/j.applthermaleng.2019.114318.

[70]. D. Vittorini and R. Cipollone, "Fin-cooled photovoltaic module modeling – Performances mapping and electric efficiency assessment under real operating conditions," *Energy*, vol. 167, pp. 159–167, 2019, doi: 10.1016/j.energy.2018.11.001.

[71]. A. M. Elbreki, M. A. Alghoul, K. Sopian, and T. Hussein, "Towards adopting passive heat dissipation approaches for temperature regulation of PV module as a sustainable solution," *Renew. Sustain. Energy Rev.*, vol. 69, no. July, pp. 961–1017, 2017, doi: 10.1016/j.rser.2016.09.054.

[72]. C. Babu and P. Ponnambalam, "The theoretical performance evaluation of hybrid PV-TEG system," *Energy Convers. Manag.*, vol. 173, no. July, pp. 450–460, 2018, doi: 10.1016/j.enconman.2018.07.104.

[73]. S. Praveenkumar *et al.*, "Experimental Study on Performance Enhancement of a Photovoltaic Module Incorporated with CPU Heat Pipe—A 5E Analysis," *Sensors*, vol. 22, no. 17, 2022, doi: 10.3390/s22176367.

[74]. N. A. S. Elminshawy, A. M. I. Mohamed, A. Osama, I. Amin, A. M. Bassam, and E. Oterkus, "Performance and potential of a novel floating photovoltaic system in Egyptian winter climate on calm water surface," *Int. J. Hydrogen Energy*, vol. 47, no. 25, pp. 12798–12814, 2022, doi: https://doi.org/10.1016/j.ijhydene.2022.02.034.

[75]. R. Gad, H. Mahmoud, S. Ookawara, and H. Hassan, "Impact of PCM type on photocell performance using heat pipe-PCM cooling system: A numerical study," *J. Energy Syst.*, vol. 7, no. 1, pp. 67–88, 2023, doi: 10.30521/jes.1159281.

[76]. N. Gupta and G. N. Tiwari, "Parametric study to understand the effect of various passive cooling concepts on building integrated semitransparent photovoltaic thermal system," *Sol. Energy*, vol. 180, no. March, pp. 391–400, 2019, doi: https://doi.org/10.1016/j.solener.2018.12.079.

[77]. M. Emam, A. Radwan, and M. Ahmed, "Chapter 2.15 - Comparative Study of Active and Passive Cooling Techniques for Concentrated Photovoltaic Systems," *Exergetic, Energ. Environ. Dimens.*, pp. 475–505, 2018, doi: https://doi.org/10.1016/B978-0-12-813734-5.00027-5.

[78]. B. Sutanto, Y. S. Indartono, A. T. Wijayanta, and H. Iacovides, "Enhancing the performance of floating photovoltaic system by using thermosiphon cooling method: Numerical and experimental analyses," *Int. J. Therm. Sci.*, vol. 180, no. October, p. 107727, 2022, doi: https://doi.org/10.1016/j.ijthermalsci.2022.107727 Get rights and content.

[79]. Y. H. Chen *et al.*, "Eco-Friendly Transparent Silk Fibroin Radiative Cooling Film for Thermal Management of Optoelectronics," *Adv. Funct. Mater.*, vol. 33, no. 33, 2023, doi: 10.1002/adfm.202370201.

[80]. Y. Liu, Z. Liu, Z. Wang, W. Sun, and F. Kong, "Photovoltaic passive cooling via water vapor sorption-evaporation by hydrogel," *Appl. Therm. Eng.*, vol. 240, no. March, p. 122185, 2024, doi: https://doi.org/10.1016/j.applthermaleng.2023.122185.

[81]. A. Abdullah, F. Attulla, O. K. Ahmed, and S. Algburi, "Effect of Cooling Method on the Performance of PV/Trombe Wall: A Case Study," *SSRN Electron. J.*, pp. 1–17, 2022, doi: 10.2139/ssrn.3994435.

[82]. S. Ahmed, S. Li, Z. Li, G. Xiao, and T. Ma, "Enhanced radiative cooling of solar cells by integration with heat pipe," *Appl. Energy*, vol. 308, no. February, p. 118363, 2022, doi: https://doi.org/10.1016/j.apenergy.2021.118363.

[83]. F. Bayrak, H. F. Oztop, and F. Selimefendigil, "Experimental study for the application of different cooling techniques in photovoltaic (PV) panels," *Energy Convers. Manag.*, vol. 212, no. May, p. 112789, 2020, doi: https://doi.org/10.1016/j.enconman.2020.112789.

[84]. A. Khanalizadeh, F. R. Astaraei, M. M. Heyhat, and M. A. V. Rad, "Experimental investigation of a PV/T system containing a TEG section between water-based heat exchanger and air-based heat sink," *Therm. Sci. Eng. Prog.*, vol. 42, no. July, p. 101909, 2023, doi: https://doi.org/10.1016/j.tsep.2023.101909.

[85]. R. P. Dewi, S. Rahmat, and H. Purnata, "Sistem Pendingin Panel Surya Otomatis Untuk," vol. 14, no. 1, pp. 1–10, 2023.

[86]. G. Zhang, M. S. Misaran, M. Adzrie, and N. Adrian, "Research on the Passive Cooling System of Solar Photovoltaic Panel Based on Hybrid Solar Chimney and Ventilator Research on the Passive Cooling System of Solar Photovoltaic Panel Based on Hybrid Solar Chimney and Ventilator," *J. Phys. Conf. Ser.*, vol. 2655, pp. 1–12, 2023, doi: 10.1088/1742-6596/2655/1/012016.

[87]. R. Salehi, A. Jahanbakhshi, J. B. Ooi, A. Rohani, and M. R. Golzarian, "Study on the performance of solar cells cooled with heatsink and nanofluid added with aluminum nanoparticle," *Int. J. Thermofluids*, vol. 20, no. August, p. 100445, 2023, doi: 10.1016/j.ijft.2023.100445.

[88]. A. H S, H. N M, M. N, A. K. Hegde, and K. V. Karanth, "Energy, exergy and environmental impact analysis of a jute cloth embedded Photovoltaic thermal cooling system wetted with floating solar fountain," *Results Eng.*, vol. 24, no. October, p. 103457, 2024, doi: 10.1016/j.rineng.2024.103457.

[89]. S. Nižetić, M. Jurčević, D. Čoko, and M. Arıcı, "A novel and effective passive cooling strategy for photovoltaic panel," *Renew. Sustain. Energy Rev.*, vol. 145, no. 8, p. 11164, 2021, doi: https://doi.org/10.1016/j.rser.2021.111164.

[90]. M. Lebbi *et al.*, "Energy performance improvement of a new hybrid PV/T Bi-fluid system using active cooling and self-cleaning: Experimental study," *Appl. Therm. Eng.*, vol. 182, no. January, p. 116033, 2021, doi: https://doi.org/10.1016/j.applthermaleng.2020.116033.

[91]. S. Fakouriyan, R. Mokhtari, and R. Ghasempour, "Investigating the effect of employing a 24-hour radiative cooling system on the photovoltaic/thermal systems performance: A case-based research," *Energy Reports*, vol. 11, no. March, pp. 3624–3640, 2024, doi: 10.1016/j.egyr.2024.02.030.